Potential impact of prevention intervention of musculoskeletal disorders (MSD) at the population level: scenarios for reduced exposure to risk factors for MSD

Aboubakari Nambiema

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« Aboubakari NAMBIEMA »

« Potential impact of prevention intervention of musculoskeletal disorders (MSD) at the population level: scenarios for reduced exposure to risk factors for MSD »

« Impact potentiel des interventions de prévention des troubles musculo-squelettiques (TMS) à l'échelle populationnelle : scénarios de réduction de l'exposition aux facteurs de risque de TMS »

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Rapporteurs avant la soutenance :

Clermont DIONNE	Professeur, Université Laval, Canada
Annette LECLERC	Directrice de recherche émérite, INSERM, HDR

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	Annette LECLERC	Directrice de recherche émérite, INSERM, HDR
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Titre : Impact potentiel des interventions de prévention des troubles musculo-squelettiques (TMS) à l'échelle populationnelle : scénarios de réduction de l'exposition aux facteurs de risque de TMS

Mots clés : TMS du membre supérieur ; facteur de risque professionnel ; effet combiné ; fraction attribuable en population ; cas évitable ; prévention.

Résumé : Les troubles musculo-squelettiques du membre supérieur (TMS-MS) constituent aujourd'hui l'une des questions les plus préoccupantes en santé au travail et santé publique du fait d'un coût humain et socioprofessionnel considérable. La prévention efficace et durable des TMS-MS reste un défi pour les praticiens et les décideurs en matière de santé publique. L'impact modéré des plans de prévention mis en œuvre au cours des dernières décennies nécessite d'approfondir la réflexion sur les stratégies de prévention à l'échelle de la population active. L'objectif de ce travail de thèse était d'estimer et de comparer les effets potentiels de la réduction des expositions professionnelles aux principaux facteurs de risque (FdR) biomécaniques et psychosociaux sur l'incidence des TMS-MS dans la cohorte COSALI.

Cette thèse a révélé qu'une proportion importante et un grand nombre de TMS-MS pourraient être évités si l'exposition aux FdR modifiables tels que les efforts physiques élevés, les postures contraignantes de l'épaule et le faible soutien social, était réduite. De plus, elle a montré qu'une intervention multidimensionnelle qui combinerait à la fois une réduction de l'exposition aux efforts physiques élevés et une amélioration du soutien social, permettrait de prévenir un plus grand nombre de cas.

En conclusion, cette thèse a permis d'estimer l'impact potentiel des interventions sur le nombre de cas de TMS-MS dans une population active salariée. Elle apporte aussi la preuve que pour être efficace, la prévention des TMS-MS ne peut se limiter à la réduction de l'exposition aux FdR biomécaniques mais nécessite une approche multidimensionnelle qui prend également en compte les FdR psychosociaux.

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This thesis revealed that an important proportion and a large number of UEMSD could be avoided if exposure to the modifiable risk factors, such as high physical exertion, uncomfortable shoulder postures and social support, were reduced in the working population. Moreover, this study showed that a multidimensional combining both a reduction of exposure to high physical exertion and improved social support would reduce a larger number of cases.

In conclusion, this thesis made it possible to estimate the potential impact of interventions on the number of UEMSD cases in a working population. It also provides evidence that to be effective, UEMSD prevention cannot be limited to reducing exposure to biomechanical risk factors but requires a multidimensional approach that also takes into account psychosocial risk factors.

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RÉSUMÉ

Les troubles musculo-squelettiques du membre supérieur (TMS-MS) constituent aujourd'hui l'une des questions les plus préoccupantes en santé au travail et santé publique du fait d'un coût humain et socioprofessionnel considérable. La prévention efficace et durable des TMS-MS reste un défi pour les praticiens et les décideurs en matière de santé publique. L'impact modéré des plans de prévention mis en œuvre au cours des dernières décennies nécessite d'approfondir la réflexion sur les stratégies de prévention à l'échelle de la population active. L'objectif de ce travail de thèse était d'estimer et de comparer les effets potentiels de la réduction des expositions professionnelles aux principaux facteurs de risque (FdR) biomécaniques et psychosociaux sur l'incidence des TMS-MS dans la cohorte COSALI. Cette thèse a révélé qu'une proportion importante et un grand nombre de TMS-MS pourraient être évités si l'exposition aux FdR modifiables tels que les efforts physiques élevés, les postures contraignantes de l'épaule et le faible soutien social, était réduite. De plus, elle a montré qu'une intervention multidimensionnelle qui combinerait à la fois une réduction de l'exposition aux efforts physiques élevés et une amélioration du soutien social, permettrait de prévenir un plus grand nombre de cas.

En conclusion, cette thèse a permis d'estimer l'impact potentiel des interventions sur le nombre de cas de TMS-MS dans une population active salariée. Elle apporte aussi la preuve que pour être efficace, la prévention des TMS-MS ne peut se limiter à la réduction de l'exposition aux FdR biomécaniques mais nécessite une approche multidimensionnelle qui prend également en compte les FdR psychosociaux.

mots-clés : TMS du membre supérieur ; facteur de risque professionnel ; effet combiné ; fraction attribuable en population ; cas évitable ; prévention.

ABSTRACT

Upper-extremity musculoskeletal disorders (UEMSD) constitute one of the most worrying issues in occupational and public health due to their considerable human, social and occupational costs. Effective and sustainable prevention of UEMSD continues to be a challenge for public health practitioners and policy-makers. The moderate impact of the prevention plans implemented over the last few decades requires further reflection on prevention strategies at the working population level. The objective of this thesis work was to estimate and compare the potential effects of reducing work-related exposures to the main biomechanical and psychosocial risk factors on the incidence of UEMSD in the COSALI cohort. This thesis revealed that an important proportion and a large number of UEMSD could be avoided if exposure to the modifiable risk factors, such as high physical exertion, uncomfortable shoulder postures and social support, were reduced in the working population. Moreover, this study showed that a multidimensional combining both a reduction of exposure to high physical exertion and improved social support would reduce a larger number of cases.

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keywords: Upper-extremity MSD; occupational risk factor; combined effect; population attributable fraction; preventable case; prevention.

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Research and teaching experience

Scientific communications relative to the doctoral thesis

Journal Publications

Nambiema, A., Bertrais, S., Bodin, J., Fouquet, N., Aublet-Cuvelier, A., Evanoff, B., Descatha, A., Roquelaure, Y., 2020. Proportion of upper extremity musculoskeletal disorders attributable to personal and occupational factors: Results from the French Pays de la Loire study. *BMC public health 20, 456*. https://doi.org/10.1186/s12889-020-08548-1

Nambiema, A., Bodin, J., Fouquet, N., Bertrais, S., Stock, S., Aublet-Cuvelier, A., Descatha, A., Evanoff, B., Roquelaure, Y., 2020. Upper extremity musculoskeletal disorders: how many cases can be prevented? Estimates from the COSALI cohort. Scand J Work Environ Health. https://doi.org/10.5271/sjweh.3911

Journal Papers in progress

Nambiema A., Bodin J., Stock, S., Aublet-Cuvelier, A., Evanoff, B., Descatha, A., Roquelaure Y. Proportion and number of upper-extremity musculoskeletal disorders attributable to the combined effect of biomechanical and psychosocial risk factors in a working population. ***(Submitted for publication)***

Research workbooks

Bodin, J., **Nambiema, A.**, Fouquet, N., Vézina, N., Marie Bellemare, M., Descatha, A., Roquelaure, Y. 2018. L'impact potentiel des scénarios de prévention des TMS : Impact potentiel des interventions de prévention des troubles musculo-squelettiques (TMS) à l'échelle populationnelle : scénarios de réduction de l'exposition professionnelle aux facteurs de risque de TMS en population active. *Les cahiers de la Recherche. Santé, Environnement, Travail, ANSES, 2018, La santé au travail, pp.44-45. Anses-01919726.* https://hal-anses.archives-ouvertes.fr/anses-01919726/document

Conference Presentations

Oral Presentations

Nambiema, A., Bodin, J., Fouquet, N., Bertrais, S., Stock, S., Aublet-Cuvelier, A., Descatha, A., Evanoff, B., Roquelaure, Y. Troubles musculo-squelettiques du membre supérieur : combien de cas peuvent être évités ? Estimations à partir de la cohorte COSALI pour la région française des Pays de la Loire. *14th Francophone Conference of CLINical EPIdemiology (EPICLIN), Full digital conference*, September 15-16, 2020.

Nambiema A., Bertrais, S., Bodin J., Fouquet, N., Aublet-Cuvelier, A., Evanoff, B., Descatha, A., Roquelaure, Y. Proportion of upper extremity musculoskeletal disorders attributable to personal and occupational factors: Results from the French Pays de la Loire study.

- *10th International Scientific Conference on the Prevention of Work-Related Musculoskeletal Disorders (PREMUS)*, Bologna, Italy, September 2-5, 2019.
- *7th Young Researchers' Day at Irset*, Rennes, France, March 28, 2019.

Nambiema, A., Bertrais, S., Bodin, J., Fouquet, N., Aublet-Cuvelier, A., Evanoff, B., Descatha, A., Roquelaure, Y. Proportion de troubles musculo-squelettiques du membre supérieur potentiellement attribuable aux facteurs de risque personnels et professionnels : Résultats de l'étude française de la région des Pays de la Loire. *Day of the Medical Inspection and the University of Angers,* Angers, France, April 1, 2019.

Poster Presentations

Nambiema, A., Bodin, J., Fouquet, N., Bertrais, S., Stock, S., Aublet-Cuvelier, A., Descatha, A., Evanoff, B., Roquelaure, Y. Proportion et nombre de cas de troubles musculo-squelettiques du membre supérieur potentiellement évitables : Estimations pour les pays de la Loire. *Biomedical Research Day*, Tours, France, December 13, 2019.

Nambiema, A., Bodin, J., Fouquet, N., Bertrais, S., Stock, S., Aublet-Cuvelier, A., Descatha, A., Evanoff, B., Roquelaure, Y. Upper extremity musculoskeletal disorders: how many cases can be prevented? Estimates from the COSALI cohort, *Annual Meeting of the Doctoral School "Biologie-Santé", Université Bretagne Loire*, Angers, France, December 10-11, 2019.

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Teaching experience

Teaching occupational health residents (lectures and practical work) the following courses in the Faculty of Health: statistics, epidemiology, statistical software (STATA, SPSS, and EXCEL). Part-time (32 hours/academic year), Faculty of medicine, University of Angers, France, September 2018 to July 2020.

Professional service

Symposium Co-Organizer

Seventh Young Researchers' Day at Irset, Rennes, France, March 28, 2019.

Meetings organizer

The Ester team doctoral students' meetings, Angers, France, 2018-2020.

List of Abbreviations

Anact	Agence nationale pour l'amélioration des conditions de travail
BLS	Bureau of Labor Statistics
BMI	Body mass index
CALMAR	CALibration on MARgins
CAN$	Canadian dollar
CCTIRS	France’s Advisory Committee on the Processing of Information in Health Research
CI	Confidence interval
CNIL	France’s National Committee for Data Protection
COSALI	COhorte des SAlariés Ligériens
CTD	cumulative trauma disorder
CTS	Carpal tunnel syndrome
CONSTANCES	CONSulTANts des Centres d'Examens de Santé
DALYs	Disability-Adjusted Life Years
DIRECCTE	Regional Directorate of Labour, Employment and Vocational Training
EBIC	Economic Burden of Illness in Canada
EU	European Union
EU-28	European Union, which consists a group of 28 countries
EU-OSHA	European Agency for Safety and Health at Work
GBD	Global Burden of Disease
GPD	Gross Domestic Product
ICD-10	10^{th} Revision of the International Classification of Diseases
ILO	International Labor Organization
ILO	International Labor Organization
INRS	National Research and Safety Institute for the Prevention of Occupational Accidents and Diseases
JCQ	Job Content Questionnaire
INRS	French National Research and Safety Institute for the Prevention of Occupational Accidents and Diseases
Inserm	Institut national de la santé et de la recherche médicale
LE or LET	Lateral epicondylitis or Lateral epicondylar tendinopathy
LEEST	Laboratory of ergonomics and epidemiology in occupational health
MS	Musculoskeletal symptoms
MSD	Musculoskeletal disorders
OCS	Occupational cervicobrachial disorder
OOS	Occupational overuse syndrome
OP	Occupational physician
OR	Odds ratio
ORES	Regional Economic and Social Observatory

PY	Person-years
PAF	Population attributable fraction
PdL	Pays de la Loire
pOR	Pooled adjusted odds ratio
RCS	Rotator cuff syndrome
RCT	Randomized controlled trial
RCT	Rotator cuff tendinopathy
RPE	Rating Perceived Exertion
RR	Relative risk
RSI	Repetitive strain injury
SALTSA	European consensus criteria document
SAS	Statistical Analysis System
SNDS	French National Health Data System
SpFrance	French National Public Health Agency
SUMER	Surveillance médicale des expositions des salariés aux risques professionnels
UEMSD	Upper extremity musculoskeletal disorders
US	United States
USBJI	United States Bone and Joint Initiative
WHO	World Health Organization
WRMSD	Work-related MSD

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Introduction

The first part of this thesis presents a background literature review of work-related musculoskeletal disorders (MSD) on studies conducted worldwide including their economic and social impact, prevention, project rationale, and demonstrates how this thesis will address the knowledge gaps in the current (epidemiological) literature. In addition, it briefly synthesizes previous studies on risk factors.

1. Background and significance

1.1. Musculoskeletal disorders

MSD are a group of soft-tissue injuries and disorders that affect the musculoskeletal system (i.e. muscles, tendons, joints, nerves, cartilages). These disorders are listed in the 10th revision of the International Classification of Diseases (ICD-10) (WHO, 2008), and refer to medically diagnosed periarticular diseases of the limbs and spine, as well as multiple or localized pain syndromes (Roquelaure, 2018). Regarding the World Health Organization (WHO) definition, work-related diseases such as MSD are multifactorial diseases in which the work environment and the performance of work contribute significantly to the causation of the disease (WHO Expert Committee on Identification and Control of Work-Related Diseases & World Health Organization, 1985). With a large majority of cases occurring in the upper extremity, these disorders result from repeated or sustained exposure to work-related activities, such as working in the same posture for long periods of time, repetitive tasks, awkward postures, excessive efforts to carry and lift heavy objects, whole-body vibration, and lack of adequate recovery time (Aptel et al., 2002; Aublet-Cuvelier et al., 2015; da Costa and Vieira, 2010; Kittusamy and Buchholz, 2004; Kozak et al., 2015; Punnett and Wegman, 2004; Roquelaure, 2015; Sluiter et al., 2001). The International Labor Organization (ILO) (ILO, 2015) estimated that about 160 million cases of non-fatal work-related diseases occur annually in the world among which a high number of MSD. According to a recent WHO Global Burden of Disease (GBD) data which enables comparisons among different diseases and different populations, MSD (in general) ranked among the top five diseases in the world (#4) in terms of disease burden, representing about 8% of the total 1.8 billion Disability-Adjusted Life Years (DALYs) (Roser and Ritchie, 2020). In the international literature, a diversity of terms, assuming a link between the clinical disorder(s) and the potential risk factor or mechanism of injury, has been used to describe these disorders. These terms include repetitive strain injury (RSI), cumulative trauma disorder (CTD), occupational cervicobrachial disorder (OCD), occupational overuse syndrome (OOS), and work-related MSD (WRMSD) (Luttmann et al., 2003; Punnett and Wegman, 2004; Sluiter et al., 2001). Furthermore, case definitions of these disorders sometimes vary in different countries, so the associated risk factors may also vary.

The above-mentioned problems make it difficult to compare the results of different epidemiological studies and to assess and compare the magnitude and nature of WRMSD between different countries and sometimes within the same country. Against this background and in order to facilitate more uniform collection, recording, and reporting of information on work-related upper extremity MSD (UEMSD) in the European Union (EU), an expert group developed in 2001 a protocol providing evidence- or consensus-based case definitions, as well as criteria for identifying and classifying them (Sluiter et al., 2001). The published document deals with 11 specific and nonspecific UEMSD occurring in the different regions of the upper extremity (shoulder/arm, elbow/forearm, and hand/wrist) and neck. These UEMSD are listed below:

1) Radiating neck complaints
2) Rotator cuff syndrome
3) Epicondylitis - lateral and medial
4) Ulnar nerve compression at the elbow: cubital tunnel syndrome
5) Radial nerve compression: radial tunnel syndrome
6) Flexor-extensor peritendinitis or tenosynovitis of the forearm-wrist region
7) De Quervain's disease
8) Carpal tunnel syndrome
9) Ulnar nerve compression at the wrist: Guyon canal syndrome
10) Raynaud's phenomenon (vibration white finger) and peripheral neuropathy associated with hand-arm vibration
11) Osteoarthrosis of the distal upper-extremity joints
12) Nonspecific upper-extremity musculoskeletal disorders

In the present doctoral thesis, the main focus is on major MSD affecting the upper extremity known to be very common in the workplace (Sluiter et al., 2001). These disorders refer to the following areas of the body: shoulder/arm, elbow/forearm, and hand/wrist.

1.2. Upper extremity musculoskeletal disorders

1.2.1. Prevalence and incidence

Several epidemiological studies conducted around the world have provided estimates of prevalence and/or incidence (rate of proportion) of UEMSD. Some of these estimates, presented in Table 1, vary across countries, study designs (cross-sectional, cohort, systematic review and meta-analysis) and populations (general/working). A systematic review by Luime et al. (Luime et al., 2004) conducted in the general population showed a prevalence of shoulder complaints ranging between 4.7% and 46.7%, and an incidence proportion varying between 0.1% and 2.5%. Regarding the working population, a systematic review conducted by Huisstede et al. (Huisstede et al., 2006) showed a clinically diagnosed prevalence of UEMSD ranging from 9.3 to 26.9% and a 12-month prevalence ranging from 2.3 to 41.0%. A meta-analysis by Spahn et al. (Spahn et al., 2012) found a prevalence of carpal tunnel syndrome ranging between 8.2% and 10.9%, and an incidence rate between 1.8 and 17.3 cases/1000 person-years.

In many countries, UEMSD account for a major proportion of all occupational diseases (registered or compensable or both) (Roquelaure, 2018). According to the United States (US) Bureau of Labor Statistics (BLS) revealed that in 2015, there were 358 890 new UEMSD cases (incidence rate: 3.2 cases/1000 full-time workers) for nonfatal occupational injuries and illnesses cases involving days away from work (Bureau of Labor Statistics, 2016). In Québec, the incidence rate was estimated at 15.4 cases/1000 full-time workers in 2006, a decrease of 4.5% compared to 2001 (Michel et al., 2010). In France, an epidemiologic surveillance study of work-related UEMSD in the Pays de la Loire (PdL) region found a prevalence of clinically diagnosed UEMSD of approximately 13% (11% in men and 15% in women) (Roquelaure et al., 2006). According to estimates from the French cohort, CONSTANCES ("CONSulTANts des Centres d'Examens de Santé") (Carton et al., 2016), the prevalence of persistent pain (≥30 days in the past 1 year) varied between 11.6% (at the elbow), 19.8% (at the wrist) and 20.7% (at the shoulder) in women, 9.4%, 12.0% and 15.5% for men (respectively for the same locations). In addition, recent social health insurance data for 2018 revealed that UEMSD accounted for 80% (39 555 cases) of all occupational diseases, an increase of about 3% compared to 2017 (Cnam. Direction des Risques Professionnels : Mission statistiques & Département tarification, 2019).

Table 1: Prevalence and incidence of UEMSD in the general population and the working population

Reference	Country	Study design	Study population; N	Outcome measures	assessment	Prevalence/incidence
(Rossignol et al., 1997)	Canada	RC	Island of Montreal general population, N=1.1 million	CTS	Surgical cases	IP=0.1%
(Walker-Bone et al., 2004)	UK	CS	General population in Southampton, N=1960	LE, RCS, CTS, de Quervain's disease, Tenosynovitis of the wrist	Q and CE	Prev=0.5 to 4.5% for men and 1.1 to 6.1% for women
(Luime et al., 2004)	–	SR of 18 studies	General population	Incidence and 1-year prevalence of shoulder complaints	Q and/or CE	Prev=4.7 to 46.7% IP=0.1 to 2.5%
(Miranda et al., 2008)	Finland	PC	General population, N=883	Chronic shoulder disorders	CE	IP=7.1%
(Spahn et al., 2012)	–	MA of 87 studies	General and working population	CTS	Q and CE or Surgery cases	Prev: 8.2% and 10.9% IR=1.8 and 17.3 cases/1000 PY
(Miranda et al., 2001)	Finland	PC	Forestry company; N=2094	Incidence and persistence of SP	Q	IP=13.6%
(Roquelaure et al., 2002)	France	PC	Shoe factory workers, N=191	LE, RCS, CTS	Q and CE	Prev=2.1 to 12.0%
(Leclerc et al., 2004)	France	PC	Working population exposed to repetitive work, N=326	Incidence SP: experienced at least 1 day within the 6 months	Q	IP=23.0%
(Huisstede et al., 2006)	–	SR of 6 studies	Working population	UEMSD in the past 1 year	Q and/or CE	Prev=9.3 to 26.9% (CE) Prev=2.3 to 41.0% (Q)
(Mattioli et al., 2009)	Italy	RC	Workers in Tuscany, N=8801	CTS	Surgery cases	IR= 2.6 and 0.5 cases/1000 PY for women and for men
(Fan et al., 2014)	US	PC	Working population, N=611	LE	Q and CE	IR=49.1 cases/1000 PY
(Dalbøge et al., 2014)	Denmark	PC	Working population, N=2.4 million	Subacromial impingement syndrome	Surgical cases	IR=1.1/1000 PY

(Kapellusch Jm et al., 2014)	US	PC	Manufacturing and service workers, N=2751	CTS	Q and Electrodiagnostic tests	IR= 29.8 cases/1000 PY
(da Costa et al., 2015)	–	SR of 27 studies	Working population	UEMSD	Q or CE and EV	IP=0.1 to 9.1% Prev=0.14 to 21.9%
(Bureau of Labor Statistics, 2016)	US	SOII	Working population	UEMSD: Cases that require medical attention beyond first aid	Registered and reported by employers	IR=3.2 cases/1000 PY
(Descatha et al., 2016)	-	SR of 5 studies	Working population, N=3449	LE	CE	IR=9.0 to 49.0 cases/1000 PY
(Heilskov-Hansen et al., 2016)	Denmark	RC	Painting workers, N=4957	CTS	CE	IR=1.4 and 4.0 cases/1000 PY for men and for women
					Surgery cases	IR=0.7 and 2.3 cases/1000 PY for men and for women
(van der Molen et al., 2016)	Netherlands	PC	Working population in construction	Repetitive strain injuries	CE	IR=6.4 cases/1000 PA
(Violante et al., 2016)	Italy	PC	Industrial and services workers, N=2032	CTS	Q and CE	IR=53.9 and 14.2 cases/1000 PY
(Thygesen et al., 2016)	Denmark	RC	Baggage handlers at Copenhagen Airport, N=3396	Subacromial shoulder disorders	CE or surgical treatment	IR=2.1 cases/1000 PY
(Dale et al., 2018)	USA	PC	Industrial workers, N=2393	CTS	Q and electrodiagnostic tests	IR=39.0 cases/1000 PY
(Balogh et al., 2019)	Sweden	CS	Working population, N=5840	RCS and CTS	Q and CE	Prev=5.0% for RCS and 2.0% for CTS in men, and 3.0% and 7.0% in women

CE: clinical examination, CS: cross-sectional, CTS: carpal tunnel syndrome, EV: ergonomic evaluation, IP: incidence proportion, IR: incidence rate, LE: lateral epicondylitis, MA: Meta-analysis, PY: person-years, PC: prospective cohort, Prev: prevalence, Q: Questionnaire, RC: retrospective cohort, RCS: rotator cuff syndrome, SOII: Survey of Occupational Injuries and Illnesses, SP: shoulder pain, SR: systematic review, UK: United Kingdom, US: United States.

1.2.2. Economic and social burden

Throughout the world, UEMSD affect workers in all sectors and occupations and constitute the main cause of morbidity, work-related disabilities, and absenteeism from work in many developed countries such as the US, Canada and EU-28 (Côté et al., 2013; de Kok et al., 2019; GBD 2017 Disease and Injury Incidence and Prevalence Collaborators, 2018; Roquelaure, 2018; Storheim and Zwart, 2014; Summers et al., 2015). These disorders constitute one of the most serious occupational and public health problems in many countries due to their considerable human and social costs, in terms of pain and discomfort in work and daily life, sometimes irreversible functional sequelae, reduced ability to work, the risk of career breaks and low quality of life, and their economic impact on companies particularly in terms of costs related to production loss (Bevan, 2015; Bhattacharya, 2014; de Kok et al., 2019; Lang et al., 2018; March et al., 2014; Moradi-Lakeh et al., 2017; Oh et al., 2011; Roquelaure, 2015; Smith et al., 2014; Storheim and Zwart, 2014; Summers et al., 2015; United States Bone and Joint Initiative, 2015; Weinstein, 2016).

From 1997 to 2005 in Washington state, 127 885 workers' compensation claims were accepted for UEMSD representing 10.3% of all claims, of which 36.9% were compensable resulting in direct costs of $1.49 billion (Silverstein and Adams, 2007). According to the United States Bureau of Labor Statistics (BLS) in 2015, one-third of lost-time work-related injuries and illnesses were due to UEMSD (Bureau of Labor Statistics, 2016). A report from the United States Bone and Joint Initiative (USBJI) (United States Bone and Joint Initiative, 2015) showed that, the annual estimated direct (compensation of victims, treatment, medication, etc.) and indirect costs (loss of production, replacement costs, absenteeism, lost wages, etc.) attributable to persons with MSD are estimated to be approximately $213 billion per year in lost wages and treatment, or 1.4% of the U.S. Gross Domestic Product (GDP) in 2011. A recent report of the USBJI has estimated the annual direct and indirect costs attributable to persons suffering from MSD to be at $322 billion in 2012–2014 (United States Bone and Joint Initiative, 2018).

Between 1998 and 2007 in Québec, UEMSD accounted for an average of 27% of all MSD compensated annually (Michel et al., 2010). In addition, UEMSD were compensated for the longest periods of time with an average compensation period of 81.1 days (median of 20 days). These disorders ranked among the top five most expensive conditions (#3) in terms of the value of lost production due to morbidity (CAN$3.1 billion), representing about 23% of the total CAN$13.3 billion allocated morbidity costs in Canada (Public Health Agency of Canada, 2018). Furthermore, the total direct and indirect costs were estimated at $8.7 billion, or 7% of the total costs of the Economic Burden of Illness in Canada (EBIC) (CAN$130.8 billion) in 2010 (Public Health Agency of Canada, 2018). In 2017, according to the GBD data, these disorders ranked among the top five diseases (#3) in terms of burden of disease in Canada, or 14% of the total 7.8 million DALYs (Roser and Ritchie, 2020). In the high-income Asia-Pacific region, WHO data on the GBD showed that in 2017, MSD represented about 8% of the total 336.9 million DALYs in this area of Asia (Roser and Ritchie, 2020).

A review conducted by Buckle and Devereux (Buckle and Devereux, 2002) on the basis of scientific data and the consensual opinion of experts, union bodies and government agencies across the EU concluded that UEMSD are a major problem in the EU in terms of poor health and costs. In France, according to social health insurance data from 2018, the costs related to all MSD (mainly UEMSD, i.e. 91% of all MSD) were estimated at €2 billion for companies (Cnam. Direction des Risques Professionnels, 2019).

In summary, MSD remain widespread and costly in the working population. The overwhelming majority of cases involve the back and the upper extremities (Aptel et al., 2002; Aublet-Cuvelier et al., 2015; Michel et al., 2010).

1.3. Risk factors of UEMSD

UEMSD may result from repeated or sustained exposure to different groups of risk factors related to the work environment together with other risk factors not related to work. Numerous studies conducted worldwide in the working population have revealed that multiple risk factors including person-related factors, biomechanical factors, psychosocial factors and organizational factors commonly interact with each other in creating the overall risk (Aptel et al., 2002; Bodin, 2017; Bodin et al., 2018; Bongers et al., 2002, 2006; da Costa and Vieira, 2010; Descatha et al., 2016; Hauke et al., 2011; Jackson et al., 2019; Kozak et al., 2015; Punnett and Wegman, 2004; Roquelaure et al., 2009b, 2020; van der Molen et al., 2017; van Rijn et al., 2009a, 2009b, 2010; Widanarko et al., 2014).

A number of theoretical models have been suggested in the ergonomics literature concerning different possible pathways of association and potential influences of different factors contributing to the development of MSD (Aptel and Vézina, 2008; Armstrong et al., 1993; Bellemare et al., 2002; Carayon et al., 1999; Hagberg et al., 1995; Karsh, 2006; Kumar, 2001; National Research Council and Institute of Medicine, 2001; Punnett et al., 2009; Sauter and Moon, 1996; Stock et al., 2013). Some of these models considered biomechanical risk factors as a primary cause of MSD, and other factors (e.g. organizational and psychosocial) as intermediate variables (Armstrong et al., 1993; Hagberg et al., 1995; Sauter and Moon, 1996). The model proposed by Karsh (Karsh, 2006) takes into account many mechanisms and factors (e.g. aging, strength, posture, job control, social support, etc.) as contributing to the development of MSD and shows the role of work organization in influencing biomechanical exposure. Stock et al. (Stock et al., 2013) presented a conceptual model of the development of MSD capitalizing the findings of epidemiological and ergonomic studies which also integrates the authors' view of the psychosocial work environment and the possible mediating role of psychological distress. Recently, Roquelaure (Roquelaure, 2016) proposed an organizational model (see Figure 1) to visualize the effects of different risk factors on MSD, which can be applied to most countries and industries.

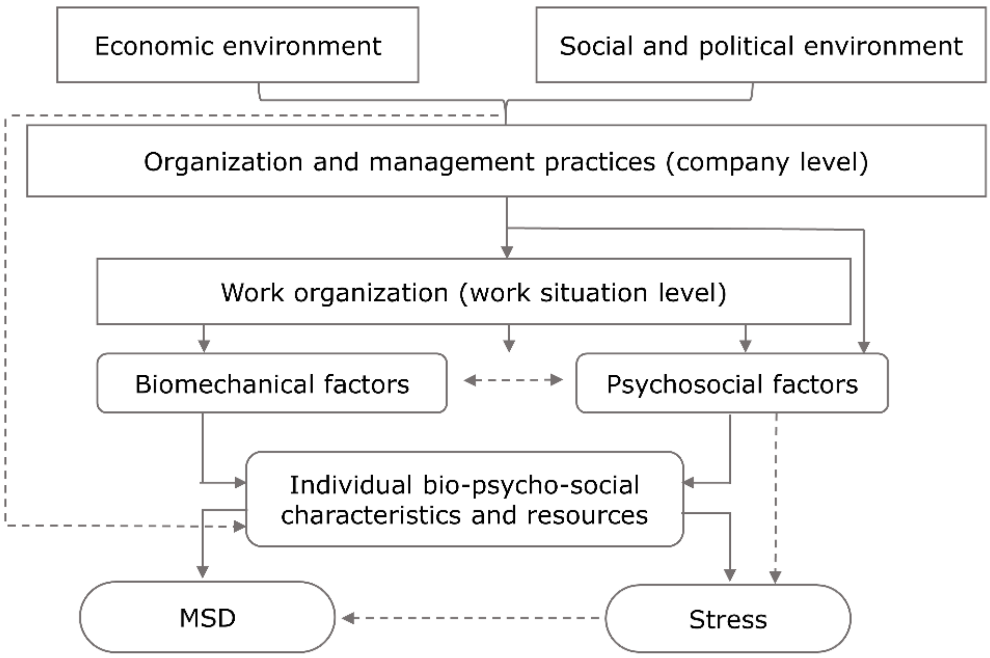

Figure 1. A conceptual model integrating the multidimensional nature of MSD (adapted from Roquelaure (Roquelaure, 2016)).

Based on the findings of epidemiological, clinical and ergonomic research conducted in the workplace, Roquelaure (Roquelaure, 2018) has provided a summary of the main UEMSD risk factors that have been identified in these investigations. The classification of results is summarized with some references in Table 2 and the findings of some of these studies (cohort study or systematic reviews or meta-analyses) are presented in the subsections below.

Table 2: Risk factors for UEMSD (Adapted from Roquelaure (Roquelaure, 2018))

Risk factors	References
Non-occupational factors	
Personal factors ○ Age ○ Female gender (carpal tunnel syndrome: CTS) ○ Genetic predispositions ○ Obesity ○ Pregnancy (CTS)	(Becker et al., 2002; Cazares-Manríquez et al., 2020; da Costa and Vieira, 2010; Fan et al., 2015; Franceschi et al., 2014; Harris-Adamson et al., 2013; Larsson et al., 2007; Leong et al., 2019; Malchaire et al., 2001; Meems et al., 2015; Moghtaderi et al., 2005; National Research Council and Institute of Medicine, 2001; Nilsen et al., 2011; Okunribido and Wynn, 2010; Padua et al., 2010; Riccò et al., 2016; Sayampanathan et al., 2020; Shiri et al., 2015; Spahn et al., 2012; van der Molen et al., 2017; Viikari-Juntura et al., 2008; Violante et al., 2016)
Medical and surgical history ○ History of tendinopathies/tunnel syndromes ○ Diabetes ○ Inflammatory rheumatism ○ Severe hypothyroidism (CTS)	(Fan et al., 2015; Leong et al., 2019; Pourmemari and Shiri, 2016; Shiri, 2016; Spahn et al., 2012; Viikari-Juntura et al., 2008)

Occupational factors	
Biomechanical ○ Highly repetitive movements (frequency, speed) ○ Intense efforts (force applied, weight carried or moved, general physical arduousness of working at the workstation) ○ Adoption of uncomfortable postures for long periods (shoulder abduction, flexion/extension of elbow or wrist, flexion/torsion of torso) ○ Using the heel of the palm or the elbow for support, or localized pressure on these areas ○ Exposure to vibrations transmitted to the hand ○ Exposure to vibrations transmitted to the entire body ○ Working in cold conditions ○ Duration of exposure to physical constraints ○ Combination of biomechanical factors (+++)	(Cail and Aptel, 2006; da Costa and Vieira, 2010; Descatha et al., 2016; Harris-Adamson et al., 2016, 2015; Kozak et al., 2019, 2015; Larsson et al., 2007; Leong et al., 2019; Malchaire et al., 2001; Mayer et al., 2012; Miranda et al., 2008; National Research Council and Institute of Medicine, 2001; Palmer et al., 2007; Sluiter et al., 2001; Spahn et al., 2012; van der Molen et al., 2017; van der Windt et al., 2000; van Rijn et al., 2010, 2009b, 2009a, 2009b)
Psychosocial ○ Job-related stress ○ Heavy mental load ○ Lack of decision-making autonomy ○ Lack of support from line managers ○ Lack of support from co-workers ○ Lack of recognition for work done	(Bernal et al., 2015; Bongers et al., 2006, 2002; Cail and Aptel, 2006; da Costa and Vieira, 2010; Harris-Adamson et al., 2013; Hauke et al., 2011; Kraatz et al., 2013; Lang et al., 2012; Larsson et al., 2007; Luttmann et al., 2003; Macfarlane et al., 2009; Malchaire et al., 2001; National Research Council and Institute of Medicine, 2001; Paul and Salve, 2020; Roquelaure, 2018; Roquelaure et al., 2020; Sluiter et al., 2001; Sobeih et al., 2006; van der Molen et al., 2017; van der Windt et al., 2000; van Rijn et al., 2010, 2009a; Vargas-Prada and Coggon, 2015)
Organizational ○ Working under time pressure ○ Very short cycle times ○ Lack of time to recover ○ Inflexibility of procedures and checks ○ Lack of individual/collective leeway ○ Lack of resources to carry out high-quality work ○ Monotonous tasks ○ Gender-based division of work	(Bodin, 2017; Bodin et al., 2018; Bongers et al., 2002; Cail and Aptel, 2006; Larsson et al., 2007; Leider et al., 2015; Malchaire et al., 2001; National Research Council and Institute of Medicine, 2001; Paul and Salve, 2020; Petit et al., 2015; Roquelaure, 2017; Roquelaure et al., 2020, 2020; Sluiter et al., 2001)

1.3.1. Non-occupational factors

Non-occupational factors such as personal risk factors including both personal characteristics (e.g. age, gender) and medical history (e.g. obesity, diabetes, rheumatoid arthritis) have been reported in the literature to be linked to UEMSD (Roquelaure et al., 2014). These factors act in combination with work-related factors to increase the risk of UEMSD.

Previous studies have shown that women are more at risk of certain UEMSD (e.g. CTS) (Heilskov-Hansen et al., 2016; Hooftman et al., 2004; Lund et al., 2019; Silverstein et al., 2009). The review by da Costa and Vieira (da Costa and Vieira, 2010) found that female gender was positively associated with the development of work-related wrist/hand disorders (with reasonable evidence) and work-related elbow/forearm disorders (with insufficient evidence). Moreover, a longitudinal population-based study of Andorsen et al. (Andorsen et al., 2014) conducted among in a Norwegian general population revealed that women have a higher burden of musculoskeletal complaints than men (63.4% versus 52.9%). In a pooled cohort study of musculoskeletal outcomes to measure CTS frequency, Dale et al. (Dale et al., 2013) found a higher combined prevalence of CTS in women than in men (10.0% versus 5.8%). Furthermore, a recent review (Cazares-Manríquez et al., 2020) based on 72 studies showed that the risk of CTS was positively associated with female sex.

An increasing prevalence of CTS in older age categories [<30 (3.7%), 30–39 (6.4%), 40–49 (10.7%), and ≥50 years (11.9%)] was observed in the study by Dale et al. (Dale et al., 2013). In their systematic review, Okunribido and Wynn (Okunribido and Wynn, 2010) concluded that older workers were more likely to suffer from UEMSD than younger workers due to reduced functional capacity, which increases the probability of developing these disorders. In their study, da Costa and Vieira (da Costa and Vieira, 2010) found an increased risk of work-related wrist/hand disorders (with reasonable evidence) or work-related elbow/forearm disorders (with insufficient evidence) with older age. A recent systematic review and meta-analysis (Leong et al., 2019) showed, with strong evidence, that age above 50 years among the working population was associated with an increased risk of rotator cuff tendinopathy (RCT) (OR=3.31 [2.30–4.76]). Another review showed an increased risk of CTS with age (Cazares-Manríquez et al., 2020).

Using criteria consistent with Hill's work (Hill, 2015, 1965) and a strict "level of evidence" classification, a systematic review (da Costa and Vieira, 2010) found that a high body mass index (BMI) was associated with an increased risk of UEMSD with a reasonable level of evidence of a causal relationship. More specifically, high BMI was found to be associated with the development of work-related wrist/hand disorders (with reasonable evidence) and with the development work-related elbow/forearm disorders (with insufficient evidence). These associations of high BMI with UEMSD are supported by a meta-analysis of 58 studies (Shiri et al., 2015) which showed that excess BMI was associated with the risk of CTS. A review by Franceschi et al. (Franceschi et al., 2014) indicated that obesity is a risk factor for tendinopathy including LE. However, the authors suggested that further studies should be conducted to establish the real strength of the association for each type of tendinopathy. Recent results from a systematic review also suggested that BMI was associated with an increased risk of CTS (Cazares-Manríquez et al., 2020).

Regarding medical conditions, findings of a systematic review and meta-analysis (Shiri, 2016) found an increased risk of CTS in persons suffering from rheumatoid arthritis (pooled adjusted odds ratio [pOR]: 1.96 (95% confidence interval [95%CI]: 1.57–2.44)) with no evidence of publication bias. In another systematic review and meta-analysis (Pourmemari and Shiri, 2016), diabetes has been shown to be associated with an increased risk of CTS (pOR: 1.69 (95%CI: 1.45–1.96)) with no evidence of publication bias. In their systematic review and recent meta-analysis, Leong et al. (Leong et al., 2019) showed, with strong evidence, that diabetes was associated with an increased risk of RCT (OR=2.24 [1.37–3.65]) among the general and working population. In their study designed to assess the incidence of LE in workers exposed physically, Descatha et al. (Descatha et al., 2013), found a positive association between medical conditions (diabetes, rheumatoid arthritis or osteoarthrosis) and the incidence of LE in bivariate analyses but not in multivariate analyses. In addition, in a case-control study (Titchener et al., 2013) the medical conditions mentioned above were not found to be associated with LE.

1.3.2. Occupational factors

Occupational factors, considered to be related to the working situation, are categorized into three groups: biomechanical, psychosocial and organizational factors. Critical reviews of the epidemiological literature show good evidence of associations of work-related risk factors with UEMSD, and in particular, when workers are exposed to multiple risk factors in combination.

a) Biomechanical factors

Biomechanical factors relate to workplace physical demands (e.g. repetitive motions, handling of heavy loads, awkward postures). Several systematic reviews and meta-analyses have demonstrated the risk of UEMSD associated with prolonged exposure to physical demands in working situations. Da Costa et al.'s review (da Costa and Vieira, 2010) based on 63 longitudinal studies demonstrated that high biomechanical demands (e.g. heavy physical work) were associated with UEMSD with a causal relationship with at least reasonable evidence; the most commonly biomechanical risk factors for UEMSD included excessive repetition, awkward postures, and heavy lifting. The repetitive motion involves the repetitive use (e.g. every few seconds) of the same muscle groups through frequent movements for long periods of time during a typical working day, which prevents recovery and can lead to muscle tensions and fatigue. The results of a review of prospective studies and meta-analysis by Descatha et al. (Descatha et al., 2016) strongly supported the assumption that there is an association between biomechanical exposure involving the wrist and/or elbow at work and the incidence of LE. Nevertheless, a recent meta-analysis (van der Molen et al., 2017) revealed moderate evidence for associations of shoulder disorders with arm-hand elevation (OR=1.90 [95% CI 1.47–2.47]) and shoulder load (OR=2.00 [1.90–2.10]), and low to very low evidence with hand force exertion (OR=1.50 [1.25–1.87]) and hand-arm vibration (OR=1.30 [1.01–1.77]). A recent systematic review and meta-analysis by Leong et al. (Leong et al., 2019) showed, with moderate evidence, that working with the shoulder above 90 degrees was associated with an increased risk of rotator cuff tendinopathy (OR=2.41 [1.31–4.45]) among the working population. In their scoping review, Kozak et al. (Kozak et al., 2019) found that the common risk factors for WRMSD in hairdressers included repetitive movements, forceful exertion of upper extremities, working with arms above shoulder level, awkward postures and movements, high mechanical workload and standing position.

b) Psychosocial factors

It is increasingly recognized that psychosocial factors also play a role in the development of UEMSD. Factors such as low social support from supervisors or co-workers, low job decision latitude, or high psychological demands can aggravate the consequences of UEMSD (Luttmann et al., 2003). The findings of a meta-analysis by Hauke et al. (Hauke et al., 2011) reported statistically significant low-to-moderate effects of psychosocial factors (low social support, high job demands, low decision authority, high job strain and psychological distress) on the development of UEMSD. Da Costa et al.'s review (da Costa and Vieira, 2010) showed that high psychosocial work demands could influence the genesis of UEMSD with at least a reasonable level of evidence of a causal relationship. A meta-analysis by Lang et al. (Lang et al., 2012) found positive associations between psychosocial work stressors including high job demands, low job control, low social support at work and highly monotonous work (pooled odd ratio between 1.17 and 1.57) and neck/shoulder symptoms, and with upper extremity symptoms separately. These results are consistent with those of Kraatz et al.'s systematic review (Kraatz et al., 2013) which included 18 prospective longitudinal studies of neck/shoulder disorders. Indeed, this review showed that there was strong evidence for adverse effects of low social support, high job demands, low job control, and high job strain, on the onset of neck and/or shoulder disorders. However, findings from a recent meta-analysis including only longitudinal studies (van der Molen et al., 2017) revealed low to very low evidence for the association between the incidence of specific shoulder disorders (clinically diagnosed) and psychosocial job demands (OR=1.10 [1.01–1.25]).

Recently, a study (Bodin et al., 2018) using structural equation models to explore the direct and indirect relationships between shoulder pain and workplace risk factors showed that high psychological demands indirectly increased the risk of shoulder pain by influencing perceived stress and biomechanical risk factors. In addition, an association was found between coworker support and biomechanical risk factors suggesting that workers exposed to high physical demands receive more social support from their coworkers (Bodin et al., 2018). A similar study (Roquelaure et al., 2020) explored the direct and indirect relationships between CTS and occupational risk factors in French workers and found that psychosocial factors such as decision authority and skill discretion indirectly increased the risk of CTS by influencing biomechanical exposure. Recently, a study by Bodin et al. (Bodin et al., 2020) aimed to assess whether their previous structural equation model (Bodin et al., 2018) could be replicated in a large manufacturer of pharmaceutical preparations, and found an indirect impact of psychosocial factors on shoulder pain by acting on biomechanical exposure and perceived stress.

c) Organizational factors

Organizational factors relate to how the work is designed and performed including allocation of tasks, working procedures, work pace, production methods and management practices. Previous studies have shown that, in addition to personal factors, biomechanical and psychosocial work-related factors, organizational work factors also contribute to the onset of UEMSD indirectly by influencing the intensity or duration of biomechanical and psychosocial exposures (figure 1) (Bodin, 2017; Roquelaure, 2016; Roquelaure et al., 2020).

A literature review by Malchaire et al. (Malchaire et al., 2001) suggested that several organizational factors (e.g. monotony, high work rate, high time pressure) were associated with MSD of the neck/shoulder region with a low level of evidence, but not with MSD of the hand-wrist. A review by Sluiter et al. (Sluiter et al., 2001) revealed a strong level of evidence for the lack of recovery time. A prospective cohort study (Bodin et al., 2012a) found an organizational factor (working together with temporary workers) to be positively associated with incident RCS in the female working population. A similar study (Petit et al., 2015) found positive associations between organizational factors such as payment on a piecework basis and work pace dependent on automatic rate and the risk of CTS. In 2014, a study by Koukoulaki (Koukoulaki, 2014) found an impact of lean production on MSD symptoms and workers' mental health, and on the risk factors for these latter, especially in the automotive industry. The author concluded that the reported findings might reflect the inflexible lean implementation approaches used in the automotive industry in the 1990s, when just-in-time work environments with an increasing pace of work and a decreasing amount of time available for recovery were introduced. In addition, studies from this period report the most adverse effects.

A dissertation by Bodin (Bodin, 2017) showed the importance of organizational factors in understanding the occurrence of shoulder pain and UEMSD in general. Indeed, these factors may influence the conditions of exposure to occupational biomechanical and psychosocial factors among workers. For example, it has been shown that exposure to manufacturing constraints increased exposure to biomechanical factors and influenced exposure to psychosocial factors. Conversely, exposure to market constraints (e.g. work pace dependent on customers' demand) decreased exposure to biomechanical factors and influenced exposure to psychosocial factors (Bodin, 2017). Recently, a study by Roquelaure et al. (Roquelaure et al., 2020) concluded to an indirect impact of organizational factors on incident CTS. Indeed, authors showed that, exposure to machine-paced work had an indirect impact on increasing the risk of CTS, either by raising biomechanical exposure or by lowering decision authority and skill discretion, which in turn increased biomechanical exposure. Another recent study (Bodin et al., 2020) analyzing a sample from an industrial company showed that organizational factors such as automatic speed of a machine/movement of a product had an indirect impact on the risk of chronic shoulder pain by acting on biomechanical and psychosocial exposure.

1.4. Prevention of UEMSD

Effective and sustainable prevention of work-related UEMSD continues to be a challenge for public health practitioners and policy makers. The incidence and impact of UEMSD can be prevented or reduced by improving the ergonomic aspects of work and workplaces that can lead to a reduction or even elimination of exposures to occupational risk factors. However, there is little consensus on the most suitable interventions. The various strategies for successful prevention interventions for these disorders are categorized in three levels according to the scientific literature (Kennedy et al., 2010; Michaelis, 2009; Podniece et al., 2008): primary prevention, secondary prevention and tertiary prevention. The goal of primary prevention is to limit the incidence of UEMSD by reducing or eliminating risk factors. Primary interventions are based on the assumption according to which: reducing and/or eliminating the risk factor(s) having a significant impact on UEMSD should in some way lead to a reduction in the incidence of that disorder. Secondary prevention focuses on early detection of symptoms and stopping their progression. More related to treatment and rehabilitation, tertiary prevention strategies are designed for individuals with long-term disabling UEMSD and aim to reduce the progression of the disorder to facilitate maintenance of fitness for work and/or early return-to-work.

The available literature on the prevention of UEMSD or upper extremity musculoskeletal symptoms in the workplace describes a range of interventions that have been implemented and evaluated (Hoe et al., 2018, 2012; Lowe and Dick, 2015; Nastasia et al., 2014; Stock et al., 2018; van der Molen et al., 2005; Van Eerd et al., 2016; Varatharajan et al., 2014). Despite this scientific knowledge accumulated over the past few years, the prevention of UEMSD remains an ongoing challenge. Difficulties in preventing these disorders in the workplace can be explained by the complexity of their determinants related to the multi-factorial nature of this condition involving biomechanical and psychosocial factors, as well as organizational factors within companies (Roquelaure, 2016). Furthermore, the implementation of effective and sustainable prevention programs remains a challenge for public health practitioners and policy makers in changing industrial environments, which means that very few interventions are actually implemented in companies.

In recent years, studies have been conducted to address these UEMSD. These studies have been mainly limited to workplace interventions aimed at "reducing the biomechanical load" and introducing technical or organizational measures to reduce workers' exposure to uncomfortable work postures and/or intense and/or repetitive physical efforts (Kennedy et al., 2010; Muñoz-Poblete et al., 2019; Van Eerd et al., 2016; van Oostrom et al., 2009). Furthermore, various systematic reviews (Cole et al., 2005; Etuknwa and Humpheries, 2018; Kennedy et al., 2010; Lowe and Dick, 2015; Rivilis et al., 2008; Soares et al., 2020; Stock et al., 2018; Van Eerd et al., 2016) and Cochrane reviews (Hoe et al., 2018, 2012) have been published on this subject.

Most controlled prevention studies have focused on the reduction of UEMSD and have mostly been conducted among professional computer users (e.g. alternative keyboards, work environment). Often based largely on low-quality prevention interventions, most of these trials have provided limited or often inconsistent evidence of positive effects. In a systematic review based on 31 interventional studies for the prevention and management of neck/upper extremity musculoskeletal conditions, Boocock et al. (Boocock et al., 2007) provided evidence to support the use of certain mechanical and modification interventions as approaches for the prevention and management of UEMSD, and moderate evidence of the effectiveness of alternative keyboards. Another systematic review by Kennedy et al. (Kennedy et al., 2010) based on 36 interventions studies to reduce UEMSD found that the combination of different type of interventions produced mixed levels of evidence and the disappearance of messages that emerges from more specific categories of intervention: the levels of evidence for interventions were moderately positive for arm supports and limited for ergonomic training in combination with workstation adjustments, new chairs, and breaks. An updated review of workplace-based interventions for preventing and managing UEMSD by Van Eerd et al. (Van Eerd et al., 2016) based on 30 different types of interventions revealed that implementing a resistance training exercise program in the workplace can help prevent and manage UEMSD and symptoms with strong evidence. The study also found moderate evidence for the effectiveness of stretching programs, vibration feedback on the use of the mouse and workstation forearm supports with moderate evidence. Stock et al.'s systematic review (Stock et al., 2018) showed, with moderate evidence, that additional breaks were effective in reducing the intensity of musculoskeletal symptoms compared to conventional break times. For the other types of organizational or psychosocial interventions investigated by researchers, the levels of evidence were low to very low. They concluded that better quality research is needed to provide definitive conclusions about the effectiveness of organizational or psychosocial interventions in the workplace to prevent or reduce work-related MSD. Recently, a systematic review by Proper and van Oostrom (Proper and van Oostrom, 2019) found strong evidence for positive effects of workplace interventions, especially resistance exercise training on MSD prevention. The narrative review by Soares et al. (Soares et al., 2020) concluded to a benefit of workplace exercise programs for both employers and workers. Benefits for companies included reduced absenteeism, time-off requests, costs and sick leave, and improved subjective employability and work ability, while benefits for workers included reduced muscle activity during tasks and increased speed of movements. In addition, the authors found a decrease in the rate of MSD among workers who exercise.

Regarding Cochrane reviews, a study of Hoe et al. (Hoe et al., 2012) based on thirteen randomized controlled trials (RCTs) studies and evaluating the effectiveness of ergonomic equipment, supplementary breaks or reduced work hours, ergonomic training, a combination of ergonomic training and equipment, and patient lifting interventions for preventing UEMSD and neck in adults has found a reduction in the incidence of neck/shoulder disorders related to the use of arm support with an alternative mouse with moderate-quality evidence (risk ratio [RR]=0.52; 95% confidence interval [95%CI]: 0.27–0.99). In addition, very-low- to low-quality evidence was found suggesting that other ergonomic interventions do not prevent UEMSD, although this finding should be put into perspective due to the rarity and heterogeneity of the available studies. The authors finally concluded that there is a need for high-quality RCTs on the prevention of UEMSD. A recent Cochrane review by Hoe et al. (Hoe et al., 2018) confirms the previous conclusions. In addition, this new review found that there is very low-quality evidence of an effect on upper extremity discomfort in the form of supplementary breaks but no evidence concerning the effect of training and multifaceted interventions on upper extremity pain or discomfort.

It follows from all of the above that, in order to better target interventions in the workplace, it would be useful to quantify the proportion and number of UEMSD cases that could be prevented if exposure to the modifiable risk factors were reduced to levels that minimize the risk of UEMSD. Such information may provide an estimate of the theoretical maximum potential impact of preventive programs in the workplace (Punnett and Wegman, 2004; Roquelaure et al., 2018).

The next sub-section will present additional tools that can help public health practitioners and policy-makers better direct UEMSD prevention interventions based on the modifiable risk factors having the greatest impact the burden of UEMSD in order to prioritize interventions that reduce exposure to these risk factors.

1.5. Population attributable fraction (PAF)

It is important and common in epidemiology to assess the association between the exposure to some factors and the occurrence of health outcomes (e.g. injury, disease, disorder). In public health, it is even more important to quantify the impact of that exposure on the occurrence of these events within the population. This information will be very relevant for public health decisions and, in this instance, for prevention. Various measures are available for assessing the impact of exposure on the occurrence of disease within the population, including the population attributable fraction (PAF). The concept of the PAF was initially introduced by Levin (Levin, 1953) to quantify the impact of smoking on the occurrence of lung cancer. This method was first proposed for a simple binary exposure (Levin, 1953) and then extended to the case of a multi-level categorical exposure (Walter, 1976) and a continuous quantitative exposure (Bruzzi et al., 1985; Lloyd, 1996).

The PAF has the advantage of simultaneously considering the prevalence of the exposure to the risk factor within the population and the strength of its association with the disease (B Rockhill et al., 1998). Moreover, the PAF can be computed using a multivariable approach to quantify the relative impact of one or more exposures, or even co-exposure, on the occurrence of disease (Bruzzi et al., 1985; Dartois et al., 2016; Hamel et al., 2012; Marant-Micallef, 2018; Rajaobelina et al., 2019; Roquelaure et al., 2009a; van der Molen et al., 2019). Assuming that other risk factors remain unchanged and that there is a causal relationship between the risk factor and the disease, the PAF provides an estimate of the proportion of disease cases that would not have occurred if the exposure to a risk factor was eliminated or reduced to an alternative ideal exposure scenario (e.g. no alcohol consumption) (B Rockhill et al., 1998). Usually expressed as a percentage, the PAF is the epidemiological measure widely used to quantify the public health impact of the exposure on the burden of the disease within the population. This quantity represents the proportion or percentage of disease cases that can be attributed to a specific risk factor (exposure) in the target population (Levin, 1953). Benichou provided an overview of these methods by discussing the appropriate implementation of the estimation techniques of the PAF and interpretation of when considering several risk factors at the same time (Benichou, 2007, 2001) in different designs of observational studies (cross-sectional, case-control and cohort). This multivariate approach is also used to take into account confounding or interaction factors.

Several denominations have been used in the literature to refer to this statistical approach, which could lead to a confusion in terminology (Benichou 2007). However, a review of the literature in recent years shows that the terms most commonly used as synonyms are: population attributable fraction (Azimi et al., 2014; Brooks-Pollock and Danon, 2017; Dartois et al., 2016; Flegal et al., 2015; Laaksonen, 2010; Mansournia and Altman, 2018; Marant Micallef et al., 2019; Mohammadi and Mirzaei, 2017; Rajaobelina et al., 2019; Soerjomataram et al., 2018; van der Molen et al., 2019; Violante et al., 2016), attributable fraction (Dahlqwist et al., 2016; Di Maso et al., 2020; Eide, 2008; Gilg Soit Ilg and Fouquet, 2017; Heeringa et al., 2014; Rückinger et al., 2009; Steenland and Armstrong, 2006), attributable risk (Benichou, 2007, 2001, 2000; Cox, 2006; Cox and Li, 2012; Gassama et al., 2017; Rämsch et al., 2009), and population attributable risk (Brenner et al., 2019; Crowson et al., 2009; Spiegelman et al., 2007; Tamimi et al., 2016; Tseng et al., 1999).

To date, the PAF has been used as an impact measure in health research around the world to quantify the proportion of cases of diseases such as cancer (Brenner et al., 2019; Dartois et al., 2016; Engmann et al., 2017; Marant Micallef et al., 2019; Shield et al., 2018; Soerjomataram et al., 2018; Spiegelman et al., 2007; Tamimi et al., 2016), diabetes (Rajaobelina et al., 2019), cardiovascular disease (Azimi et al., 2014; Pirani and Khiavi, 2017; Tunaiji et al., 2019), hypertension (Mohammadi and Mirzaei, 2017), musculoskeletal disorders (Hamel et al., 2012; Roquelaure et al., 2009a; van der Molen et al., 2019; Violante et al., 2016) attributable to risk factors.

1.6. Contribution of epidemiology to ergonomics in the prevention of UEMSD

In the framework of UEMSD prevention, the objective of the ergonomic approach is to intervene effectively in the workplace by acting on various work determinants (e.g. tasks, working conditions, social environment) that contribute most to the development of these UEMSD. The identification of these determinants is therefore an essential step and will allow the implementation of interventions acting on these determinants, particularly the modifiable ones that have the greatest impact within the population.

The main contribution of epidemiology to the prevention of UEMSD is the gradual increase over several years in the literature on risk models, particularly through epidemiological and ergonomic studies but also through exchanges between epidemiologists, physiologists and ergonomists. Epidemiological studies have contributed important and necessary scientific knowledge to ergonomics that is needed for the prevention of UEMSD, in particular by providing growing evidence of causality in the relationship between occupational exposures and the occurrence of UEMSD (identification of risk factors) (da Costa and Vieira, 2010; Descatha et al., 2016; Kozak et al., 2015; Mansfield et al., 2018; Punnett and Wegman, 2004; Roquelaure et al., 2020; van der Molen et al., 2017) and statistical justification for recognizing the contribution of these occupational exposures to the development of UEMSD (Dalbøge et al., 2014; Melchior et al., 2006; National Research Council and Institute of Medicine, 2001; Rossignol et al., 1997; van der Molen et al., 2019; Violante et al., 2016). These contributions from epidemiology can be made by (a) modelling the determinants of UEMSD, (b) identifying the modifiable and non-modifiable risk factors associated with these UEMSD, and finally (c) modelling the effectiveness of prevention by estimating the PAF associated with modifiable UEMSD risk factors (Yves Roquelaure et al., 2012). This information will make it possible to design better prevention strategies based on the modifiable work-related risk factors with the greatest effect within the working population. In addition, contributions from epidemiology have also made it possible to support the implementation of reparation-compensation procedures for affected workers.

With regard to points (a) and (b), there is international scientific consensus in the literature on a bio-psycho-social model of UEMSD that integrates certain psychological, social and organizational characteristics of work situations (Bongers et al., 2006; Descatha et al., 2016, 2015; Hauke et al., 2011; Kraatz et al., 2013; Leider et al., 2015; National Research Council and Institute of Medicine, 2001; van der Molen et al., 2017; van Rijn et al., 2010). In recent years, the results of epidemiological studies have contributed significantly to the evidence of a causal relationship between exposure several risk factors and the occurrence of UEMSD (Bernal et al., 2015; Bongers et al., 2002; da Costa and Vieira, 2010; Descatha et al., 2016; Harris-Adamson et al., 2016, 2015; Kozak et al., 2015; Kraatz et al., 2013; Lang et al., 2012; Leider et al., 2015; Mayer et al., 2012; Punnett and Wegman, 2004; Sluiter et al., 2001; van der Molen et al., 2017; van Rijn et al., 2010). These risk factors include personal factors (e.g. age, female gender, obesity), biomechanical factors (e.g. high repetitive movements, intense efforts, uncomfortable postures), psychosocial factors (e.g. lack of decision-making autonomy, lack of support from co-workers or managers) and organizational factors (e.g. working under time pressure, lack of time to recover, inflexibility of procedures and checks). To date, the impact of these risk factors remains substantial for workers and companies even though most of them are potentially avoidable (e.g. those related to work conditions) (Aublet-Cuvelier et al., 2018; Hoe et al., 2018, 2012; Roquelaure, 2015; Van Eerd et al., 2016) or modifiable through biomedical interventions or prevention programs combining health promotion and reduction of the constraints of work situations (e.g. obesity, diabetes) (Kennedy et al., 2010). This evidence from various epidemiological studies constitutes a strong rationale for the prevention of UEMSD through workplace interventions, in particular by eliminating or reducing worker exposure to the main modifiable risk factors.

Based on the identification of risk factors, the effectiveness of the prevention intervention to be implemented in the workplace can be assessed theoretically by estimating the fraction of UEMSD potentially preventable by this prevention action i.e. the proportion of UEMSD cases (CTS, RCS, etc...) that could be prevented if workers were not or less exposed to the risk factor. A Swedish study based on the review of epidemiologic studies (Hagberg et al., 1992) concluded that at least 50%, and as much as 90%, of all of the CTS cases in working populations exposed to physical work load factors (e.g. repetition) appeared to be attributable to physical work load. A Montreal study (Rossignol et al., 1997) estimating the attributable fraction in exposed people by comparing the incidence of CTS surgery among different working groups concluded that 55% of surgical CTS in women and 76% in men were attributable to work among manual workers. In the US, findings from the 2001 National Research

Council extensive review (National Research Council and Institute of Medicine, 2001) concluded that improving low social support of coworkers and supervisors in exposed workers could potentially reduce the risk for UEMSD by 28–52%. In a French study, Roquelaure et al. (Roquelaure et al., 2008) showed that the proportion of CTS that could be attributed to industry sectors and occupational categories ranged between 36 and 93%.

A study conducted in the French region of PdL (Melchior et al., 2006) to investigate the reasons for the excess risk of UEMSD among manual workers estimated that over 50% of the excess risk in manual workers was explained by biomechanical exposures, particularly repetitive movements and forceful exertion at work. In addition, results revealed that, up to 23–31% of cases of UEMSD could have been prevented by reducing biomechanical exposures in the working population, particularly among manual workers (Melchior et al., 2006).

A prospective cohort study (Dalbøge et al., 2014) conducted in the Danish general working population showed that 24% of all first-time events of surgery for RCS could be attributed to occupational exposures.

The OCTOPUS cohort study conducted in Italy (Violante et al., 2016) showed that about one third of CTS cases could be attributed to forceful manual work (exposure above levels of Action Limit) i.e. approximatively 30% of CTS could be avoided if workers exposure to forceful manual were low (under the Action Limit). Recently, a study by van der Molen et al. (van der Molen et al., 2019) among the Dutch working population revealed that 25% of LE cases and 10% of shoulder soft tissue disorders could theoretically be avoided if workers did not exert force during work or did so only occasionally. The study also showed that, a proportion of 15% of LE cases and 9% of shoulder soft tissue disorders were attributable to awkward posture defined as a combined physical exposure of the wrist and elbow. Due to the multi-factorial nature of UEMSD, one can reasonably assume that the proportion of preventable cases would be even higher if comprehensive workplace interventions involved a more diverse range of risk factors. These results, although theoretical, suggest that prevention interventions should focus as a priority on the risk factors having the greatest impact on UEMSD; i.e. those that are both associated with UEMSD and have a high prevalence. It should be noted, however, that even ideally effective interventions could not completely reduce the incidence of UEMSD. In contrast, epidemiological models can guide ergonomic intervention by considering different scenarios based on the impact of the modifiable risk factor(s).

2. Objectives of the thesis

Today, UEMSD are a major concern for occupational and public health due to the considerable human, social and occupational costs. There is therefore a great need for prevention, which remains an occupational health priority. The moderate impact of the prevention plans implemented over the last few decades requires further studies on prevention strategies at the working population level. In order to better design prevention programs, it is essential to know the modifiable risk factors that have the greatest impact in the working population to enhance the effectiveness of interventions. The proportion of UEMSD attributable to work (therefore theoretically preventable through workplace interventions) varies by occupation/industry and exposure to risk factors for UEMSD. However, few available studies have estimated the potential impact of various prevention scenarios on the incidence of UEMSD in the working population.

The principal objective of this doctoral thesis work was to estimate and compare the potential effects of reducing work-related exposures to the main biomechanical and psychosocial risk factors on the incidence of UEMSD using data from the French COSALI (COhorte des SAlariés LIgériens) cohort. Three studies in the form of research papers presented in the "results" section were conducted to attain this objective.

(a) the first study examined the associations between potential risk factors and the incidence of UEMSD, and estimated the proportion of UEMSD cases that could be attributed to each of these risk factors through the calculation of PAF;
(b) the second study estimated the proportion and number of incident UEMSD cases that could be potentially prevented in the working population in the PdL region;
(c) the last study assessed the combined effect of biomechanical and psychosocial risk factors on the incidence of UEMSD and estimated the proportion and number of UEMSD cases attributable to these risk factors in the working population in the PdL region.

In the framework of the present thesis, organizational risk factors were not investigated due to the complex interrelationships between these risk factors and the development of UEMSD (see figure 1 for the conceptual causation model linking organizational risk factors to UEMSD) (Bao et al., 2016; Roquelaure, 2016). As shown in the conceptual causation model, organizational factors are not at the same level on the chain of determinants as biomechanical and psychosocial risk factors, as they act as indirect determinants in the development of UEMSD (Bodin et al., 2018; Roquelaure et al., 2020). These factors, at the level of the work structure (meso-level), influence the exposure to biomechanical and psychosocial risk factors at the individual level (micro-level) (figure 1). Conventional modelling methods (e.g. logistic regression, Cox regression) would not take into account the complex interrelationships between organizational, biomechanical and psychosocial risk factors involved in the development of UEMSD, which may lead to problems of collinearity (Bao et al., 2016; Roquelaure, 2016). To better account for the weight of these risk factors together in the risk models, structural equation models are increasingly used to obtain an integrated assessment of the complex associations between UEMSD and risk factors (Bodin et al., 2020, 2018, 2017; Roquelaure et al., 2020). To the best of our knowledge, structural equation models, which better account for the weight of organizational factors in the risk models, do not enable the calculation of PAFs and hence the number of attributable cases.

As a result of all the above, organizational variables were therefore not studied in this thesis, which focused mainly on the calculation of PAFs and numbers of potentially preventable cases of UEMSD.

3. Organization of the thesis

The first part of this doctoral thesis dealt with a background literature review of work-related MSD studies worldwide, including their economic and social impact and prevention, and also provided a brief synthesis of previous risk factor studies and the rationale for this thesis project. The next part (part two) presents details regarding the database used in this thesis including the study design and population, how UEMSD were diagnosed based on a standardized clinical examination, data collection techniques, and description of the analysis variables. This part also explains in detail the statistical techniques and analyses used to compute the estimates. The results of analyses in the current thesis are presented in part three. These results are presented in the form of three research articles (published or in progress). The presentation of each manuscript is preceded by a short summary of the main results of the manuscript. Part four provides a summary of the key findings and a general discussion of the thesis. Part five relates to the conclusions of the current thesis including its contributions, recommendations for future research, and finally a summary in French.

All appendices are presented at the end of the references section. They include self-questionnaire, the clinical notebook describing the French translation of the clinical protocol with diagnostic criteria charts, the clinical guide using photographs of clinical tests and results of descriptive statistics.

Material and methods

1. Setting and study design

The present thesis used the data from the COSALI cohort, a prospective study of MSD and their risk factors in the working population. This cohort was based on two successive surveys of workers in the French region of PdL (Bodin et al., 2012b). The study received approval from France's Advisory Committee on the Processing of Information in Health Research ("CCTIRS") and the National Committee for Data Protection ("CNIL"), initially in 2001 and again in 2006.

In 2002, the French National Institute for Health Surveillance (merged in 2016 with other health agencies to form the current French National Public Health Agency: SpFrance) and the former Laboratory of ergonomics and epidemiology in occupational health (LEEST) implemented a pilot epidemiological surveillance system for work-related MSD in the PdL region. This pilot network involved the University of Angers, the Regional Directorate of Labour, Employment and Vocational Training (DIRECCTE), SpFrance and the occupational health services of the PdL region, and consisted of three components:

(a) epidemiological surveillance of sentinel health events in the general population: CTS, the most commonly reported nerve entrapment syndrome, was chosen as the sentinel event for UEMSD and lumbar disc surgery as the sentinel event for low back pain.

(b) epidemiological surveillance of the main UEMSD and exposure to risk factors in the workplace.

(c) registration of notification data on compensation claims for work-related diseases related to MSD.

The program was set up in the PdL region (Loire valley area, west central France, 3 305 000 inhabitants and 1 247 839 salaried workers in 2002). This region represented 5.5% of the French population and 5.6% of the French working population, and its diversified socioeconomic structure was similar to that of France as a whole (Ha et al., 2009).

2. Study population

The study population of the present thesis was based only on data from the component (b) of the pilot network presented above. To provide data comparable with other European countries, the surveillance protocol of the sentinel network globally followed the recommendations of the European consensus criteria document (the SALTSA consensus) (Sluiter et al., 2001).

2.1. Inclusion period

2.1.1. Sentinel network of occupational physicians

In France, all salaried workers, including those in temporary and part-time employment, undergo a mandatory annual health examination by a qualified occupational physician (OP). The OPs were salaried by occupational health services in charge of the medical surveillance of the companies. Each OP worked across several companies at a time and supervised the health of approximately 1400 to 1700 part-time workers and 2800 to 3200 full-time workers. As part of the sentinel network, all OPs who practiced in the PdL region (n=460) were invited to participate in the study, and 83 of them (18%) volunteered to take part in the study. These OPs were characteristic of the region's OPs in terms of medical practice, working time, geography, and economic sectors covered (Roquelaure et al., 2006).

2.1.2. Inclusion of workers

Between April 2002 and April 2005, the 83 volunteer OPs in the sentinel network selected participants among the many workers attending their regularly scheduled mandatory health examination. OPs selected workers by following a 2-stage sampling standardized random selection procedure: first, 15–30 half days of scheduled examinations for each OP were chosen for sampling by the investigators; second, each OP was asked to randomly select from the schedule 1 of 10 workers on the selected half days of worker examinations. Workers aged between 20 and 59 years of age (according to the classifications of INSEE, the French National Institute of Statistics and Economic Studies), working in the PdL region regardless of their type of employment contract, and under surveillance by the 83 OPs were eligible for inclusion. Each worker provided informed written consent to participate in this study.

Out of 184 600 workers under surveillance, 3710 participants (2.0% of workers under surveillance; 2161 men, 1549 women) undergoing a regularly scheduled annual health examination were included. More than 90% of the selected workers participated in this study (<10%: no shows, refusals, duplications). Women were slightly underrepresented in the sample (42% vs. 47% in the region, $P<0.001$) (Roquelaure et al., 2006). Overall, the distribution of occupations in the sample was close to that of the regional workforce, except for the occupations not surveyed by OPs (e.g. farmers, shopkeepers, and self-employed workers) (Ha et al., 2009; Roquelaure et al., 2009b, 2006).

2.2. Follow-up period

A self-questionnaire follow-up between February 2007-May 2009 and a medical follow-up between January 2007-September 2010 of the workers initially included was undertaken (figure 2). This period coincided with a major economic crisis in the PdL region during 2008–2009, in which the regional salaried workforce declined by 3.4% (33.7% in temporary employment agencies) (Hautbois, 2010). Workers usually supervised by a non-participant OP, people on parental or long-term sick leave, retired people, and those who had lost their job were excluded from the follow-up. Several reminders were sent out to all occupational medicine services, and then to each OP now responsible for the medical surveillance of at least one worker of the cohort. For workers who had changed

OP, the research team systematically contacted the last OP responsible for their medical surveillance (Sérazin et al., 2014).

Of the 3710 workers initially included, a total of 1611 clinical examinations were carried out during the follow-up, for an overall response rate of 43% and 65%, considering all workers initially included and only those whose OP was known at the time of follow up, respectively (Sérazin et al., 2014).

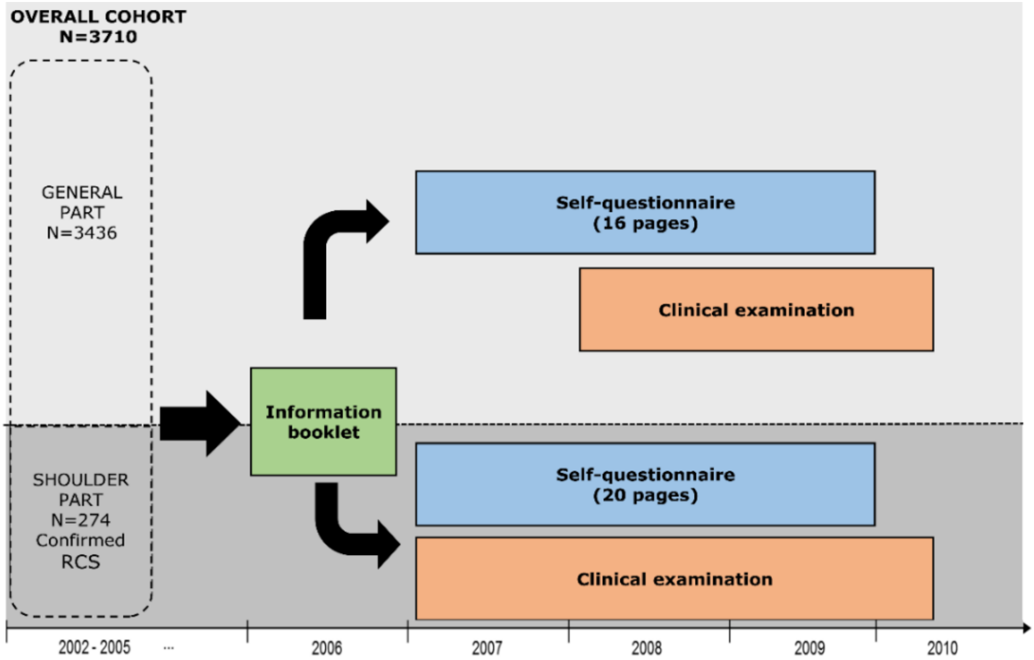

Figure 2. Schematic organization of the COSALI cohort

3. Data collection

3.1. Inclusion period

3.1.1. Exposure data

A self-administered questionnaire (Appendix 1) was used to assess personal characteristics (except for medical characteristics: e.g. diabetes mellitus, arthritis, inflammatory rheumatism, etc.) and work exposures. The questionnaire was completed (approximately 45 min) by workers in the OP waiting room just before the medical visit and checked by the OP at the beginning of the medical examination. The questionnaire included five parts following sections on personal characteristics and musculoskeletal symptoms (MS). The personal characteristics included information on gender, year of birth, weight, height. Concerning work exposures, two categories of data were collected at baseline:

(a) General characteristics of the current job;

(b) Risk factors for UEMSD, classified into three categories: organizational (e.g. lack of time to recover), biomechanical (e.g. high repetitiveness movements) and psychosocial (e.g. low social support).

The information collected on the general characteristics of the professional activity (contract, schedules, etc.) was modeled after by major French epidemiological investigations (Anact-Inserm (Anact et al., 1996; Leclerc et al., 2004, 1998), SUMER (Dares, 2003) and Estev (Cassou et al., 2002)). The organization of work was assessed using items from the main French epidemiological investigations (Anact et al., 1996; Cassou et al., 2002; Dares, 2003; Roquelaure et al., 2001) and supplemented by questions from the SALTSA consensus (Sluiter et al., 2001). Items were designed using a 4-level Likert-type scale (Likert, 1932; Robinson, 2014) as follows: "totally disagree" (scored 1), "disagree" (scored 2), "agree" (scored 3), and "totally agree" (scored 4) for the JCQ, and "never or almost never", "rarely (<2 hours/day)", "often (2–4 hours/day)", and "always (≥4 hours/day)" for items concerning the other occupational exposures. The questions on biomechanical factors presented awkward postures in picture form to facilitate workers' understanding and thus increase the validity of posture self-assessment (Halpern et al., 2001). The perceived physical exertion (force) was evaluated using the Borg Rating Perceived Exertion (RPE) scale (Borg, 1982) ranging from 6 (no exertion at all) to 20 (maximal exertion).

Concerning psychosocial factors, the Karasek's Job Content Questionnaire (JCQ) (Karasek et al., 1998) in its validated French version with 26 questions (Niedhammer, 2002; Niedhammer et al., 2006) evaluating three dimensions of the psychosocial environment at work: decision latitude (9 items), psychological demands (9 items) and social support (8 items).

3.1.2. Clinical data

Data on diagnosed UEMSD were collected in observation notebooks by performing a standardized clinical examination. Additional, personal factors (e.g. gender and birthday year) and medical and surgical history including information on diabetes mellitus, inflammatory arthritis, history of MSD were ascertained during the clinical examination and by a self-administered questionnaire. The case definition for each specific UEMSD was based on both symptoms and signs.

The clinical examination was based on the presence of MS over the past 12 months according to the standardized clinical approach of the SALTSA consensus to diagnose UEMSD (Sluiter et al., 2001). Each included worker (participant) underwent the clinical examination performed by the OP immediately. If symptoms occurred during the past 12 months, the OP performed a clinical examination lasting from 2 to 15 minutes strictly applying the methodology and clinical tests of the SALTSA consensus to diagnose UEMSD.

All data were collected in observation notebooks that included diagnostic criteria in diagrams, which provided physicians with a standardized diagnostic tool. The diagrams provide a visual aid to the decision process that occurs when the criteria are applied to the case definitions. The clinical examination protocol for the diagnosis of UEMSD and the clinical manipulations performed during the examination are presented in Appendix 2.

In order to reduce the inter-operator variability, all participating OPs were trained to perform a standardized clinical examination that strictly applied the methodology and clinical tests of the SALTSA consensus to diagnose UEMSD (Sluiter et al., 2001). Each participating OP in charge of the medical surveillance of salaried workers received guidelines describing the French translation of the clinical protocol (including diagnostic criteria charts and photographs of clinical tests) and underwent a 3-hour training program to standardize clinical examinations. See (Roquelaure et al., 2006) for specific details.

In this study, the standardized clinical examination focused on six specific UEMSD presented below with the corresponding codes of the ICD-10 (WHO, 2008).

(a) Rotator cuff syndrome (M75.1);
(b) Lateral epicondylitis (M77.1);
(c) Ulnar tunnel syndrome (G56.2);
(d) Carpal tunnel syndrome (G56.0);
(e) Flexor-extensor peritendinitis or tenosynovitis of the forearm-wrist region (M70.0);
(f) De Quervain's disease (M65.4).

The following three classifications of UEMSD were possible from the clinical examination according to the frequency of symptoms:

(a) **Latent case** if symptoms exist, but the temporal criteria may not be met.
(b) **Symptom case** if symptoms are present at the time of examination or in the immediate past (present on the date of the examination or for at least 4 days in the preceding week prior to the examination or at least 4 days in any one week during the past 12 months), but there are **no positive signs** on clinical examination.
(c) **Confirmed case** if symptoms are at the time of examination or present at least 4 days in the week prior to the examination and there are **positive signs** on clinical examination.

3.2. Follow-up period

A total of 1611 workers included at baseline were re-examined by their OPs using the same procedure as in the initial assessment (Sluiter et al., 2001). In order to reduce the inter-operator variability, all new participating OPs included were given the same training as at inclusion to perform a standardized clinical examination that strictly applied the methodology and clinical tests of the SALTSA consensus to diagnose UEMSD (Sluiter et al., 2001). The same clinical data as for inclusion were collected. For the purposes of this thesis, only workers who underwent a follow-up clinical examination were analyzed.

4. Analysis variables

4.1. Outcomes of interest

The outcome of interest for the present study was defined as incident cases of UEMSD including only workers free of the following six main clinically diagnosed UEMSD at baseline but who met the criteria for at least one of the disorders at follow-up: 1-Rotator cuff syndrome (RCS), 2-Lateral epicondylar tendinopathy (LET), 3-Carpal tunnel syndrome (CTS), 4-Ulnar tunnel syndrome, 5-Flexor-extensor peritendinitis or tenosynovitis of the forearm-wrist region, and 6-De Quervain's tenosynovitis. Cases were assessed by subject, and therefore bilateral cases of UEMSD counted as one disorder, not two.

4.2. Potential risk factors

The examined risk factors assessed at baseline included: (a) personal factors, medical history and history of the work, (b) exposure to work-related biomechanical and work-related psychosocial factors. These variables are known or suspected to be potential risk factors for at least one of the disorders under study on the basis of epidemiological and ergonomic studies.

(a) Personal factors and medical history

Female gender

Female gender was defined as an indicator variable (yes/no).

Age

Age at the date of filling out the inclusion questionnaire was divided into three categories (<35, 35–44 and ≥45 years)

Body mass index (BMI)

BMI was calculated by dividing weight (kg) by height squared (m^2) and was defined based on the WHO cut-off points (WHO, 2000): <18.50 for underweight, 18.50–24.99 for normal weight, 25.00–29.99 for overweight and ≥30 for obesity. Due to the low number of obese workers, a binary variable (*overweight/obesity* [yes/no]) was created from the BMI for the statistical analyses.

Rheumatoid arthritis and *diabetes mellitus status*

These two variables were defined as binary (yes/no) variables based on the information collected by the occupational physicians during the clinical examination.

(b) Work-related biomechanical factors

The considered biomechanical variables were as follows:

- high repetitiveness of tasks (≥4 hours/day);
- use of vibrating hand tools (≥2 hours/day);
- repeated/sustained elbow movements (flexion/extension) (≥2 hours/day);
- repeated/sustained posture with arms above shoulder level (≥2 hours/day);
- repeated/sustained posture with shoulder abduction (approximately 60°);
- pronation and supination movements (≥2 hours/day);
- wrist twisting movements (≥2 hours/day);
- use of the pinch grip (≥4 hours/day);
- high perceived physical exertion (RPE Borg Scale≥12 and ≥13).

All these variables listed above were defined using the cut-offs of the SALTSA consensus (SALTSA cut-offs) (Sluiter et al., 2001) except for the variable "*repeated/sustained posture with shoulder abduction*" defined as workers who reported being exposed "rarely (<2 hours/day)", "often (2–4 hours/day)" or "always (≥4 hours/day)" due to low number of exposed workers according to the SALTSA threshold: ≥2 hours/day). In addition, the "*high perceived physical exertion*" was assessed using the Rating Perceived Exertion Borg scale (RPE Borg Scale) (Borg, 1982) ranging from 6 (no exertion at all) to 20 (maximal exertion). The variable was defined as a binary variable based on the thresholds proposed by the French National Research and Safety Institute for the Prevention of Occupational Accidents and Diseases (INRS cut-offs): RPE Borg Scale≥12 (INRS, 2014) and RPE Borg Scale≥13 (INRS, 2019).

(c) Work-related psychosocial factors

Psychosocial factors were assessed using the twenty-six items of the French version of the Karasek JCQ (Karasek et al., 1998). Median values of the national French SUMER study (Niedhammer et al., 2006) to classify exposed and unexposed workers were used to define the following variables: low decision latitude (≤70), low social support (≤23) and high psychological demands (≥22).

4.3. Other analysis variables

The other analysis variables included variables related to work history such as:

Seniority in current job

This variable represents the duration of the worker's current employment at the date of inclusion. It was divided into four classes: <1 year, 1-2 years, 3-10 years, and >10 years.

Temporary employment

Temporary employment was defined as an indicator variable (yes/no) according to whether the worker had a temporary employment contract (e.g. fixed-term contract, interim, seasonal contract, trainee) or not (permanent contract or official).

Occupational class

This variable was defined into five categories using the French classification of occupations (1994 version, 1-digit numerical code): 2=craftsmen, salespersons and managers, 3=professionals, 4=technicians and associate professionals, 5=low-grade white-collar workers, and 6=blue-collar workers.

Economic sector

The variable of economic sector was categorized using the French classification of economic sectors (2000 version): agriculture, industry, construction, and trade and services.

5. Statistical methods

This section focuses on the statistical methodologies related to the main objective of this thesis and which were implemented throughout this work.

5.1. The population attributable fraction method

At the population level, the effect of a risk factor on a disease can be quantified by the computation of the population attributable fraction (PAF). This measure can be estimated from the main types of epidemiologic studies, namely cross-sectional, case–control, cohort, and case–cohort studies (Benichou, 2007, 2001).

(a) Estimation of the PAF in the case of a binary exposure (exposed E vs unexposed $\overline{E}$)

The PAF is defined according to Levin's equation (Levin, 1953):

$$\mathrm{PAF} = \frac{\mathrm{P}_r(\mathrm{D}) - \mathrm{P}_r(\mathrm{D}\backslash\overline{E})}{\mathrm{P}_r(\mathrm{D})} \quad (1)$$

where $\mathrm{P}_r(D)$, refers to the probability of the disease (incidence) in the population consisting of both exposed subjects E and unexposed subjects $\overline{E}$, and $\mathrm{P}_r(\mathrm{D}\backslash\overline{E,})$ refers to the hypothetical probability of the disease in the same population after elimination of all exposure. This formula by Levin quantifies the additional probability of the disease in the population that is associated with the presence of the exposure. Thus, PAF measures the additional probability of disease in the population that is associated with the presence of exposure in the population (Walter, 1976).

Walter (Walter, 1980) showed that Levin's estimate would be biased and overestimated in view of the often multifactorial nature of the conditions under study, since the sum of cases attributable to all the exposure factors investigated is systematically greater than the total number of events observed. In public health, PAF is interpreted as a measure of the proportion of the disease attributable to one or several exposures. However, for this interpretation to be correct, three conditions must be met (Walter, 1976):

- The estimate of attributable risk must be unbiased;
- Exposure must be causal and not simply associated with the disease;
- Elimination of exposure should not affect the distribution of other risk (or protective) factors in the population.

In epidemiology, it is often difficult to state the causal nature of a relationship between an exposure and a disease. Demonstrating an association between exposure and disease is not sufficient to conclude that there is a causal relationship. This problem of causality has been discussed by several authors (Greenland and Robins, 1988; Robins and Greenland, 1989; Rothman and Greenland, 1998).

Since PAF depends on both the strength of the association between disease and exposure, and the prevalence of exposure in the population, equation (1) can be rewritten as follows using Bayes' theorem (Cole and MacMahon, 1971; Levin, 1953):

$$\mathrm{PAF} = \frac{P_r(E)(RR-1)}{1+P_r(E)(RR-1)} = 1 - \frac{1}{1+P_r(E)(RR-1)} = 1 - \frac{1}{\sum_{s=1}^{2} P_r(E)_s RR_s} \quad (2)$$

where $\mathrm{P}_r(E)$, refers to the prevalence of the risk factor (exposure) in the population under consideration, s, the indicator variable of the two strata determined by the value of the risk factor, and RR, the relative risk associating the exposure to the disease. The formula (2) can be rewritten as (Miettinen, 1974):

$$\mathrm{PAF} = \frac{P_r(E\backslash D)(RR-1)}{RR} \quad (3)$$

where $\mathrm{P}_r(E\backslash D)$, refers to the prevalence of the risk factor in the affected population.

A high RR may correspond to a low or high PAF depending on the prevalence of exposure. This leads to very different public health consequences, as the prevalence of exposure can vary considerably in populations that are spatially and temporally separated (Benichou, 2007).

When restricted to exposed subjects, the attributable fraction (AF) is a measure of the proportion of disease attributable to exposure in exposed subjects (Levin, 1953; Miettinen, 1974). AF depends on RR only (Benichou, 1991) and is defined as follows:

$$\mathrm{AF}_E = \frac{\mathrm{P}_r(\mathrm{D}\backslash\mathrm{E}) - \mathrm{P}_r(\mathrm{D}\backslash\overline{E})}{\mathrm{P}_r(\mathrm{D}\backslash\mathrm{E})} \quad (4)$$

(b) Estimation of the PAF in the case of multi-level exposure or an adjustment factor

Miettinen (Miettinen, 1974) was the first to propose a generalization of the definition of RA in the case of multi-level exposure with the following formula:

$$PAF = \sum_{s=1}^{S} P_r(E|D)_s \frac{(RR_s - 1)}{RR_s} = 1 - \sum_{s=1}^{S} \frac{P_r(E|D)_s}{RR_s} \quad (5)$$

where $s = 1, \dots, S$, denotes the level of exposure, $P_r(E|D)_s$, the prevalence of s-level exposure in the population of cases, and RR_s is the associated RR relative to the chosen reference exposure.

Later, Walter (Walter, 1976) proposed an extension of Levin's formula to multi-level categorical exposure (formula 6). This new definition is often the most widely used.

$$PAF = \frac{\sum_{s=1}^{S} P_r(E)_s (RR_s - 1)}{1 + \sum_{s=1}^{S} P_r(E)_s (RR_s - 1)} = 1 - \frac{1}{\sum_{s=1}^{S} P_r(E)_s RR_s} \quad (6)$$

where $P_r(E)_s$ denotes the prevalence of s-level exposure.

Property of the PAF

There are two important properties of PAF that should be noted:

- **Reference level dependence:** PAF values are highly dependent on the definition of the reference level for exposure. This level corresponds to a total absence or the lowest level of exposure. The narrower the reference level by not including the most exposed subjects (and therefore in principle the most at risk), the higher the PAF values.
  This property has a major impact on estimates of the PAF and has been illustrated by Benichou (Benichou, 1991) and Wacholder et al. (Wacholder et al., 1994).
- **Distributivity:** This property of the PAF applies strictly to crude PAF estimates and adjusted estimates calculated on the basis of a full model including all major effects and possible interactions (Benichou, 1991). It applies approximately to adjusted estimates that are not based on a full model (Wacholder et al., 1994). Thus, if several exposure categories are considered instead of one, then the sum of the PAF of each exposure category is equal to the overall PAF calculated by combining these exposure categories

into one, regardless of the division of the exposure categories, on condition that the reference category remains the same (Benichou, 1991; Wacholder et al., 1994; Walter, 1976).

Since the PAF is often estimated in multifactorial situations when assessing the individual and joint impact of multiple exposures, a problem of non-additivity of the PAF for separate exposures arises since the individual contributions of exposures to the PAF are usually non-additive. Walter (Walter, 1983) demonstrated that the sum of the separate $PAFs$ for each exposure, i.e. $PAF_1 + PAF_2$, does not equal the joint PAF (PAF_{12}) unless at least one of the following two specific conditions is met:

- There is no joint exposure to the different exposures in the population;
- The effects of exposures on the risk of disease are additive.

The PAF can be estimated from the main types of epidemiological studies, namely cohort studies, case-cohort studies, case-control studies and cross-sectional studies (Benichou, 2007, 2001, 2000).

The computation of the PAF can be implemented using several statistical software packages such as SAS (Hertzmark et al., 2012; Laaksonen, 2010; Mezzetti et al., 1996), R (Chen, 2014; Dahlqwist and Sjölander, 2017; Rämsch et al., 2009; Schenck et al., 2014) or STATA (Newson, 2015, 2013).

Within the framework of this PhD thesis, the following PAF formula (Spiegelman et al., 2007), implemented in the SAS software, was applied:

$$PAF = \frac{\sum_{s=1}^{S}\sum_{t=1}^{T} p_{st}RR_{1s}RR_{2t} - \sum_{s=1}^{S}\sum_{t=1}^{T} p_{st}RR_{2t}}{\sum_{s=1}^{S}\sum_{t=1}^{T} p_{st}RR_{1s}RR_{2t}} = 1 - \frac{\sum_{s=1}^{S} p_{.t}RR_{2t}}{\sum_{s=1}^{S}\sum_{t=1}^{T} p_{st}RR_{1s}RR_{2t}} \quad (7)$$

where t denotes a stratum of unique combinations of levels of all background risk factors which are not under study, $t = 1; \ldots; T$ and RR_{2t} is the relative risk in combination t relative to the lowest risk level, where $RR_{2,t} = 1$. s indicates an index exposure group defined by each of the unique combinations of the levels of the index risk factors, that is, those risk factors to which the PAF applies, $s = 1; \ldots; S$, and RR_{1s} is the relative risk corresponding to combinations relative to the lowest risk combination, $RR_{1,1} = 1$. The joint prevalence of exposure group s and stratum t is denoted by p_{st}, and $p_{.t} = \sum_{s=1}^{S} p_{st}$.

5.2. Weighting adjustment: the calibration method

All survey research is likely to have various types of errors (e.g. nonresponse issues, unequal selection probabilities) that affect different parts of the survey process. When present in the sample, non-response may in some cases lead to the data collected not being representative of the population, and therefore have different implications for data quality, particularly for prevention. In order to produce correct statistics, it is essential to remove any error. To correct for unequal selection probabilities and nonresponse, a weighting adjustment procedure is often carried out.

Weighting adjustment is a frequently applied statistical correction technique that is used and applied in surveys to overcome these problems, and also to make sample-weighted estimates as consistent as possible with known external population totals by improving the efficiency of estimates (Bethlehem, 2009; Kalton and Flores-Cervantes, 2003; Szymkowiak, 2014; Zhang, 2002). This technique is based on the use of auxiliary information, i.e. information available on a certain number of variables (called auxiliary variables) and assigns an adjustment weight to each survey respondent with a large weight for subjects in under-represented groups, and a small weight for those in over-represented groups.

A number of adjustment weighting techniques are available, among which simple poststratification, linear weighting, multiplicative weighting, and calibration estimation of which linear weighting and multiplicative weighting are special cases (Bethlehem, 2009). Linear and multiplicative weighting methods can be applied in situations where the poststratification is not possible. The most frequently used method is the calibration approach when only the marginal distributions of the auxiliary variables (also called calibration variables) are known (Kalton and Flores-Cervantes, 2003; Szymkowiak, 2014). This is the case in practice, since often the cross-classification cell counts of auxiliary variables is usually insufficient, or the size of the cells is very small (Smith et al., 2015).

Deville and Särndal (Deville et al., 1993; Deville and Särndal, 1992) were the first to develop and formalize the general idea of the calibration estimation method; although, many previous work (Deming and Stephan, 1940; Stephan, 1942) have already used similar methods. With the calibration method, weights are assigned to all survey respondents in order to make the sample as representative as possible of the inference population. Over-represented groups will then have a small weight and under-represented groups a large weight. The weighted sample will thus become more representative of the population, resulting in estimates with a lower bias than those that are unweighted. The calibration approach is based on the use of auxiliary information defined as a set of variables that have been measured in the survey and for which information on the population distribution is available. This can be done through census data or other large surveys. The efficiency of the estimates is one of the major reasons why calibration method should be used in survey sampling. This efficiency can be obtained by using external data and can result in a low variance of estimators that are based on calibration weights. The calibration method is used around the world in many surveys by many statistical offices: in Canada (Estevao et al., 1995), the United Kingdom (Office For National Statistics. Social Survey Division, 2017), Belgium (Vanderhoeft, 2001), the Netherlands (Nieuwenbroek and Boonstra, 2002) and France (Sautory, 1993). See (Aude, 2010; Davies, 2018; Kalton and Flores-Cervantes, 2003; Sautory, 2018; Smith et al., 2015) for more details of the weighting adjustment method with examples.

In the present doctoral thesis, the calibration method, the most commonly used weighting adjustment method, was used to adjust the distribution of the weighted sample for auxiliary variables available in both the COSALI cohort and the 2007 French population census for the PdL region to make it consistent with the distribution of the PdL working population. The objective was to compute an estimate of the projected number of incident UEMSD cases in the working population at the PdL region level using the new weights. Furthermore, through the calibration method, potential improvements in the accuracy of the estimates can be expected (Szymkowiak, 2014).

Principle of the calibration method

The principle behind this approach, developed and formalized by Deville et al. (Deville et al., 1993; Deville and Särndal, 1992), consists in modifying the unit weights by adjusting the margins of the sample to population margins using available auxiliary available on a set of variables referred to as calibration variables or margins

(Roux and Armoogum, 2010, 2008), and meeting the equality requirements specified in (a) and (b) further below. This helps minimize the sampling variance and, in certain cases, reduce the bias due to unit non-response.

The method involves minimizing a distance function between the base weights and final weights to obtain an optimal set of survey weights i.e. that the final weights produce totals that match external population totals. It consists in replacing, by reweighting individuals, the base weights, which are generally the "sampling weights" of individuals, with "final weights" (also called "calibration weights" or "new weights") as similar as possible using calibration variables. For these calibration variables, the population totals as well as the sample values are known. This can be done through census data or other large surveys.

Practically, after applying the method (Smith et al., 2015), the weights obtained will be such that:

(a) the weighted frequencies of the categories of the variable in the sample will be equal to the corresponding counts known in the population after adjustment, if the calibration variable is qualitative (categorical);
(b) the weighted total of the variable in the sample will be equal to the known total in the population after adjustment, if the calibration variable is quantitative (numeric).

Theoretical aspects of calibration

The calibration problem

Consider a population $U = \{1 \ldots k \ldots N\}$ of N individuals from which a sample s of size n was drawn. For any individual k of U, π_k denotes its inclusion probability in s ($\pi_k = n/N$ for any k in the case of a simple random sampling).

Suppose Y a variable of interest, which needs to be estimated for the total in the population. It can be obtained from the following formula:

$$Y = \sum_{k \in U} y_k \quad (8)$$

The estimator of Y conventionally used is the **Horvitz-Thompson estimator ($\mathbf{HT}$)** formulated as follows:

$$\hat{Y}_{HT} = \sum_{k \in s} \frac{1}{\pi_k} y_k = \sum_{k \in s} d_k y_k \quad (9)$$

Using this unbiased estimator of Y ($\hat{Y}_{HT}$) means assigning to each individual in the sample a weight d_k equal to the inverse of his inclusion probability (i.e. "extrapolation coefficient" $N/n = 1/\pi_k$ in the case of a simple random sampling).

Let $X_1, \ldots, X_j, \ldots, X_J$ be J **auxiliary variables** (e.g. gender, degree, income, occupation, economic activity, etc...) available for all observations in the sample s, with known population totals (for quantitative variables) or marginal counts (for qualitative variables). These variables are referred to as "calibration variables". The total of the calibration variable X_j in the population U can be obtained by the following formula:

$$X_j = \sum_{k \in U} x_{jk} \quad (10)$$

To account for this information, and the total Y will be estimated using the adjustment weighting that replaces the Horvitz-Thompson estimator $\hat{Y}_{HT}$ with a new estimator $\hat{Y}_{CAL}$ (calibration estimator). This estimator can be formulated as follows:

$$\hat{Y}_{CAL} = \sum_{k \in s} w_k y_k \tag{11}$$

where w_k, equals $d_k \times e_k$, denotes the calibration weight of unit k, accounting for both the sample weights and the values of selected auxiliary population variables X to which the sample estimate is adjusted, e_i denotes the correction weight generated by the weighting adjustment method.

Furthermore, w_k, as close as possible to the original sample weights in the meaning of certain "distance function" G, ensure the calibration on the totals of the variables X_j i.e. verify the calibration constraints as follows:

$$\forall\, j = 1 \ldots J \qquad \sum_{k \in s} w_k x_{jk} = X_j \tag{12}$$

Theoretical resolution

The idea is to find an adapted Horvitz–Thompson estimator (to replace the Horvitz-Thompson estimator) that "calibrates" the sample on the totals of the auxiliary variables. To this end, Deville and Särndal (Deville and Särndal, 1992) introduced a "distance function" G with argument $r = w_k/d_k$ for measuring the distances between w_k and d_k in some way. This function G is positive and convex and verifies $G(1) = 0$. The inverse of the derivative of G is called the calibration function $F(.) = G'^{-1}(.)$ which allows one to calculate the calibration weights w_k.

Once the function G has been chosen, the problem consists in determining the weights w_k minimizing the following quantity D under calibration constraints according to formula (5) i.e. minimizing a weighted sum (by the d_k) of the distances between the sample weights d_k and the new weights w_k under calibration constraints.

$$D = \sum_{k \in s} d_k G(w_k/d_k) \tag{13}$$

This calibration problem depends on the chosen distance function, and in some cases also on boundary constraints. It can be resolved by using by the following formula (7) by introducing a vector λ of J Lagrange multipliers associated with the constraints (5) and the application of the Newton iterative method.

$$w_k = d_k F(x_k'\lambda) \tag{14}$$

where $x_k' = (x_{1k} \ldots x_{Jk})$ and F, called the calibration function, is the inverse of the derivative of the function G.

Selection of the calibration method (distance functions)

Several calibration methods are possible among which four calibration methods corresponding to four types of distance functions are the most commonly used (Sautory, 1993). Each of these four types of distance functions, presented below, has specific properties of G and F. Figure 3 provides a graphical representation of the method. Notice that, all calibrated estimators have the same asymptotic accuracy (Deville and Särndal, 1992), regardless of the method used when the sample size is sufficiently large.

After the use of calibration, the following quality indicators should be checked and verified in order to evaluate the final results and which method to use: lowest dispersion, smallest extent and general appearance of the distribution of initial and final weights.

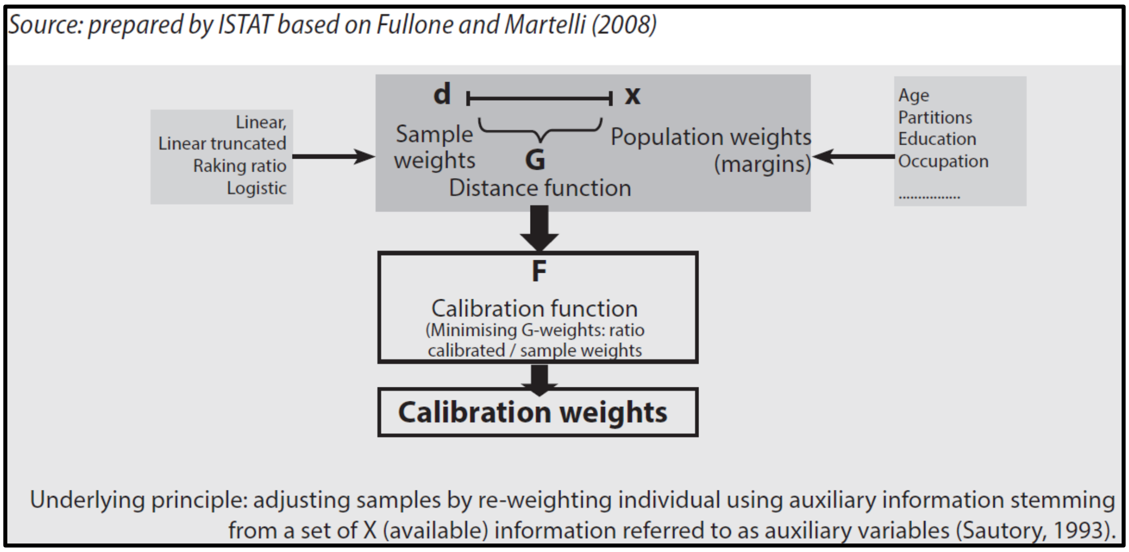

Figure 3. Graphical representation of the Calibration method (Smith et al., 2015)

The calibration function chosen will determine the adjustments to be performed by the calibration function. The following functions are the most commonly used in practice:

1) *"linear"* method: based on the Chi-squared quadratic distance function, this method which systematically converges, is the fastest because Newton's algorithm always converges after two iterations, and the weights are not upper bounded. One of the disadvantages of this method is that calibrated weights w_k can be negative, which is undesirable. However, this can be avoided by limiting the weight ratios r (g-weights) as with the *"truncated linear"* method, which imposes limits.
2) *"exponential" or "raking ratio"* method: proposed by Deming and Stephan (Deming and Stephan, 1940), is frequently used in quota surveys. This method converges quasi-systematically, always produces positive weights as opposed to the linear method. However, it can lead to weights below 1 or with quite large values.
3) *"logit"* method provides positive weights and ensures that the ratios "new_weights/initial_weights" are in the range]L, U[. With successive approximations to determine L and U, there is usually a maximum value Lmax (<1) for L, and a minimum value Umin (>1) for U, depending on the data and margins of the calibration. The more the sample structure differs from the population structure regarding the calibration variables, the further away these values are from 1.
4) *"truncated linear"* method also provides positive weights with "new_weights/initial_weights" ratios that are within the [L, U] range.

NOTE: Methods 3) and 4) allow the maximum weight deformations induced by calibration to be controlled via parameters L and U, but do not always converge.

Practical aspects of the calibration

The calibration approach is used to adjust the distribution of the weighted sample for auxiliary variables (also called "calibration variables") and can only be applied in situations, as is often the case in practice, where the auxiliary variables are available. The auxiliary variables refer to variables for which individual values are assumed to be known for the whole finite population or for which totals are known. Such variables have to be measured in the survey, their population distribution must be known, and they must be (strongly) correlated with the target variable of the survey, i.e. the dependent variable (variable of interest). With the calibration method, weights are assigned to all survey respondents in order to make the sample as representative as possible of the (inference) population. Over-represented groups then have a small weight and under-represented groups a large weight. The resulting weights are called calibration weights, new weights or final weights.

An auxiliary variable, known as a calibration variable, can only be used in the calibration approach if, and only if, it is available for each of the observations from the calibration sample and its total is known in the target population. For instance, it may be a variable in the sampling frame, or a variable measured in a survey and for which the total is known from other sources. In the case where the total is known from other sources, it is important that the variable available in the sample corresponds exactly to the variable for which the total is known, i.e. variables must be measured at the same time, according to the same concepts and the total on which the calibration is applied must correspond to the population which the sample seeks to describe. Ideally, this total should be known exactly.

The calibration method being quite sophisticated and the calculations quite complex, it is important to note that programs are available for various statistical software packages including SAS (Sautory, 1993), STATA (Álvarez and Mercado, 2017; D'Souza, 2011, 2010; Luca and Rossetti, 2018; Pitblado, 2018) and R (Lumley, 2020; Rebecq, 2019, 2016) for the calculation of calibration weights so that researchers can apply these techniques.

Within the framework of this thesis, the calibration method was implemented by using the program available for the SAS software (Sautory, 1993).

6. Statistical analysis

For analyses within the framework of this doctoral thesis, only workers who took part in the follow-up clinical examination were considered (1611 of the 3710 workers included at baseline).

All statistical analyses were performed using the Statistical Analysis System (SAS) software, version 9.4 TS Level 1M6 (SAS Institute Inc., Cary, NC, USA).

6.1. Description of study population

Study population characteristics were described according to the follow-up status (who underwent the second clinical examination: yes/no), the presence of missing data (yes/no) and the gender with the significance of differences between percentages for qualitative variables determined using Chi-square or Fisher's exact tests. These descriptions are presented in Appendices 3A, 3B and 3C, respectively.

6.2. Analysis of risk factors

A complete case analysis was conducted by excluding individuals with missing values for at least one risk factor (covariate) or with an unknown diagnosis of UEMSD at follow-up. Figures 4 and 5 present the study population and the one included in the analyses. In the first study of the thesis (article 1), a total of 1275 complete case data were analyzed. For the analyses in studies 2 and 3 (articles 2 and 3), 29 observations were excluded in order to standardize auxiliary variable data between the study sample and the 2007 French population census data of the PdL region prior to the computation of the sample weights by the calibration on margins method. After this exclusion, the final sample for studies 2 and 3 analyses consisted of 1246 participants.

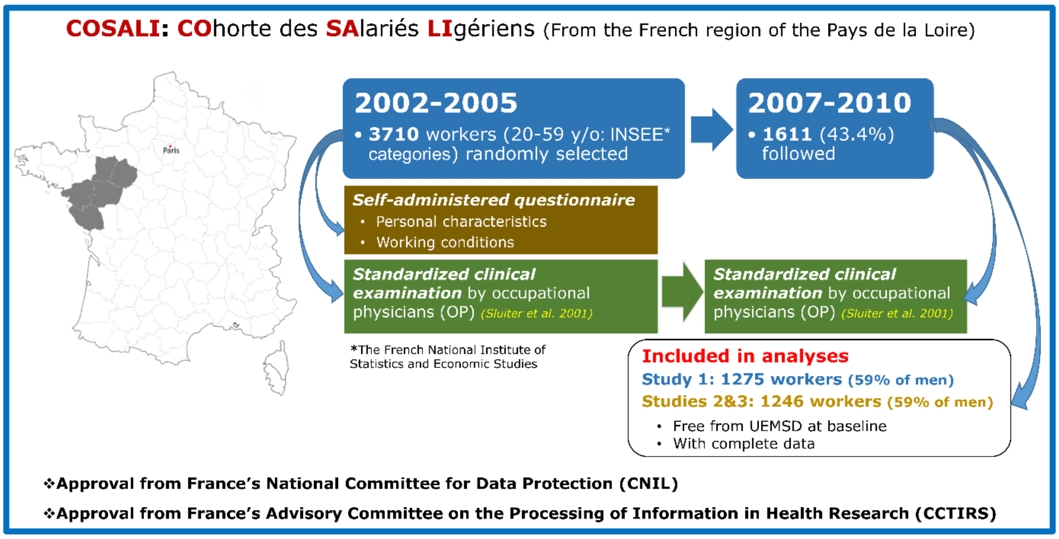

Figure 4. Study and analysis populations

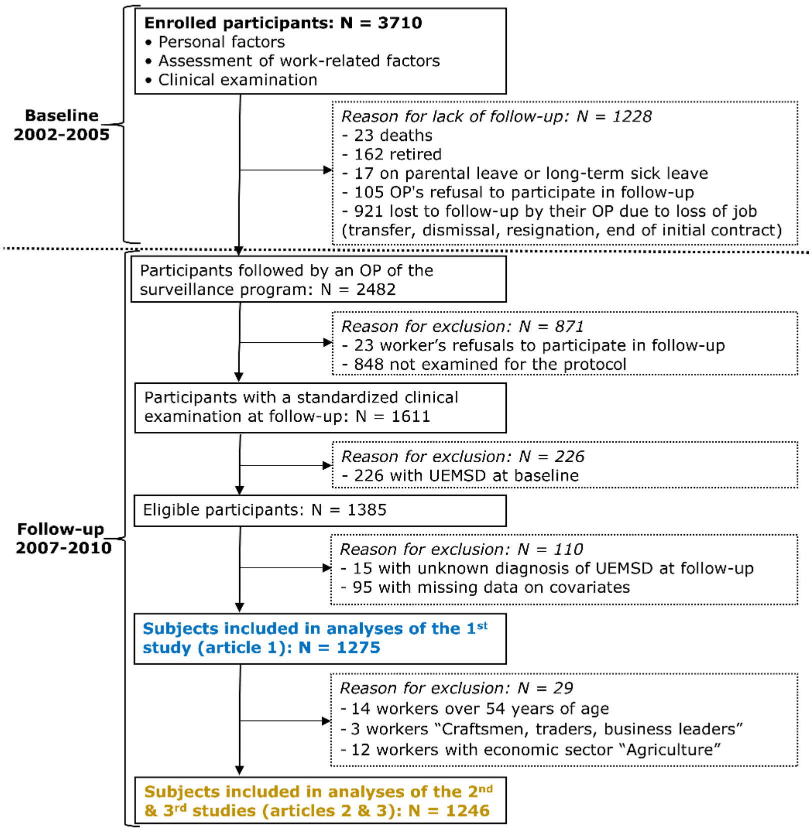

Figure 5. Study population flow diagram

To investigate the risk of incident UEMSD and its association with potential risk factors, Cox multivariable regression models with constant follow-up time for each subject and robust variance (Dwivedi et al., 2014) were used according to a 2-stage process (age-adjusted and multivariate analyses). Age-adjusted analyses were performed only in the first part of the thesis (article 1). Concerning parts 2 and 3 of the thesis (articles 2 and 3), the investigations were conducted based on the multivariate model obtained previously i.e. in the first article.

The Cox regression model with robust variance or modified Poisson regression approach is recommended when examining the association of exposure with a binary outcome in cohort studies where the high incidence of the outcome is higher than 10% (Dwivedi et al., 2014), instead of the logistic regression which is frequently used. Indeed, the logistic regression model may overestimate the effect of the exposure (risk factor) when the incidence of the outcome is high (more than 10%) (Dwivedi et al., 2014; Zhao, 2013). The use of the Cox regression with robust variance approach will result in exactly the same estimates and standard errors as when using the modified Poisson regression (Barros and Hirakata, 2003; Dwivedi et al., 2014; Zhao, 2013; Zou, 2004). However, the Cox model provides the covariance matrix needed to compute the PAF estimate with the SAS macro proposed by Spiegelman et al. (Spiegelman et al., 2007).

Analyses were systematically conducted for the entire cohort. In addition, sex-stratified analyses were performed to account for possible differences (Silverstein et al., 2009; Treaster and Burr, 2004) in exposure to work between men and women.

6.2.1. Age-adjusted analyses

Age-adjusted analyses were performed to assess the relationship between each of the potential explanatory variables and the incident UEMSD. Age-adjusted Cox regression models with equal follow-up time and robust variance were used to estimate relative risks (RRs) and 95% confidence intervals (CIs) of UEMSD risk associated with each potential risk factor. Only factors with a Wald test p-value of less than 0.20 (Bouyer et al., 2009a) in the age-adjusted models were included in the multivariate models.

6.2.2. Multivariate analyses

Multivariate Cox regression models with equal follow-up time and robust variance were used to estimate RRs and 95% CIs of UEMSD risk associated with the risk factors. Age being recognized as a major risk factor for UEMSD in the literature (da Costa and Vieira, 2010; Okunribido and Wynn, 2010), we decided to force it into all multivariate models even if it was not statistically significant in age-adjusted models.

6.3. Estimation of the PAF in the COSALI cohort

To quantify the attributable proportion of UEMSD incident cases, the PAF associated with a risk factor with the assumption of a causal relationship was estimated, all other factors remaining unchanged. Point estimates and 95% CIs were computed using a method for the estimation of PAFs in cohort studies, described by Spiegelman et al. (Spiegelman et al., 2007). The estimation of PAF took into account exposure (risk factor) prevalence and RR of UEMSD risk associated with that exposure in multivariate models. PAFs were estimated separately for each factor included in the model and expressed as the percentage of UEMSD cases that could be attributed to a scenario in which all workers were in the lower risk group (usually the reference category); the artificial removal of exposure could potentially prevent associated cases.

6.4. Estimation of the number of UEMSD cases attributable to risk factors in the working population at the regional level

The computation of the estimated number of incident UEMSD cases attributable to risk factors in the working population of the PdL region was implemented in two steps.

In the first step of the procedure, the study sample was weighted to provide estimates of incident UEMSD cases, which were representative of the PdL working population, using data from the 2007 population census of the PdL region (conducted by the French National Institute of Statistics and Economic Studies (INSEE)). The calibration on margins method proposed by Deville et al. (Deville et al., 1993; Deville and Särndal, 1992) was used to take the characteristics of the PdL working population into account. Weights are assigned to all survey respondents in order to make the sample as representative as possible of the working population in the PdL region.

The new weights were calculated using the following auxiliary variables (also called calibration variables): sex, age (seven categories: 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, and ≥50 years), occupational class (four categories: "professionals", "technicians, associate professionals", "low-grade white-collar workers" and "blue-collar workers") and economic sectors (three categories: "industry", "construction", and "trade and services"). These auxiliary variables were measured in both the COSALI cohort and the 2007 French population census for the PdL region, i.e. their population distribution was known. The "linear" calibration method was used to compute the new weights from the CALMAR (CALibration on MARgins) macro developed by Sautory (Sautory, 1993). The program calculates new weights, based on the method described in point 5.2 of the statistical methods section.

At the second step, the estimated number of incident cases of UEMSD in the working population at the regional level (and the variation range) attributable to risk factor was obtained by multiplying the PAF (and the 95% CI) by the projected number of incident UEMSD in the PdL region in 2007.

Results

1. Study sample characteristics and incident UEMSD diagnosed at follow-up

Study sample characteristics

A comparison of baseline characteristics of workers with follow-up (who underwent the second clinical examination) and workers without follow-up demonstrated that workers lost to follow-up were significantly more likely to be younger, temporary workers or individuals with a short length of service at baseline (Appendix 3A). Overall, no difference was observed in working conditions under study except for working posture with arms above shoulder level (followed: 11.8% vs 14.2 %: not followed; p=0.035), elbow movements (flexion/extension) (30.9% vs 34.5%; p=0.020) and low social support (36.8% vs 40.9%; p=0.011).

A description according to gender of characteristics and working conditions at baseline is provided in Appendix 3C and showed that the prevalence of being overweight/obese was higher in men than in women (p < 0.001). Most men worked as blue-collar workers in the industry sector, while most women were low-grade white-collar workers and worked in the trade and services sectors (p < 0.001). No difference was observed considering the history of diabetes mellitus, rheumatoid arthritis and seniority in the current job.

Incident UEMSD diagnosed at follow-up

At least one of the six UEMSD was diagnosed at follow up in 143 workers free from UEMSD at baseline (76 men vs 67 women; p=0.122) out of the 1275 followed (study 1: article 1). Regarding studies 2 and 3, there were 139 UEMSD cases (incidence proportion in the study sample: 11.2%) corresponding to a projected number of 129 320 new UEMSD cases in the PdL region in 2007 (table 3). The incidence proportion of UEMSD observed in the PdL region did not significantly differ between sexes (10.3% for men versus 12.4% for women; P=0.287). The most common diagnoses at follow-up were RCS (incidence proportion 6.5%), LET (incidence proportion 2.2%) and CTS (incidence proportion 2.0%). The estimate of the projected number of workers in the PdL with two or more UEMSD at follow-up was 19 404 (1.7%) workers.

Table 3: Distribution of the six upper-extremity musculoskeletal disorders (UEMSD) among the study population and its projection at the regional level.

	Study sample							Projection of the study sample at the level of the PdL region						
	Overall (N=1246)		Men (N=734)		Women (N=512)		p¶	Overall (N=1 141 324)¥		Men (N=582 950)¥		Women (N=558 373)¥		p#
	n	%	n	%	n	%		n	%	n	%	n	%	
Rotator cuff syndrome (RCS)	78	6.3	41	5.6	37	7.2	0.242	73 858	6.5	32 827	5.6	41 032	7.3	0.259
Lateral epicondylar tendinopathy (LET)	28	2.3	22	3.0	6	1.2	0.032	24 767	2.2	18 117	3.1	6650	1.2	0.033
Carpal tunnel syndrome (CTS)	24	1.9	7	1.0	17	3.3	0.003	22 456	2.0	7228	1.2	15 228	2.7	0.084
Ulnar tunnel syndrome	12	1.0	7	1.0	5	1.0	1.000*	12 022	1.1	7796	1.3	4227	0.8	0.332
De Quervain tenosynovitis	10	0.8	4	0.6	6	1.2	0.334*	7878	0.7	2159	0.4	5719	1.0	0.138
Flexor-extensor peritendinitis or tenosynovitis of the forearm-wrist region	9	0.7	5	0.7	4	0.8	1.000*	9399	0.8	3988	0.7	5410	1.0	0.625
At least one of the six UEMSD	139	11.2	74	10.1	65	12.7	0.149	129 320	11.3	60 133	10.3	69 187	12.4	0.287
At least two of the six UEMSD	20	1.6	11	1.5	9	1.8	0.720	19 404	1.7	10 921	1.9	8483	1.5	0.652

¶p-value of Chi-square test; *Fisher's exact test; ¥Weighted; #p-value of the Rao-Scott Chi-square test for weighted samples.

2. Paper1: Proportion of upper extremity musculoskeletal disorders attributable to personal and occupational factors: Results from the French Pays de la Loire study

ORIGINAL RESEARCH

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Key Findings and Messages

At least one of the six UEMSD was diagnosed at follow-up in 143 workers (incidence rate 11.2). The most common diagnoses UEMSD was RCS (incidence rate 6.4%).

Concerning work-related risk factors:

- High physical exertion plays an important role in the development of UEMSD, 30% of cases of incident UEMSD could potentially be avoided by lowering the physical exertion on the RPE Borg scale below 12 (RPE Borg scale range = 6 to 20) in the working population.
- This study showed that 7% of incidents UEMSD were attributable to working with arms above shoulder level in the overall working population. Furthermore, a noticeable proportion of UEMSD (15%) could be attributed to working with shoulder abduction in female workers.
- The results of this study suggest that an estimated 12% of incident cases of UEMSD could potentially be prevented by improving social support from coworkers and supervisors in the workplace.

Concerning personal risk factors:

- The present study suggests that female gender is associated with 12% of UEMSD cases occurring in the working population.
- Advanced age may contribute importantly to the incidence of UEMSD; about 13% and 20% of cases of UEMSD were attributable to the age groups 35-44 years and ≥ 45 years, respectively.
- A BMI ≥25.0 kg/m^2 (overweight/obesity) may explain 16.5% of incident cases of UEMSD in female workers.

To date, to the best of our knowledge, this is the first prospective study to estimate the PAF related to personal and occupational factors for the incidence of six main UEMSD in a working population. This study adds evidence to the literature that a high proportion of UEMSD can be avoided.

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Proportion of upper extremity musculoskeletal disorders attributable to personal and occupational factors: results from the French Pays de la Loire study

Aboubakari Nambiema[1*], Sandrine Bertrais[1], Julie Bodin[1], Natacha Fouquet[2], Agnès Aublet-Cuvelier[3], Bradley Evanoff[4], Alexis Descatha[1,5] and Yves Roquelaure[1]

Abstract

Background: Upper extremity musculoskeletal disorders (UEMSD) are one of the most common and costly occupational health problems. We aimed to assess the population-attributable fraction (PAF) of personal and occupational risk factors associated with incident UEMSD in a working population.

Methods: From 2002 to 2005, a random sample of 3710 workers from the Pays de la Loire region in France, aged 20–59 were included by occupational physicians (OPs). Between 2007 and 2010, 1611 workers were re-examined by their OPs. Subjects free from UEMSD at baseline were included in this study (1275 workers, mean age: 38.2 years). Cox regression models with equal follow-up time and robust variance estimates were used to estimate age-adjusted and multivariable-adjusted relative risks (RRs) and their 95% confidence intervals (CIs). Based on multivariable models, PAF associated with each factor included in the models was estimated.

Results: During the follow-up period, 143 (11%) cases of UEMSD were diagnosed. PAFs for factors associated with the incident UEMSD risk were 30% (7 to 51) for high physical exertion (RPE Borg scale ≥12), 12% (− 0.2 to 24) for low social support, 7% (− 3 to 17) for working with arms above shoulder level (≥2 h/day), 20% (12 to 28) for age group ≥45, 13% (3 to 22) for the age group 35–44, and 12% (0.3 to 24) for female gender.

Conclusions: Our study suggests that an important fraction of UEMSD can be attributed to occupational exposures after the contributions of personal and other work-related factors are considered. In terms of public health, our findings are in agreement with the ergonomic literature postulating that a high proportion of UEMSD are preventable through modifying workplace risk factors. Such information is useful to help public health practitioners and policy makers implement programs of prevention of UEMSD in the working population.

Keywords: Risk factors, Population attributable fraction, Upper extremity musculoskeletal disorders

* Correspondence: aboubakari.nambiema@univ-angers.fr
[1]Univ Angers, CHU Angers, Univ Rennes, Inserm, EHESP, Irset (Institut de recherche en santé, environnement et travail) - UMR_S 1085, F-49000 Angers, France
Full list of author information is available at the end of the article

Background

Work-related Upper Extremity Musculoskeletal Disorders (UEMSD), which include peripheral nerve entrapments and tendon disorders, as well as nonspecific musculoskeletal regional pain disorders, are the main source of morbidity and work disability in the working populations of industrialized and developing countries [1–3]. UEMSD are a major cause of occupational disease leading to considerable human and socio-professional cost in terms of pain and discomfort in work and daily life, sometimes irreversible functional sequelae, reduced ability for work, and the risk of work disability [3–5].

The World Health Organization (WHO) defined work-related diseases as multifactorial diseases in which the work environment and the performance of work contribute significantly to the causation of the disease [6]. There is a broad consensus on the multifactorial nature of UEMSD, where both non-occupational factors and occupational factors interact in etiology and prognosis [7–18]. Most personal susceptibility attributes (e.g. age) cannot be modified by prevention interventions or medical interventions, in contrast to potentially modifiable systemic conditions (e.g., obesity) [19, 20]. Exposure to work-related biomechanical factors (e.g., repetitive movements, forceful manual exertion) and psychosocial factors (e.g., psychological job demand, social support) could be modified by workplace-based interventions [20–23].

Identifying the modifiable risk factors for UEMSD in the workplace with the highest impact can help public health practitioners and policy makers to better target interventions at the working population level [24]. In this context, the effect of a particular risk factor depends not only on the strength of the association between the risk factor and the disease, but also on the prevalence of the risk factor. Nevertheless, when associations between a disease and a risk factor are assessed using classical statistical measures (relative risk or odds ratio), the population effect of some factors associated with high values of these estimates may be overestimated if few people are actually exposed to these factors [25, 26]. Confounding issues should also be considered in the assessment of a risk factor effect due to the multifactorial origin of disease.

The population attributable fraction (PAF) [27] is now a commonly used measure of the population-level contribution of a risk factor on a disease. This approach has the advantage of simultaneously considering the prevalence of the exposure to risk factors within the population and their associations with the disease. Moreover, the PAF can be computed using a multivariable approach to quantify the relative impact of one or more work-related exposures, or even co-exposure, on the occurrence of UEMSD [28–33]. Assuming that other risk factors remain unchanged and that there is a causal relationship between the risk factors and UEMSD, the partial PAF [34] describes the proportion of UEMSD that could be prevented if exposure to modifiable risk factor(s) is reduced from the target working population [26]. Such information may provide an estimation of the theoretical maximum potential impact of prevention programs in the workplace [35]. The partial PAF is appropriate when the disease of interest is multifactorial, and other risk factors are not expected to change as a result of the hypothetical intervention [36]. This contribution assessment method of some risk factors to the disease burden at the population level is widely used in studies of cancer [37–44], diabetes [25], cardiovascular disease [45, 46] and hypertension [47] studies.

To date, to the best of our knowledge, no prospective study has estimated the partial PAF of work-related exposures for UEMSD in a working population. Such information may be useful to estimate the proportion of theoretically preventable UEMSD and improve prevention of UEMSD in the working population. Therefore, the aim of this study was to determine the partial PAF related to personal and occupational factors for UEMSD using the French Cosali cohort.

Methods

Study population

The current study used data from the Cosali cohort, which focused on musculoskeletal disorders (MSD) and working conditions among workers in the Pays de la Loire region. Between 2002 and 2005, 3710 subjects (2161 men, 1549 women) with a mean age of 38.7 (standard deviation [SD] = 10.3) were included. Data on personal characteristics and working conditions were collected by a self-administered questionnaire. Participants underwent a clinical examination performed by occupational physicians (OPs) in charge of the medical surveillance of salaried workers. The OPs were trained to perform the standardized clinical examination according to the European consensus criteria for evaluating the work-relatedness of UEMSD [48]. Medical conditions, such as rheumatoid arthritis and diabetes mellitus, were collected during this clinical examination. During the follow-up period between 2007 and 2010, 1611 workers were re-examined by their OP using the same procedure as for inclusion. See [49] for more details.

Each worker provided informed written consent to participate in this study and the study received approval from France's Advisory Committee on the Processing of Information in Health Research ("CCTIRS") and the National Committee for Data Protection ("CNIL"), first in 2001 and again in 2006.

Outcome definition

Using the European consensus criteria for evaluating the work-relatedness of UEMSD [48], incident cases of UEMSD were defined as workers free of the six following clinically diagnosed UEMSD at baseline, and having at least one of them diagnosed at the follow-up: 1-Rotator cuff syndrome (RCS), 2-Lateral epicondylar tendinopathy (LET), 3-Carpal tunnel syndrome (CTS), 4-Ulnar tunnel syndrome, 5-Flexor-extensor peritendinitis or tenosynovitis of the forearm-wrist region, and 6-De Quervain's tenosynovitis. Details about these disorders have been previously described [50].

Assessment of potential risk factors

Three groups of potential risk factors were assessed at baseline: personal, biomechanical and psychosocial factors.

1. ***Personal factors*** included gender, age divided into three categories (< 35, 35–44 and ≥ 45 years), overweight/obesity (body mass index (BMI) ≥25.0 kg/m^2), using the World Health Organization criteria [51]), rheumatoid arthritis (yes/no) and diabetes mellitus status (yes/no).
2. ***Biomechanical factors*** (using the European consensus criteria [48]): high repetitiveness of tasks (≥4 h/day), use of vibrating hand tools (≥2 h/day), repeated/sustained elbow movements (flexion/extension) (≥2 h/day), repeated/sustained posture with arms above shoulder level (≥2 h/day), pronation and supination movements (≥2 h/day), wrist twisting movements (≥2 h/day), and use of the pinch grip (≥4 h/day). The definition of exposure to repeated/sustained posture with shoulder abduction included, as previously defined [49], workers who reported being exposed "rarely (<2 hours/day)", "often (2–4 hours/day)" or "always (≥4 hours/day)". Using the Rating Perceived Exertion Borg scale (RPE Borg Scale) [52] ranging from 6 (no exertion at all) to 20 (maximal exertion), high perceived physical exertion was defined based on the threshold (RPE ≥12) proposed by the French National Research and Safety Institute for the Prevention of Occupational Accidents and Diseases [53].
3. ***Psychosocial factors*** were assessed using the 26 items of the French version of the Karasek Job Content Questionnaire (JCQ) [54]. High psychological demand, low decision latitude and low social support were defined based on the median values of the national French SUMER study to classify exposed and unexposed workers [55].

Statistical analysis

Cox regression models with equal follow-up time and robust variance estimates were used to estimate age-adjusted and multivariable-adjusted relative risks (RRs) and their 95% confidence intervals (CIs) [56] in the overall cohort. In addition, we conducted a sensitivity analysis separately for men and women to account possible differences in exposure to work constraints between genders [57]. Multivariable models included only factors significant with a Wald test p-value of less than 0.20 in age-adjusted models [58]. Age being recognized as a major risk factor for UEMSD in the literature [33, 59, 60], we decided to force it into multivariable models even if it was not statistically significant in age-adjusted models. Diabetes mellitus and rheumatoid arthritis were excluded from analyses due to a low number of UEMSD cases exposed (less than five UEMSD cases for each gender). Interactions between all occupational exposures have been explored to verify that these risk factors are independent factors in relation to the risk of UEMSD.

Estimation of the partial population-attributable fractions (PAFs)

Based on the multivariable models, PAFs were estimated separately for each factor included in the multivariable models. The calculation of partial PAF is recommended for multifactorial diseases when some risk factors are unmodifiable or not expected to change after intervention [36]; the calculated PAFs were considered as partial because the set of the risk factors taken into account includes unmodifiable risk factors (in theory) (e.g. age). PAFs express the percentage of UEMSD cases that could have been avoided for each risk factor separately, with the assumption of a causal relationship from the risk factors and if all other risk factors did not change.

For the estimation of PAFs and their CIs, we used the method described by Spiegelman and colleagues [61] with the SAS macro, which is fully-documented and publicly available (https://www.hsph.harvard.edu/donna-spiegelman/software/par/). The CIs were estimated using the multivariable delta method [61, 62] as carried out by Rajaobelina and colleagues [25]. The prevalence of the exposure and adjusted RRs were considered in PAF estimates. The PAF indicated the percentage of UEMSD cases theoretically preventable if all workers were exposed in the lowest risk group. Only PAFs for factors associated with the risk of UEMSD in multivariable models with a p-value of ≤10% have been reported in the text.

All statistical analyses were performed using the SAS software, version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

Baseline characteristics

Of the 3170 workers included at baseline, 1228 were excluded from follow-up due to the death, retirement, parental leave, long-term sick leave, unemployment, etc. Among the remainder, 23 refused to participate in the follow-up. In addition, 848 workers did not undergo the second clinical examination because they did not have a mandatory examination scheduled between the time the OP was notified that he/she was in charge for a worker and the end of the follow-up period. A comparison of baseline characteristics of workers with follow-up and workers without follow-up (see Additional file 1, Appendix A) showed a significant difference in age between the workers who were followed up and those lost to follow-up. Workers aged < 35 years and ≥ 45 years were more frequent in those lost to follow-up. Moreover, workers with length of service of < 2 years and temporary workers were more frequent among the workers lost to follow-up.

Of the 1611 workers re-examined during follow-up, 226 were with UEMSD at baseline (prevalent cases). Out of 1385 eligible participants i.e. free of UEMSD at baseline, 95 workers with missing covariates data and 15 workers with an unknown UEMSD diagnosis at follow-up were excluded.

A total of 1275 participants (mean age: 38.2 years, SD = 8.7), 754 (59.1%) men and 521 (40.9%) women, were included in current analyses (Fig. 1). Participants with missing data did not differ with regards to BMI, diabetes, arthritis and seniority in current job, exposures and outcome compared to those with complete data. Participants with missing data were significantly older than those with complete data ($p = 0.001$), were more likely to be low-grade white-collar workers ($p = 0.008$) and were more likely to work in the trade and services sectors ($p = 0.013$) (see Additional file 1, Appendix B).

A description of characteristics and working conditions at baseline according to gender is provided in an additional file (see Additional file 1, Appendix C). The prevalence of being overweight/obese was higher in men than in women ($p < 0.001$). Most men worked as blue-collar workers in the industry sector, while most women were low-grade white-collar workers and worked in the trade and services sectors ($p < 0.001$). No difference was observed considering the history of diabetes mellitus, rheumatoid arthritis and the seniority in the current job.

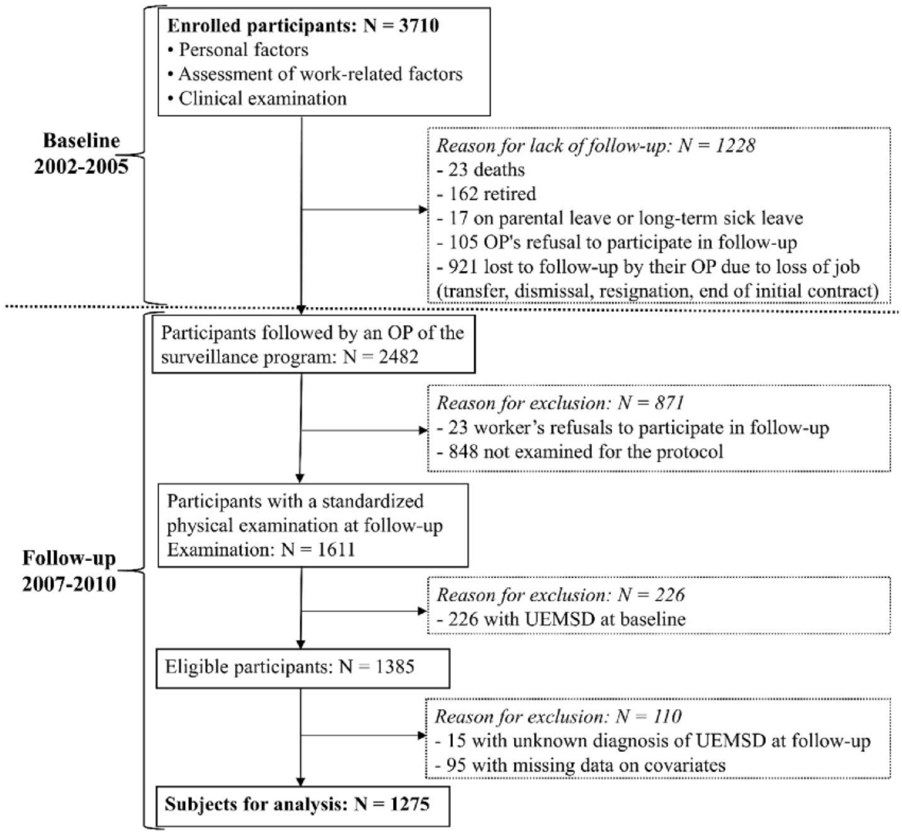

Fig. 1 Participants flow diagram

Table 1 Distribution of the six Upper Extremity Musculoskeletal Disorders (UEMSD) among the study population

	Overall population (***N*** = 1275)		Men (***N*** = 754)		Women (***N*** = 521)		P
	UEMSD	%	UEMSD	%	UEMSD	%	
Rotator cuff syndrome (RCS)	81	6.4	43	5.7	38	7.3	0.255
Lateral epicondylar tendinopathy (LET)	28	2.2	22	2.9	6	1.2	**0.034**
Carpal tunnel syndrome (CTS)	25	2.0	7	0.9	18	3.5	**0.001**
Ulnar tunnel syndrome	12	0.9	7	0.9	5	1.0	0.956
De Quervain tenosynovitis	10	0.8	4	0.5	6	1.2	0.333*
Flexor-extensor peritendinitis or tenosynovitis of the forearm-wrist region	9	0.7	5	0.7	4	0.8	1.000*
At least one of the six UEMSD	143	11.2	76	10.1	67	12.9	0.122
At least two of the six UEMSD	20	1.6	11	1.5	9	1.7	0.704

P: Chi-square test for difference between genders; *Fisher's exact test for difference between genders; $P < 0.05$ are in bold

UEMSD at follow up

At least one of the six UEMSD was diagnosed at follow up in 143 workers (76 men and 67 women) out of the 1275 followed (Table 1). The incidence rate of UEMSD observed did not significantly differ between genders (10.1% for men and 12.9% for women; $p = 0.122$). The most common diagnoses at follow-up was RCS (incidence rate 6.4% for the overall population, 5.7% for men and 7.3% for women). LET was more common in men than in women (2.9% vs 1.2% cases, $p = 0.034$) while CTS was more common in women (3.5% vs 0.9% cases; $p = 0.001$). More than one UEMSD was diagnosed at follow-up in 20 workers (incidence rate 1.6%).

Risk factors and UEMSD

Age-adjusted models have shown that personal, biomechanical and, psychosocial risk factors were positively associated with the incident of UEMSD (with a *p*-value less than 20%) (Table 2).

In the multivariable models (Table 3), the personal risk factors associated with increased risks of incident UEMSD were female gender (RR = 1.36; (95% CI 1.00–1.85)) and age (RR = 1.55 (1.04–2.29) for the age group 35–44 and, RR = 2.17 (1.47–3.19) for the age group ≥45). The occupational factors positively associated with an increased risk of UEMSD were high perceived physical exertion (RR = 1.80 (1.24–2.62), repeated/sustained posture with arms above shoulder level (RR = 1.59 (1.06–2.37)) and low social support (RR = 1.37 (1.01–1.87)). No interaction was found between occupational exposures.

The sensitivity analysis (Table 3) showed that, in male workers, high perceived physical exertion was associated with an increased risk of UEMSD (RR = 1.80 (1.24–2.62)). The risk of UEMSD associated with low social support was of the borderline of significance (RR = 1.41 (0.93–2.15)). In female workers, being overweight or obese was associated with an increased risk of UEMSD (RR = 1.74 (1.10–2.75)). The association with arms above shoulder level (RR = 1.6 (0.9–2.6)) and shoulder abduction (RR = 1.6 (0.9–2.7)) approached statistical significance but the 95% CI included the value one.

Partial population attributable fraction (PAF) for UEMSD risk factors

Considering the PAF of UEMSD for occupational risk factors, a high perceived physical exertion explained 30% (7 to 51) of cases (Fig. 2a). An estimated of 7% (− 3 to 17) and 12% (− 0.2 to 24) of UEMSD cases were attributable to working with arms above shoulder level (≥2 h/day) and low social support, respectively. Concerning personal risk factors PAFs were of 12% (95% CI: 0.3 to 24) for female gender, 13% (3 to 22) for the age group 35–44, and 20% (12 to 28) for the age group ≥45.

Sensitivity analysis (Fig. 2b) in men showed that a high perceived physical exertion was the leading risk factor with a PAF of 43% (95% CI: 13 to 65), followed by the age group 35–44 (PAF: 26% (15 to 36)), the age group 35–44 (PAF: 17% (3 to 30)) and, low social support (PAF: 14% (− 5 to 32)). In women, the PAF was of 17% (− 2 to 33) for being overweight or obese, followed by working posture with shoulder abduction (15% (− 10 to 38)) and, working posture with arms above shoulder level (7% (− 6 to 20)).

Discussion

For multifactorial diseases, such as UEMSD, the PAFs allows an estimation of the contribution of the work-related and non-work-related risk factors to the burden of disease in the working population. In the multivariable models, our results showed that the main risk factors of UEMSD were, in decreasing order, high perceived physical exertion (PAF: 30%), the age group ≥45 (PAF: 20%), age group 35–44 (PAF: 13%), female gender (PAF: 12%), low social support (PAF: 12%) and, working with arms above shoulder level (PAF: 7%).

Table 2 Age-adjusted models for risk factors of incident UEMSD in the Cosali cohort

	Overall population (N = 1275)				Men (N = 754)				Women (N = 521)			
	UEMSD = 143	RR	95% CI	P	UEMSD = 76	RR	95% CI	P	UEMSD = 67	RR	95% CI	P
Personal factors												
Female gender	67	1.25	(0.90–1.73)	**0.188**								
Age: 35–44 years	51	1.38	(0.91–2.11)	**0.129**	28	1.65	(0.91–2.99)	**0.096**	23	1.13	(0.62–2.06)	0.686
Age: ≥45 years	54	1.91	(1.26–2.90)	**0.002**	30	2.46	(1.37–4.42)	**0.003**	24	1.41	(0.78–2.57)	0.249
Overweight/obesity[a]	59	1.20	(0.86–1.68)	0.295	33	0.91	(0.57–1.44)	0.683	26	1.87	(1.14–3.08)	**0.013**
Biomechanical factors[b]												
High perceived physical exertion (RPE Borg scale ≥12)[c]	98	2.10	(1.47–2.99)	**< 0.001**	58	2.60	(1.53–4.43)	**< 0.001**	40	1.84	(1.13–3.01)	**0.015**
High repetitiveness of tasks (> 4 h/day)	41	1.54	(1.07–2.22)	**0.020**	16	1.27	(0.73–2.22)	0.398	25	1.79	(1.09–2.95)	**0.021**
Use of vibrating tools (≥2 h/day)	19	1.12	(0.69–1.82)	0.650	17	1.33	(0.77–2.28)	0.307	2	0.86	(0.21–3.50)	0.828
Repeated/sustained posture with arms above shoulder level (≥2 h/day)	27	2.16	(1.42–3.29)	**< 0.001**	14	1.96	(1.09–3.51)	**0.024**	13	2.41	(1.30–4.46)	**0.005**
Repeated/sustained posture with shoulder abduction[d]	57	1.58	(1.13–2.22)	**0.007**	29	1.26	(0.79–2.00)	0.329	28	2.23	(1.37–3.63)	**0.001**
Repeated/sustained elbow movements (flexion/extension) (≥2 h/day)	49	1.36	(0.96–1.93)	**0.079**	29	1.61	(1.01–2.56)	**0.045**	20	1.13	(0.67–1.90)	0.658
Pronation and supination movements (≥2 h/day)	23	1.32	(0.84–2.06)	0.228	18	1.40	(0.82–2.37)	0.216	5	1.47	(0.59–3.65)	0.411
Wrist twisting movements (≥2 h/day)	53	1.39	(0.99–1.96)	**0.057**	24	1.07	(0.66–1.75)	0.780	29	1.92	(1.18–3.11)	**0.009**
Use of the pinch grip (≥4 h/day)	12	1.23	(0.68–2.23)	0.487	4	0.93	(0.34–2.55)	0.885	8	1.47	(0.70–3.09)	0.303
Psychosocial factors[e]												
Low social support	64	1.47	(1.06–2.05)	**0.022**	37	1.59	(1.01–2.49)	**0.045**	27	1.39	(0.85–2.27)	**0.184**
Low decision latitude	76	1.14	(0.82–1.59)	0.424	35	1.08	(0.69–1.70)	0.737	41	1.16	(0.71–1.90)	0.554
High psychological demand	71	1.04	(0.75–1.45)	0.802	41	1.35	(0.86–2.11)	**0.198**	30	0.77	(0.48–1.25)	0.295

P p-value of Wald test; $P < 0.20$ are in bold; *RR* relative risk; *95% CI* 95% confidence interval, [a]assessed using the World Health Organization criteria [51], [b]assessed using exposure criteria from the European consensus criteria for evaluating the work-relatedness of UEMSD [48], [c]assessed using the RPE Borg scale [52], [d]Workers were defined as being at risk if they responded "rarely (<2 h/day)", "often (2–4 h/day)" or "always (≥4 h/day)" [49], [e]assessed using the French JCQ [55]

Table 3 Multivariable models for risk factors of incidence of UEMSD in Cosali cohort

	Overall population (N = 1275)				Men (N = 754)				Women (N = 521)			
	UEMSD = 143	RR	95% CI	P	UEMSD = 76	RR	95% CI	P	UEMSD = 67	RR	95% CI	P
Personal factors												
Female gender	67	1.36	(1.00–1.85)	**0.049**								
Age: 35–44 years	51	1.55	(1.04–2.29)	**0.030**	28	1.83	(1.04–3.21)	**0.036**	23	1.32	(0.76–2.28)	0.326
Age: ≥45 years	54	2.17	(1.47–3.19)	**< 0.001**	30	2.85	(1.66–4.91)	**< 0.001**	24	1.48	(0.86–2.57)	0.158
Overweight/obesity[a]									26	1.74	(1.10–2.75)	**0.019**
Biomechanical factors[b]												
High perceived physical exertion (RPE Borg scale ≥12)[c]	98	1.80	(1.24–2.62)	**0.002**	58	2.27	(1.32–3.92)	**0.003**	40	1.10	(0.60–2.00)	0.759
High repetitiveness of tasks (> 4 h/day)	41	1.22	(0.87–1.70)	0.248					25	1.37	(0.89–2.11)	0.156
Repeated/sustained posture with arms above shoulder level (≥2 h/day)	27	1.59	(1.06–2.37)	**0.024**	14	1.32	(0.74–2.37)	0.348	13	1.60	(0.93–2.74)	0.089
Repeated/sustained posture with shoulder abduction[d]	57	1.16	(0.81–1.64)	0.418					28	1.56	(0.93–2.64)	0.092
Repeated/sustained elbow movements (flexion/extension) (≥2 h/day)	49	1.00	(0.70–1.44)	0.997	29	1.25	(0.79–1.99)	0.334				
Wrist twisting movements (≥2 h/day)	53	0.98	(0.67–1.42)	0.903					29	1.29	(0.76–2.18)	0.341
Psychosocial factors[e]												
Low social support	64	1.37	(1.01–1.87)	**0.042**	37	1.41	(0.93–2.15)	0.106	27	1.33	(0.85–2.09)	0.217
High psychological demand					41	1.34	(0.87–2.05)	0.185				

P *p*-value of Wald test; $P < 0.05$ are in bold, *RR* relative risk, *95% CI* 95% confidence interval, [a]assessed using the World Health Organization criteria [51], [b]assessed using exposure criteria from the European consensus criteria for evaluating the work-relatedness of UEMSD [48], [c]assessed using the RPE Borg scale [52], [d]Workers were defined as being at risk if they responded "rarely (<2 h/day)", "often (2–4 h/day)" or "always (≥4 h/day)" [49], [e]assessed using the French JCQ [55]

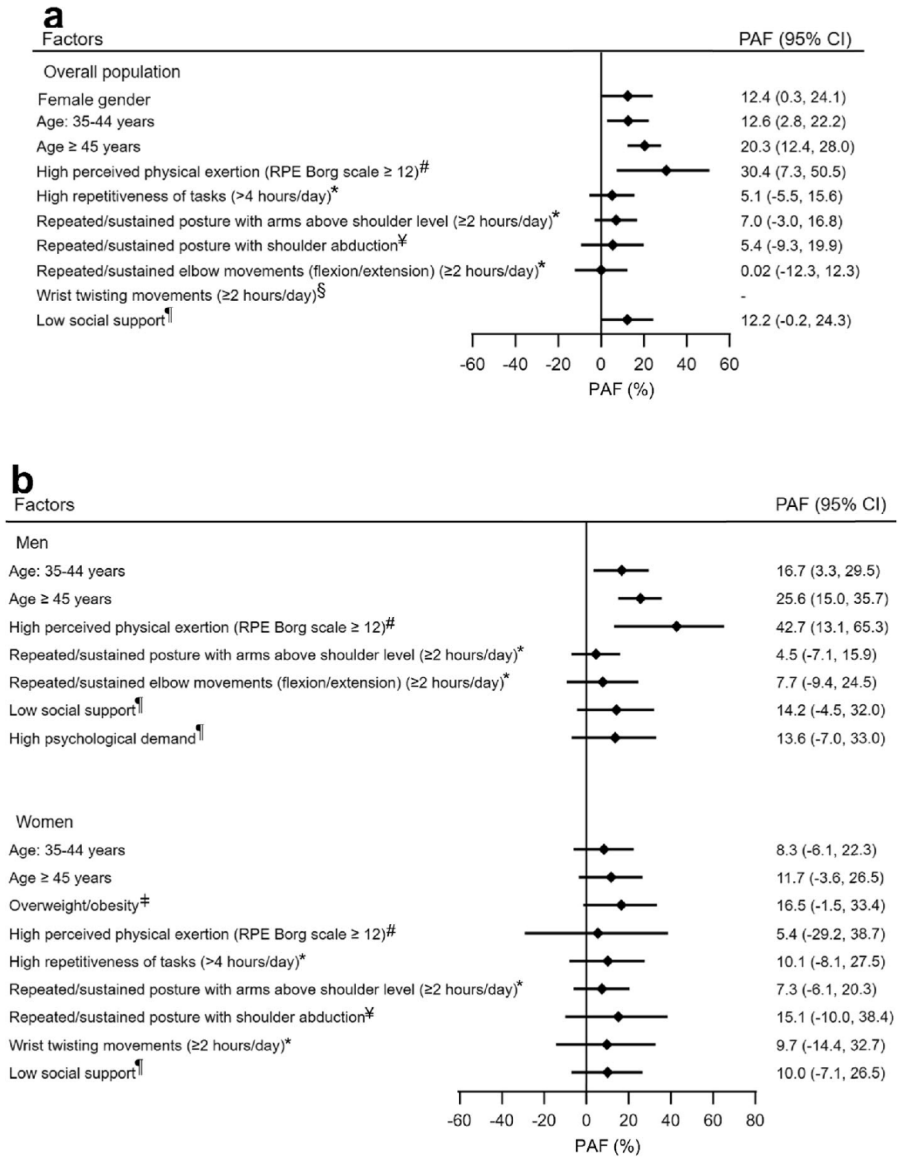

Fig. 2 Population-attributable fraction (PAF) for UEMSD risk factors, adjusting for all factors shown, in Cosali cohort. The PAF was calculated using the lowest risk group for each factor as the reference group, with all other factors remaining unchanged. **a** Overall population, **b** Stratify by gender, #assessed using the RPE Borg scale [52], *assessed using exposure criteria from the European consensus criteria for evaluating the work-relatedness of UEMSD [48], §relative risk < 1 and the PAF was not calculated, ¶assessed using the French JCQ [55], ‡assessed using the World Health Organization criteria [51], ¥Workers were defined as being at risk if they reported being exposed “rarely (<2 hours/day)”, “often (2–4 hours/day)” or “always (≥4 hours/day)” [49]

Literature comparison

There are extensive literature demonstrating the links between personal factors and work-related risk factors and UEMSD [2, 7, 8, 10, 11, 14–18, 50, 63–72]. Most studies of provided RRs or odds ratios associated with these personal or work-related risk factors. Only few studies assessed the proportion of UEMSD cases attributable to these risk factors and their contribution to the burden of UEMSD in the working population [28, 30, 73]. Most of them [2, 29, 30, 74] have quantified the impact of work-related exposures on the occurrence of UEMSD only in exposed population. One study [28] estimated PAFs for CTS ranging from 19 to 50% according to occupational categories and from 5 to 17% according to industrial sectors.

In our study, age ≥ 45 years contributed importantly to the incidence of UEMSD: 20% of cases of UEMSD that could be attributed to this age group. However, this major personal factor is unmodifiable. In this case, age can be considered as a marker of the degenerative process of the periarticular soft tissues, but also as a marker of the cumulative exposure of work-related risk factors [75]. Female gender was associated with 12% of UEMSD cases occurring in the working population. This PAF was lower than the one (34%) associated with CTS in a cohort study conducted in Italy (OCTOPUS study) [33].

Considering work-related exposures, our results showed that the risk of UEMSD was associated with high physical exertion, working with arms above shoulder level and, low social support. These findings are consistent with a large body of epidemiologic studies that evaluated the relation between UEMSD and occupational exposures [7, 8, 11, 14, 16–18, 66, 67, 71, 76, 77].

Regarding PAFs, we found high PAFs for both biomechanical and psychosocial factors, after adjustment for personal risk factors. Concerning biomechanical factors, findings suggested that nearly 30% of UEMSD could potentially be avoided by lowering the physical exertion on the RPE Borg scale below 12 (RPE Borg scale range = 6 to 20). The United States National Research Council and Institute of Medicine [2] report on MSD estimated an attributable fraction (AF) for work-related upper extremity disorders risk in exposed population at the workplace. AF estimates were 78% for high forces, between 28 and 52% for low social support, and between 33 and 58% for high psychological demand, based on how specifically the exposure and the outcome were defined. A Canadian study [30] estimated AF in exposed people by comparing the incidence of CTS surgery among different working groups, using non-manual workers as the reference population. Among manual workers in Montreal, 55% of surgical CTS in women and 76% in men were attributable to work. A Swedish study based on the review of epidemiologic studies [74] concluded that at least 50%, and as much as 90%, of all of the CTS cases in working populations exposed to physical work load factors such as repetitive and forceful gripping appeared to be attributable to physical work load. A French study [29] has shown that a proportion of CTS ranging between 36 and 93% could be attributed to industry sectors and occupational categories. The findings of these studies support the results observed in the working population characterized by a high contribution of work-related factors, especially in male workers. The current study found a PAF of 7% that could be attributed to working with arms above shoulder level. A prospective cohort study of Harkness et al. [78] found an association between new of onset shoulder pain and working with hands above shoulder. A recent systematic review and meta-analysis [16] have revealed moderate evidence for associations between shoulder disorders and arm-hand elevation.

For psychosocial factors in this study, we demonstrated that 12% of UEMSD cases could be attributed to low social support, although the PAF did not reach the statistical level of significance. However, epidemiologic investigations have demonstrated the relationship between some types of UEMSD and work-related psychosocial factors. A systematic literature review of van Rijn et al. [17] showed that psychosocial factors including low social support at work were associated with an increased occurrence of LET. Moreover, a pooled study cohort [68] has reported that workers with high social support in the workplace had half the risk of CTS incidence compared with those with low social support.

Sensitivity analyses were stratified by gender to account possible differences in personal risk factors and exposure to occupational hazards exposure between men and women [57]. In men, factors affected the risk of UEMSD were high perceived physical exertion, low social support, and age. In women, these factors were working with shoulder abduction, working with arms above shoulder level, and overweight/obese. The OCTOPUS study found a PAF of 30% for being overweight/obese associated with CTS risk [33]. Several patho- or biomechanical mechanisms might be involved in relationship between overweight/obesity and the risk of UEMSD in women. Obesity may increase the risk of CTS [68, 79], a disorder more frequent in the women in our study, due to the accumulation of fat tissue within the carpal tunnel; this has been hypothesized to increase intra-carpal tunnel pressure [80, 81]. Secondly, obesity may increase the risk of rotator cuff tendinopathy [82, 83] and LET [84] due to failure of tendon repair in obese workers. Another explanation is that severe obesity may modify the worker's anthropometric characteristics leading to (i) increased shoulder abduction at rest and in activity and (ii) increased moment of forces applied on the shoulder joint and rotator cuff tendons due to increased weight of the upper limb [85]. Such mechanisms may be particularly important in workers who are exposed to high physically demanding jobs [86]. Our study found a noticeable PAF value (15%) for working with shoulder abduction in women, even if this result was not statistically significant possibly due lack of statistical power (only 38 cases of RCS). This PAF estimate is consistent with recent meta-analyses showing increased risks of rotator cuff tendinopathy with shoulder abduction [16, 87].

Strengths and limitations

There were some potential limitations of our study that could have affected the results. Of the 3710 workers initially included, about 57% (young workers, those in short-time working or with a short period of service) did not undergo the follow-up clinical examination. According a longitudinal study of MSD [88], differences in occupational conditions between participants and those lost to follow-up did not significantly influence estimates of risk ratios. Diabetes mellitus and rheumatoid arthritis which are associated with UEMSD in the literature were not studied due to a low number of UEMSD cases exposed (less than five UEMSD cases in each gender) (see Additional file 1, Appendix C).

The thresholds used to define exposure levels may influence PAF estimates [89]. However, these cut-points were chosen based on the literature and public health recommendations. A second limitation is that the assessment of exposures was based on self-reported exposure, whereas assessing UEMSD cases was based on clinical examination. The non-differential misclassification of exposures may have occurred due to workers' inability to precisely recall or describe their current work exposures. Lack of measurement precision may also have occurred when quantifying exposures due to the 1 to 4 point ordinal scale used in exposure questions, except for physical exertion which was assessed using the RPE Borg Scale [52]. To the extent that the risk of UEMSD is increased by cumulative or chronic physical exposures, our analyses may have underestimated the true contribution of work exposures to the incidence of UEMSD in our study population. This may be especially true for RCS, as studies of occupational risk factors for shoulder pain have consistently identified duration of employment as a risk factor [90]. Furthermore, it's important to note that the PAF associated with single risk factors cannot be added to obtain a combined PAF associated with a combination of risk factors and that a combined PAF cannot be subtracted from 100% to determine the "unexplained" proportion of cases [26]. Further studies on a larger sample could appropriately assess the PAF associated with co-exposures. Despite the importance of PAF estimates, which are useful to rank risk factors, we should note that public health interventions are not possible for all factors (e.g. age) and a total elimination of risk factors in the population level is practically impossible. Finally, we should note that, the estimation of PAFs was assumed to have a causal relationship between exposure and UEMSD and should therefore be interpreted with caution.

The study has also several strengths. A major strength is that the study included a representative sample of the working population at baseline. Secondly, the definition of incidence cases was based on a standardized clinical examination performed by a trained occupational physician. Due to the prospective design of the study, exposure information gathered prior to UEMSD diagnosis resulted in low risk of recall bias. Another strength is the formula used to estimate the PAF from multivariable regression models, allowing a non-biased estimation of adjusted PAF [26]. This regression-based PAF estimation method allows to control confounding and interaction, and can be used for the main epidemiologic designs [91].

Conclusions

Our study suggests that an important fraction of UEMSD can be attributed to occupational exposures such as physical exertion and low social support, after the contributions of personal and other work-related factors are considered. Potentially modifiable personal factors, such as being overweight or obesity, contribute to the population burden of UEMSD in women. Despite the lack statistical significance of the PAF associated with factors such as working with shoulder abduction in women, interventions should still consider these factors recognized in literature as being associated with UEMSD. In terms of public health, the findings of the present study are in agreement with the ergonomic literature postulating that a high proportion of UEMSD are preventable through modifying workplace risk factors [92, 93]. Interventions should still consider recognizable risk factors that have been found to be associated with UEMSD in the literature. Such information is useful to help public health practitioners and policy makers implement programs of prevention of UEMSD in the working population.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12889-020-08548-1.

Additional file 1 : Appendix A. Comparison of baseline characteristics of workers with follow-up and workers without follow-up. **Appendix B.** Comparison of baseline characteristics, outcome and working conditions between respondents with complete and missing data. **Appendix C.** Characteristics and working conditions of the study population at baseline according to gender.

Abbreviations

UEMSD: Upper extremity musculoskeletal disorders; RCS: Rotator cuff syndrome; CTS: Carpal tunnel syndrome; LET: Lateral epicondylar tendinopathy; OP: Occupational physician; BMI: Body mass index; RPE: Rating perceived exertion; RR: Relative risk; 95% CI: 95% confidence interval; PAF: Population-attributable fraction; WHO: World Health Organization

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Conflict of interest

The authors have none to declare.

Authors' contributions

YR and NF participated to the design of the study. AN analyzed the data, performed the statistical analysis and wrote the manuscript. YR had full access to all of the data in the study and takes responsibility for the integrity of the data. SB, JB, NF, AAC, AD, BE and YR reviewed and commented on the final manuscript. All authors read and approved the final manuscript to be published.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Each worker provided informed written consent to participate in this study, and the study received the approval of the French Advisory Committee on the Processing of Information in Health Research ("CCTIRS") and the National Committee for Data Protection ("CNIL").

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests associated with this manuscript.

Author details

[1]Univ Angers, CHU Angers, Univ Rennes, Inserm, EHESP, Irset (Institut de recherche en santé, environnement et travail) - UMR_S 1085, F-49000 Angers, France. [2]Santé publique France, the French national public health agency, Direction of Occupational Health, EpiprevTMS team associated to the University of Angers, F-49000 Angers, France. [3]INRS, Département Homme au travail, 1 rue du Morvan CS60027, 54519 Vandoeuvre, France. [4]Division of General Medical Sciences, Washington University School of Medicine, St. Louis, St. Louis, MO 13 63310, USA. [5]Inserm, UMS 011, unité cohortes épidémiologiques en population, Villejuif, France.

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References

1. Ha C, Roquelaure Y, Leclerc A, Touranchet A, Goldberg M, Imbernon E. The French Musculoskeletal Disorders Surveillance Program: Pays de la Loire network. Occup Environ Med. 2009;66:471–9.
2. National Research Council (U.S.), Institute of Medicine (U.S.). Musculoskeletal disorders and the workplace: low back and upper extremities. Washington, D.C: National Academy Press; 2001.
3. Summers K, Jinnett K, Bevan S. Musculoskeletal disorders, workforce health and productivity in the United States. Musculoskelet Disord. 2015. https://pdfs.semanticscholar.org/99e7/db4d88d398a612aa4d16fb0fd16425a86560.pdf?_ga=2.50245743.895633849.1584971278-1374044221.1584971278.
4. Bevan S. Economic impact of musculoskeletal disorders (MSDs) on work in Europe. Best Pract Res Clin Rheumatol. 2015;29:356–73.
5. Roquelaure Y. Musculoskeletal disorders: a major challenge for occupational risk prevention in Europe. Brussels: ETUI; 2015. https://www.etui.org/Publications2/Policy-Briefs/European-Economic-Employment-and-Social-Policy/Musculoskeletal-disorders-a-major-challenge-for-occupational-risk-prevention-in-Europe.
6. WHO Expert Committee on Identification and Control of Work-Related Diseases & World Health Organization. Identification and control of work-related diseases : report of a WHO expert committee. Geneva: World Health Organization; 1985. [meeting held in Geneva from 28 November to 2 December 1983. http://www.who.int/iris/handle/10665/40176. Accessed 26 Feb 2019.
7. da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. Am J Ind Med. 2010;53:285–323.
8. Descatha A, Albo F, Leclerc A, Carton M, Godeau D, Roquelaure Y, et al. Lateral Epicondylitis and physical exposure at work? A review of prospective studies and meta-analysis. Arthritis Care Res. 2016;68:1681–7.
9. Hauke A, Flintrop J, Brun E, Rugulies R. The impact of work-related psychosocial stressors on the onset of musculoskeletal disorders in specific body regions: a review and meta-analysis of 54 longitudinal studies. Work Stress. 2011;25:243–56.
10. Jackson JA, Olsson D, Burdorf A, Punnett L, Järvholm B, Wahlström J. Occupational biomechanical risk factors for radial nerve entrapment in a 13-year prospective study among male construction workers. Occup Environ Med. 2019;76:326–31.
11. Keir PJ, Farias Zuniga A, Mulla DM, Somasundram KG. Relationships and mechanisms between occupational risk factors and distal upper extremity disorders. Hum Factors. 2019. https://doi.org/10.1177/0018720819860683.
12. Kozak A, Schedlbauer G, Wirth T, Euler U, Westermann C, Nienhaus A. Association between work-related biomechanical risk factors and the occurrence of carpal tunnel syndrome: an overview of systematic reviews and a meta-analysis of current research. BMC Musculoskelet Disord. 2015;16:231.
13. Lang J, Ochsmann E, Kraus T, Lang JWB. Psychosocial work stressors as antecedents of musculoskeletal problems: a systematic review and meta-analysis of stability-adjusted longitudinal studies. Soc Sci Med 1982. 2012;75:1163–74.
14. Lund CB, Mikkelsen S, Thygesen LC, Hansson G-Å, Thomsen JF. Movements of the wrist and the risk of carpal tunnel syndrome: a nationwide cohort study using objective exposure measurements. Occup Environ Med. 2019;76:519–26.
15. Roquelaure Y, Ha C, Rouillon C, Fouquet N, Leclerc A, Descatha A, et al. Risk factors for upper-extremity musculoskeletal disorders in the working population. Arthritis Care Res. 2009;61:1425–34.
16. van der Molen HF, Foresti C, Daams JG, Frings-Dresen MHW, Kuijer PPFM. Work-related risk factors for specific shoulder disorders: a systematic review and meta-analysis. Occup Environ Med. 2017;74:745–55.
17. van Rijn RM, Huisstede BMA, Koes BW, Burdorf A. Associations between work-related factors and specific disorders at the elbow: a systematic literature review. Rheumatology. 2009;48:528–36.
18. van Rijn RM, Huisstede BM, Koes BW, Burdorf A. Associations between work-related factors and specific disorders of the shoulder — a systematic review of the literature. Scand J Work Environ Health. 2010;36:189–201.
19. Feltner C, Peterson K, Palmieri Weber R, Cluff L, Coker-Schwimmer E, Viswanathan M, et al. The effectiveness of Total worker health interventions: a systematic review for a National Institutes of Health pathways to prevention workshop. Ann Intern Med. 2016;165:262–9.
20. Van Eerd D, Munhall C, Irvin E, Rempel D, Brewer S, van der Beek AJ, et al. Effectiveness of workplace interventions in the prevention of upper extremity musculoskeletal disorders and symptoms: an update of the evidence. Occup Environ Med. 2016;73:62–70.
21. Aubé K, Duchaine CS, Dionne CE, Vézina M, Mantha-Bélisle M-M, Sultan-Taïeb H, et al. Evaluation of the Quebec healthy Enterprise standard: effect on adverse physical and psychosocial work factors and work-related musculoskeletal problems. J Occup Environ Med. 2019;61:203–11.
22. Kennedy CA, Amick BC, Dennerlein JT, Brewer S, Catli S, Williams R, et al. Systematic review of the role of occupational health and safety interventions in the prevention of upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time. J Occup Rehabil. 2010;20:127–62.
23. Stock SR, Nicolakakis N, Vézina N, Vézina M, Gilbert L, Turcot A, et al. Are work organization interventions effective in preventing or reducing work-related musculoskeletal disorders? A systematic review of the literature. Scand J Work Environ Health. 2018;44:113–33.
24. Roquelaure Y, Fouquet N, Chazelle E, Descatha A, Evanoff B, Bodin J, et al. Theoretical impact of simulated workplace-based primary prevention of carpal tunnel syndrome in a French region. BMC Public Health. 2018;18:426.

25. Rajaobelina K, Dow C, Romana Mancini F, Dartois L, Boutron-Ruault M-C, Balkau B, et al. Population attributable fractions of the main type 2 diabetes mellitus risk factors in women: findings from the French E3N cohort: population attributable fractions in T2DM. J Diabetes. 2018. https://doi.org/10.1111/1753-0407.12839.
26. Rockhill B, Newman B, Weinberg C. Use and misuse of population attributable fractions. Am J Public Health. 1998;88:15–9.
27. Levin ML. The occurrence of lung cancer in man. Acta - Unio Int Contra Cancrum. 1953;9:531–41.
28. Roquelaure Y, Ha C, Fouquet N, Descatha A, Leclerc A, Goldberg M, et al. Attributable risk of carpal tunnel syndrome in the general population: implications for intervention programs in the workplace. Scand J Work Environ Health. 2009;35:342–8.
29. Roquelaure Y, Ha C, Nicolas G, Pélier-Cady M, Mariot C, Descatha A, et al. Attributable risk of carpal tunnel syndrome according to industry and occupation in a general population. Arthritis Rheum. 2008;59:1341–8.
30. Rossignol M, Stock S, Patry L, Armstrong B. Carpal tunnel syndrome: what is attributable to work? Montreal Stud Occup Environ Med. 1997;54:519–23.
31. Tanaka S, Petersen M, Cameron L. Prevalence and risk factors of tendinitis and related disorders of the distal upper extremity among U.S. workers: comparison to carpal tunnel syndrome. Am J Ind Med. 2001;39:328–35.
32. van der Molen HF, Hulshof CT, Kuijer PPF. How to improve the assessment of the impact of occupational diseases at a national level? The Netherlands as an example. Occup Environ Med. 2019;76:30–2.
33. Violante FS, Farioli A, Graziosi F, Marinelli F, Curti S, Armstrong TJ, et al. Carpal tunnel syndrome and manual work: the OCTOPUS cohort, results of a ten-year longitudinal study. Scand J Work Environ Health. 2016;42:280–90.
34. Bruzzi P, Green SB, Byar DP, Brinton LA, Schairer C. Estimating the population attributable risk for multiple risk factors using case-control data. Am J Epidemiol. 1985;122:904–14.
35. Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. J Electromyogr Kinesiol. 2004;14:13–23.
36. Wong BHW, Peskoe SB, Spiegelman D. The effect of risk factor misclassification on the partial population attributable risk. Stat Med. 2018;37:1259–75.
37. Tuyns AJ, Péquignot G, Abbatucci JS. Oesophageal cancer and alcohol consumption; importance of type of beverage. Int J Cancer. 1979;23:443–7.
38. Parkin DM, Boyd L, Walker LC. The fraction of cancer attributable to lifestyle and environmental factors in the UK in 2010. Br J Cancer. 2011;105:S77–81.
39. Wang JB, Jiang Y, Liang H, Li P, Xiao HJ, Ji J, et al. Attributable causes of cancer in China. Ann Oncol. 2012;23:2983–9.
40. Schottenfeld D, Beebe-Dimmer JL, Buffler PA, Omenn GS. Current perspective on the global and United States Cancer burden attributable to lifestyle and environmental risk factors. Annu Rev Public Health. 2013;34:97–117.
41. Dartois L, Fagherazzi G, Baglietto L, Boutron-Ruault M-C, Delaloge S, Mesrine S, et al. Proportion of premenopausal and postmenopausal breast cancers attributable to known risk factors: estimates from the E3N-EPIC cohort: population-attributable fraction for invasive breast cancer. Int J Cancer. 2016;138:2415–27.
42. Gassama M. Estimation du risque attribuable et de la fraction préventive dans les études de cohorte. 2016. https://tel.archives-ouvertes.fr/tel-01699279/document. Accessed 11 Jun 2018.
43. Engmann NJ, Golmakani MK, Miglioretti DL, Sprague BL, Kerlikowske K, for the Breast Cancer Surveillance Consortium. Population-Attributable Risk Proportion of Clinical Risk Factors for Breast Cancer. JAMA Oncol. 2017;3:1228.
44. Islami F, Goding Sauer A, Miller KD, Siegel RL, Fedewa SA, Jacobs EJ, et al. Proportion and number of cancer cases and deaths attributable to potentially modifiable risk factors in the United States: potentially preventable cancers in US. CA Cancer J Clin. 2018;68:31–54.
45. Azimi SS, Khalili D, Hadaegh F, Yavari P, Mehrabi Y, Azizi F. Calculating population attributable fraction for cardiovascular risk factors using different methods in a population based cohort study. J Res Health Sci. 2014;15:22–7.
46. Pirani N, Khiavi FF. Population attributable fraction for cardiovascular diseases risk factors in selected countries: a comparative study. Mater Socio-Med. 2017;29:35–9.
47. Mohammadi M, Mirzaei M. Population-attributable fraction of hypertension associated with obesity, abdominal obesity, and the joint effect of both in the central provinces of Iran. J Epidemiol Glob Health. 2017;7:71–9.
48. Sluiter JK, Rest KM, Frings-Dresen MH. Criteria document for evaluating the work-relatedness of upper-extremity musculoskeletal disorders. Scand J Work Environ Health. 2001;27:1–30 & 43–5.
49. Bodin J, Ha C, Petit Le Manac'h A, Sérazin C, Descatha A, Leclerc A, et al. Risk factors for incidence of rotator cuff syndrome in a large working population. Scand J Work Environ Health. 2012;38:436–46.
50. Roquelaure Y, Ha C, Leclerc A, Touranchet A, Sauteron M, Melchior M, et al. Epidemiologic surveillance of upper-extremity musculoskeletal disorders in the working population. Arthritis Care Res. 2006;55:765–78.
51. WHO. Obesity: preventing and managing the global epidemic: report of a WHO consultation. Geneva: World Health Organization; 2000.
52. Borg GAV. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14:377–81.
53. INRS. Méthode d'analyse de la charge physique de travail - ED 6161 1ère édition. 2014; 1ère édition (2014)-réimpression 10/2015:43.
54. Karasek RA, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B. The job content questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. J Occup Health Psychol. 1998;3:322–55.
55. Niedhammer I, Chastang J-F, Gendrey L, David S, Degioanni S. Psychometric properties of the French version of Karasek's "job content questionnaire" and its scales measuring psychological pressures, decisional latitude and social support: the results of the SUMER. Santé Publique. 2006;18:413–27.
56. Barros AJ, Hirakata VN. Alternatives for logistic regression in cross-sectional studies: an empirical comparison of models that directly estimate the prevalence ratio. BMC Med Res Methodol. 2003;3:21.
57. Silverstein B, Fan ZJ, Smith CK, Bao S, Howard N, Spielholz P, et al. Gender adjustment or stratification in discerning upper extremity musculoskeletal disorder risk? Scand J Work Environ Health. 2009;35:113–26.
58. Bouyer J, Hémon D, Cordier S, Derriennic F, Stücker I, Stengel B, et al. Analyse multivariée - Principes généraux. In: Epidémiologie: principes et méthodes quantitatives. Lavoisier. Paris: Editions INSERM; 2009. p. 240–265.
59. Fan ZJ, Silverstein BA, Bao S, Bonauto DK, Howard NL, Smith CK. The association between combination of hand force and forearm posture and incidence of lateral epicondylitis in a working population. Hum Factors. 2014;56:151–65.
60. Herquelot E, Bodin J, Roquelaure Y, Ha C, Leclerc A, Goldberg M, et al. Work-related risk factors for lateral epicondylitis and other cause of elbow pain in the working population. Am J Ind Med. 2013;56:400–9.
61. Spiegelman D, Hertzmark E, Wand HC. Point and interval estimates of partial population attributable risks in cohort studies: examples and software. Cancer Causes Control. 2007;18:571–9.
62. Benichou J, Gail MH. Variance calculations and confidence intervals for estimates of the attributable risk based on logistic models. Biometrics. 1990;46:991.
63. Coronado RA, Seitz AL, Pelote E, Archer KR, Jain NB. Are psychosocial factors associated with patient-reported outcome measures in patients with rotator cuff tears? A Systematic Review. Clin Orthop. 2018;476:810–29.
64. Fan ZJ, Silverstein BA, Bao S, Bonauto DK, Howard NL, Spielholz PO, et al. Quantitative exposure-response relations between physical workload and prevalence of lateral epicondylitis in a working population. Am J Ind Med. 2009;52:479–90.
65. Geoghegan JM, Clark DI, Bainbridge LC, Smith C, Hubbard R. Risk factors in carpal tunnel syndrome. J Hand Surg. 2004;29:315–20.
66. Haahr JP, Andersen JH. Physical and psychosocial risk factors for lateral epicondylitis: a population based case-referent study. Occup Environ Med. 2003;60:322–9.
67. Harris-Adamson C, Eisen EA, Kapellusch J, Garg A, Hegmann KT, Thiese MS, et al. Biomechanical risk factors for carpal tunnel syndrome: a pooled study of 2474 workers. Occup Environ Med. 2015;72:33–41.
68. Harris-Adamson C, Eisen EA, Dale AM, Evanoff B, Hegmann KT, Thiese MS, et al. Personal and workplace psychosocial risk factors for carpal tunnel syndrome: a pooled study cohort. Occup Environ Med. 2013;70:529–37.
69. Kraatz S, Lang J, Kraus T, Münster E, Ochsmann E. The incremental effect of psychosocial workplace factors on the development of neck and shoulder disorders: a systematic review of longitudinal studies. Int Arch Occup Environ Health. 2013;86:375–95.
70. Mansfield M, Thacker M, Sandford F. Psychosocial risk factors and the association with carpal tunnel syndrome: a systematic review. HAND. 2018;13:501–8.
71. Mayer J, Kraus T, Ochsmann E. Longitudinal evidence for the association between work-related physical exposures and neck and/or shoulder complaints: a systematic review. Int Arch Occup Environ Health. 2012;85:587–603.

72. Roquelaure Y, Bodin J, Ha C. Petit Le Manac'h a, Descatha a, Chastang J-F, et al. personal, biomechanical, and psychosocial risk factors for rotator cuff syndrome in a working population. Scand J Work Environ Health. 2011;37:502–11.
73. Melchior M, Roquelaure Y, Evanoff B, Chastang J-F, Ha C, Imbernon E, et al. Why are manual workers at high risk of upper limb disorders? The role of physical work factors in a random sample of workers in France (the pays de la Loire study). Occup Environ Med. 2006;63:754–61.
74. Hagberg M, Morgenstern H, Kelsh M. Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome. Scand J Work Environ Health. 1992:337–45. MID: 1485158 https://doi.org/10.5271/sjweh.1564.
75. Belin A, Dupont C, Oulès L, Kuipers Y. Safer and healthier work at any age final overall analysis report. Luxembourg: European Agency for Safety and Health at Work; 2016.
76. Leclerc A, Landre M-F, Chastang J-F, Niedhammer I, Roquelaure Y, Work SG on R. Upper-limb disorders in repetitive work. Scand J Work Environ Health. 2001 268–278.
77. van Rijn RM, Huisstede BM, Koes BW, Burdorf A. Associations between work-related factors and the carpal tunnel syndrome—a systematic review. Scand J Work Environ Health. 2009;35:19–36.
78. Harkness EF, MacFarlane GJ, Nahit ES, Silman AJ, McBeth J. Mechanical and psychosocial factors predict new onset shoulder pain: a prospective cohort study of newly employed workers. Occup Environ Med. 2003;60:850–7.
79. Shiri R, Pourmemari MH, Falah-Hassani K, Viikari-Juntura E. The effect of excess body mass on the risk of carpal tunnel syndrome: a meta-analysis of 58 studies: obesity and carpal tunnel syndrome. Obes Rev. 2015;16:1094–104.
80. Werner RA, Albers JW, Franzblau A, Armstrong TJ. The relationship between body mass index and the diagnosis of carpal tunnel syndrome. Muscle Nerve. 1994;17:632–6.
81. Werner RA, Franzblau A, Albers JW, Armstrong TJ. Influence of body mass index and work activity on the prevalence of median mononeuropathy at the wrist. Occup Environ Med. 1997;54:268–71.
82. Miranda H, Viikari-Juntura E, Martikainen R, Takala EP, Riihimäki H. A prospective study of work related factors and physical exercise as predictors of shoulder pain. Occup Environ Med. 2001;58:528–34.
83. Luime JJ, Kuiper JI, Koes BW, Verhaar JA, Miedema HS, Burdorf A. Work-related risk factors for the incidence and recurrence of shoulder and neck complaints among nursing-home and elderly-care workers. Scand J Work Environ Health. 2004;30:279–86.
84. Descatha A, Dale AM, Jaegers L, Herquelot E, Evanoff B. Self-reported physical exposure association with medial and lateral epicondylitis incidence in a large longitudinal study. Occup Environ Med. 2013;70:670–3.
85. Freivalds A. Biomechanics of the upper limbs: mechanics, modeling and musculoskeletal injuries. 2nd ed: CRC Press; 2011. https://doi.org/10.1201/b11547.
86. Burt S, Deddens JA, Crombie K, Jin Y, Wurzelbacher S, Ramsey J. A prospective study of carpal tunnel syndrome: workplace and individual risk factors. Occup Environ Med. 2013;70:568–74.
87. Leong H, Fu S, He X, Oh J, Yamamoto N, Yung S. Risk factors for rotator cuff tendinopathy: a systematic review and meta-analysis. J Rehabil Med. 2019; 51:627–37.
88. Bildt C, Alfredsson L, Punnett L, Theobald H, Torgén M, Wikman A. Effects of drop out in a longitudinal study of musculoskeletal disorders. Occup Environ Med. 2001;58:194–9.
89. Rockhill B, Weinberg CR, Newman B. Population attributable fraction estimation for established breast Cancer risk factors: considering the issues of high prevalence and Unmodifiability. Am J Epidemiol. 1998;147:826–33.
90. van der Windt DA, Thomas E, Pope DP, de Winter AF, Macfarlane GJ, Bouter LM, et al. Occupational risk factors for shoulder pain: a systematic review. Occup Environ Med. 2000;57:433–42.
91. Benichou J. Biostatistics and epidemiology: measuring the risk attributable to an environmental or genetic factor. C R Biol. 2007;330:281–98.
92. St-Vincent M, Vézina N, Bellemare M, Denis D, Ledoux É, Imbeau D. Ergonomic intervention. BookBaby: Cork; 2014.
93. Winkel J, Westgaard RH. Development and implementation of interventions managing work-related musculoskeletal disorders: inadequacy of prevalent research framework and future opportunities. Scand J Work Environ Health. 2019;45:316–7.

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3. Paper2: Upper extremity musculoskeletal disorders: how many cases can be prevented? Estimates from the COSALI cohort

ORIGINAL RESEARCH

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Key Findings and Messages

- Of the total projected estimate of 129 320 new cases of UEMSD in the working population of the French region of PdL in 2007, an estimated **53 021 would be attributable to all the occupational risk factors** in the multivariate model, i.e. 41.0% of all new projected incident UEMSD cases.
- **High physical exertion was responsible for the largest number of cases** (an estimated 26 381 cases of UEMSD, representing 20.4% of all new projected UEMSD cases). It was followed by low social support from coworkers and supervisors (16 682 incident cases, i.e. 12.9%), and working posture with arms above shoulder level (8535 incident cases, i.e. 6.6%). Furthermore, a significant number of new UEMSD cases (10 863 cases, i.e. 8.4%) could be attributed to working posture with shoulder abduction despite the associated relative risk not reaching the 5% statistical significance level.
- The observed relationship between incident UEMSD and high physical exertion or low social support was primarily observed among men, and the relationship observed between incident UEMSD and shoulder abduction or working with arms above shoulder level was primarily observed among women.
- The total projected estimate of UEMSD incident cases was higher in female workers than in male workers (69 187 cases in women vs 60 133 cases in men). However, **estimated fractions and numbers of UEMSD cases were higher in males than in female**s; 35 899 new cases in males and 29 411 in females were attributable to all occupational risk factors in the model, representing 59.7% and 42.5% of all new cases, respectively.
- Out of the projected total estimate of 60 133 UEMSD incident cases among male workers, 25 015 were attributable to high physical exertion (41.6% of all new cases) while 8599 (14.3%) could be attributed to low social support. Similarly, of the projected estimate of 69 187 new UEMSD cases in women, 12 315 (17.8% of all new cases) were attributable to working with shoulder abduction while 5258 (7.6%) could be attributed to working with arms above shoulder level.
- Among the potentially personal modifiable risk factors, the present study suggests that **an important number of projected incident UEMSD could be attributed to high BMI** (overweight/obesity: 10 586 incident UEMSD, i.e. 15.3% of all new cases) in the PdL female working population.

To our knowledge, this is a **first prospective cohort study estimating the number of potential cases of UEMSD attributable to occupational risk factors** in an entire working population.

According to our findings, **an important proportion and a large number of incident UEMSD** in the workplace in the PdL region **could potentially be prevented** by reducing occupational exposures such as physical exertion, working with shoulder abduction, and improving social support from coworkers and supervisors.

Original article

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Upper-extremity musculoskeletal disorders: how many cases can be prevented? Estimates from the COSALI cohort

by Nambiema A, Bodin J, Fouquet N, Bertrais S, Stock S, Aublet-Cuvelier A, Descatha A, Evanoff B, Roquelaure Y

This is the first cohort study estimating the number of potentially preventable cases of work-related upper-extremity musculoskeletal disorders (UEMSD) in a working population. A large number of incident UEMSD were attributable to occupational exposures. Theoretically, they could have been prevented by reducing exposures related to physical exertion and awkward postures and improving social support from co-workers and supervisors.

Affiliation: Irset - Inserm UMR 1085 - Equipe Ester, Faculté de santé - Département Médecine, 28 Rue Roger Amsler, 49100 Angers, France. aboubakari.nambiema@univ-angers.fr, orcid.org/0000-0002-4258-3764

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Key terms: cohort study; COSALI; France; MSD; musculoskeletal disease; musculoskeletal disorder; occupational risk factor; physical exertion; preventable case; prevention; upper-extremity musculoskeletal disorder

Additional material

Please note that there is additional material available belonging to this article on the *Scandinavian Journal of Work, Environment & Health* -website.

Original article

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Upper-extremity musculoskeletal disorders: how many cases can be prevented? Estimates from the COSALI cohort

by Aboubakari Nambiema, MSc, MPH,[1] Julie Bodin, PhD,[1] Natacha Fouquet, PhD,[2] Sandrine Bertrais, PhD,[1] Susan Stock, MD, MSc, FRCPC,[3,4] Agnès Aublet-Cuvelier, MD,[5] Alexis Descatha, MD, PhD,[1,6] Bradley Evanoff, MD, MPH,[7] Yves Roquelaure, MD, PhD [1]

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Objective This study aimed to estimate the proportion and number of incident upper-extremity musculoskeletal disorders (UEMSD) cases attributable to occupational risk factors in a working population.

Methods Between 2002–2005, occupational physicians randomly selected 3710 workers, aged 20–59, from the Pays de la Loire (PdL) region. All participants underwent a standardized clinical examination. Between 2007–2010, 1611 workers were re-examined. This study included 1246 workers who were free of six main clinically diagnosed UEMSD at baseline but were diagnosed with at least one of these UEMSD at follow-up [59% of men, mean age: 38 (standard deviation 8.6) years]. Relative risks and population-attributable fractions (PAF) were calculated using Cox multivariable models with equal follow-up time and robust variance. The total number of incident UEMSD in the PdL region was estimated after adjustment of the sample weights using 2007 census data. The estimated number of potentially avoidable UEMSD was calculated by multiplying PAF by the total number of incident UEMSD in PdL.

Results At follow-up, 139 new cases of UEMSD (11% of the study sample) were diagnosed. This represented an estimated 129 320 incident cases in the PdL in 2007. Following adjustment for personal factors, 26 381 (20.4% of all incident UEMSD) were attributable to high physical exertion, 16 682 (12.9%) to low social support, and 8535 (6.6%) to working with arms above shoulder level.

Conclusions A large number and important proportion of incident UEMSD may be preventable by reducing work exposures to physical exertion and working with arms above shoulder level as well as improving social support from co-workers/supervisors.

Key terms cohort study; France; MSD; musculoskeletal disease; occupational risk factor; physical exertion; preventable case; prevention.

Upper-extremity musculoskeletal disorders (UEMSD) are among the leading causes of morbidity and work disability in the working population of industrialized and developing countries (1, 2). Today, these disorders are a major concern for occupational and public health due to the considerable human, social and occupational costs (2–4). According to Eurostat, MSD account for almost 60% of work-related problems and are, therefore, the main work-related disease in the European Union (5). In France, according to 2018 social health insurance data, UEMSD accounted for 80% (39 555 cases) of all occupational diseases (6).

1 Univ Angers, CHU Angers, Univ Rennes, Inserm, EHESP, Irset (Institut de recherche en santé, environnement et travail) - UMR_S 1085, Angers, France.
2 Santé publique France, the French national public health agency, Direction of Occupational Health, EpiprevTMS team associated with the University of Angers, Angers, France.
3 INSPQ - Institut National de Santé Publique du Québec, Montréal, QC, Canada.
4 Department of Social & Preventive Medicine, University of Montréal, QC, Canada.
5 INRS, Département Homme au travail, Vandœuvre, France.
6 Inserm, UMS 011, unité cohortes épidémiologiques en population, Villejuif, France.
7 Division of General Medical Sciences, Washington University School of Medicine, St. Louis, MO, USA, Saint-Louis, USA.

Correspondence to: Aboubakari Nambiema, MSc, MPH, Irset - Inserm UMR 1085 - Equipe Ester, Faculté de santé - Département Médecine, 28 Rue Roger Amsler, 49100 Angers, France. [E-mail: aboubakari.nambiema@univ-angers.fr] ORCID iD: orcid.org/0000-0002-4258-3764

Numerous epidemiologic studies in working populations have identified a wide range of personal and work-related risk factors associated with UEMSD (7–12). While some personal attributes (eg, age) cannot be modified by preventive or medical interventions, exposure to work-related factors can potentially be modified by workplace-based interventions (13–15). In order to target and prioritize risk factors for more effective interventions in the workplace, it would be useful to quantify the proportion and number of UEMSD cases that could be prevented if exposure to these factors were reduced to levels that minimize the risk of UEMSD. Such information may provide an estimate of the theoretically maximum potential impact of preventive programs in the workplace (16). Identifying the occupational risk factors of UEMSD with the greatest impact may help public health practitioners and policy-makers prioritize interventions that reduce exposure to these factors (17).

At the population level, the effect of a risk factor on a disease can be quantified by the computation of the population attributable fraction (PAF) by taking into account both the strength of the association between a risk factor and a disease and the prevalence of that risk factor within the population (18). Thus, the PAF provides an estimate of the proportion of cases that would not have occurred if the exposure to a risk factor was reduced or eliminated (19); and it is therefore relevant to decision-making in public health.

Although there is extensive literature providing evidence of the associations between UEMSD and exposures in the workplace, few studies have assessed the PAF in the general working population (20–25) and specifically exposed populations (26–28). Moreover, none of these studies has estimated the number of incident UEMSD cases attributable to occupational risk factors. Identifying potential modifiable risk factors that preventive interventions could target to avert the greatest number of cases would improve the prevention of UEMSD in the working population. Consequently, the objective of this study was to estimate, using the multivariable model we previously obtained (29), the proportion and number of incident UEMSD cases attributable to occupational risk factors in the working population of the French region of Pays de la Loire (PdL).

Methods

Study population

We used data from the COSALI cohort, a prospective study of MSD and their risk factors in the working population based on two successive surveys of workers from the PdL region (30, 31). The region accounts for about 6% of the French working population and its diversified socioeconomic structure is similar to that of France as a whole (30).

Between 2002–2005, 83 occupational physicians (OP) (18% of OP in the region) volunteered to take part in the study. They selected 3710 workers (2161 men, 1549 women) at random (out of 184 600 under the surveillance of the 83 OP, 2.0%). More than 90% of the selected workers participated in this study (<10%: no shows, refusals, duplications). Women were slightly underrepresented in the sample (42% versus 47% in the region, P<0.001). Overall, the distribution of occupations in the sample was close to that of the regional workforce, except for the occupations not surveyed by OP (eg, farmers, shopkeepers, and self-employed workers). Data on personal characteristics and working conditions were collected by a self-administered questionnaire. The OP conducted a clinical examination of the participants using a standardized clinical protocol that strictly applied the methodology and clinical tests of the European consensus criteria to diagnose work-related UEMSD (WRUEMSD) (32). Each participating OP in charge of medical surveillance of salaried workers received guidelines describing the clinical protocol (including diagnostic criteria charts and photographs of clinical tests) and underwent a 3-hour training program to standardize clinical examinations. Between 2007–2010, the OP re-examined 1611 workers using the same procedure as the initial assessment [see (30, 31) for more details about the COSALI cohort].

This study received approval from France's Advisory Committee on the Processing of Information in Health Research ("CCTIRS") and the National Committee for Data Protection ("CNIL"), initially in 2001 and again in 2006. Each worker provided written informed consent prior to participation.

For the present study, 1228 of the workers included at baseline did not participate in the follow-up due to death, retirement, parental leave, long-term sick leave, unemployment, etc. Of the remaining 2482 participants, 23 refused to participate and 848 workers did not undergo the second clinical examination because they had no mandatory examination scheduled during the follow-up period. A comparison of baseline characteristics of workers who attended a follow-up (ie, second clinical examination) and workers who did not attend was described previously (29) and demonstrated that workers who did not attend a follow-up were significantly more likely to be younger, temporary workers or individuals with a short length of service at baseline.

Among the 1611 participants with a standardized clinical examination at follow-up, 226 had at least one UEMSD at baseline and were excluded from the present study. Out of the 1385 eligible participants, ie, free of UEMSD at baseline, 110 workers with missing data for exposure or UEMSD were excluded (figure 1). In addition, 29 workers were excluded in order to standardize the auxiliary variables data between the sample and the external source, ie, the 2007 French population census data of the PdL region, before applying the weighting method (the calibration approach). After exclusions among eligible participants, the final study sample for current analyses consisted of 1246 participants.

Outcome definition

Incident cases of UEMSD were defined as workers free of the six main clinically diagnosed UEMSD at baseline but who met the criteria for at least one of the disorders at follow-up. This definition was based on the European consensus criteria to diagnose WRUEMSD for health surveillance or epidemiologic studies (32). This consensus is intended to facilitate more consistent collection, recording and reporting of information on WRUEMSD across the European Union by providing evidence-based or consensus-based case definitions and criteria for their identification and categorization. The six main diagnosed UEMSD were: (i) rotator cuff syndrome, (ii) lateral epicondylar tendinopathy, (iii) carpal tunnel syndrome (CTS), (iv) ulnar tunnel syndrome, (v) flexor-extensor peritendinitis or tenosynovitis of the forearm-wrist region, and (vi) De Quervain's tenosynovitis. Details regarding measurement of these disorders have been previously described (31).

UEMSD risk factors

Only baseline factors retained as independent risk factors of UEMSD that were previously in the same sample (29) were assessed in this study.

Personal factors included sex, age divided into three categories (<35, 35–44 and ≥45 years) and overweight/obesity [body mass index (BMI) ≥25.0 kg/m^2 (33)].

Work-related biomechanical factors [assessed using the European consensus criteria (32)] included: high repetitiveness of tasks (≥4 hours/day); repeated/sustained posture with arms above shoulder level (≥2

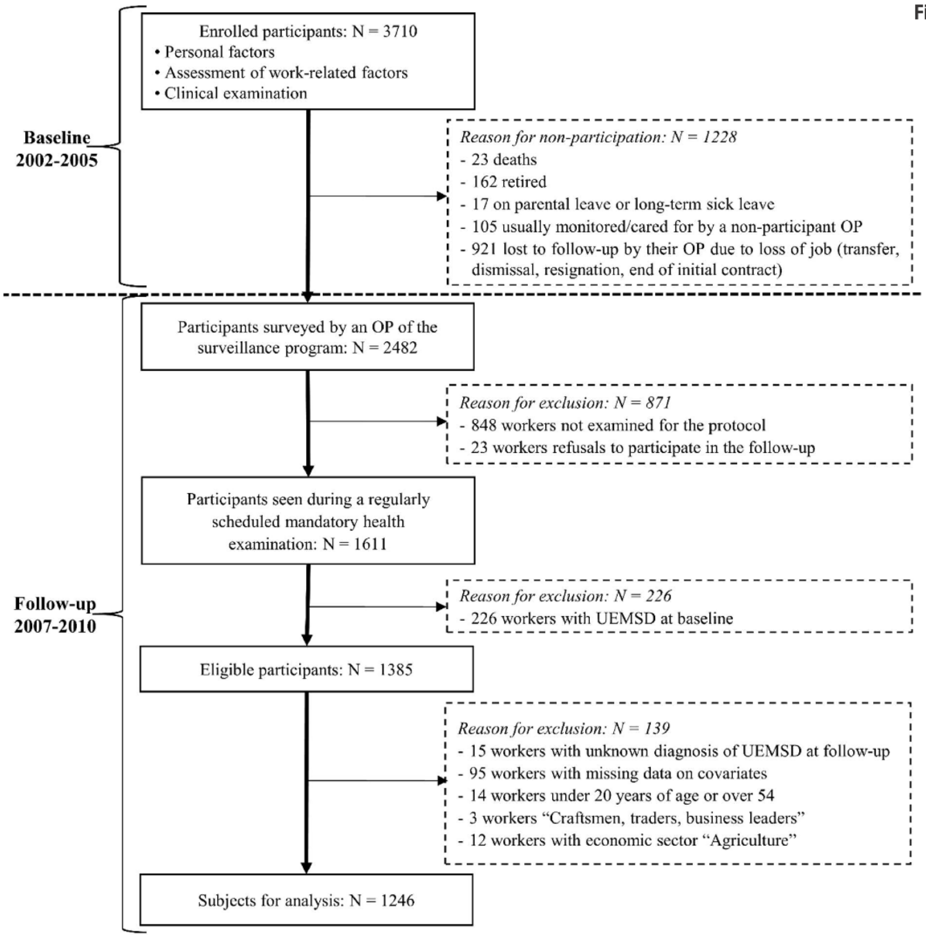

Figure 1. Participant flow diagram.

hours/day); repeated/sustained elbow movements (flexion/extension) (≥2 hours/day); and wrist twisting movements (≥2 hours/day). Concerning the exposure "repeated/sustained shoulder abduction", workers who responded "rarely (<2 hours/day)", "often (2–4 hours/day)" or "always (≥4 hours/day)" were defined as being at risk of this posture (30). The questionnaire presented awkward postures in picture form to facilitate workers' understanding and thus increase the validity of posture self-assessment (34). The perceived physical exertion was evaluated using the Borg Rating Perceived Exertion (RPE) scale (35), ranging from 6 (no exertion at all) to 20 (maximal exertion). RPE was dichotomized using the threshold (Borg RPE scale ≥13) proposed by the French National Research and Safety Institute for the Prevention of Occupational Accidents and Diseases (INRS cut-offs) (36).

Work-related psychosocial factors – high psychological demands and low social support – were assessed using the 26 items of the French version of the Karasek Job Content Questionnaire (JCQ) (37). Scores were dichotomized using the median values of the French national SUMER study to classify exposed and unexposed workers (38).

Statistical analysis

Analyses were conducted for the entire cohort, and a sex-stratified analysis was also performed to account for possible sex differences in occupational exposures (39, 40).

Assessment of risk factors and population-attributable fraction (PAF) estimate in the COSALI cohort

Using a Cox multivariable regression model with constant follow-up time for each subject and robust variance (41), relative risks (RR) and their 95% confidence intervals (CI) were estimated for incident UEMSD occupational risk factors after adjustment for personal risk factors (age, sex, and BMI) in the COSALI cohort.

To quantify the proportion of UEMSD incident cases attributable to each risk factor, PAF were estimated for each risk factor in the multivariable model in addition to a combined PAF of all occupational factors. Point estimates and 95% CI of the PAF were calculated using the method described by Spiegelman et al (42). The PAF estimate accounted for the prevalence of the exposure and RR of UEMSD risk associated with that exposure (42):

$$PAF = \frac{\sum_{s=1}^{S}\sum_{t=1}^{T} p_{st}RR_{1s}RR_{2t} - \sum_{s=1}^{S}\sum_{t=1}^{T} p_{st}RR_{2t}}{\sum_{s=1}^{S}\sum_{t=1}^{T} p_{st}RR_{1s}RR_{2t}}$$

where t denotes a stratum of unique combinations of levels of all background risk factors which are not under study, $t=1;...; T$, and RR_{2t} is the relative risk in combination t relative to the lowest risk level, where $RR_{(2,t)}=1$. s indicates an index exposure group defined by each of the unique combinations of the levels of the index risk factors, that is, those risk factors to which the PAFapplies, $s=1;...; S$, and RR_{1s} is the relative risk corresponding to combinations relative to the lowest risk combination $RR_{1,1}=1$. The joint prevalence of exposure group s and stratum t is denoted by p_{st}, and $p_{.t} = \sum_{s=1}^{S} p_{st}$.

The calculation of PAF is recommended for multifactorial diseases when some risk factors are unmodifiable or not expected to change after intervention (43). To facilitate the comprehension and interpretation of the PAF estimate, the lower limit of its 95% CI was set to zero when this lower limit was negative.

Estimated number of incident UEMSD attributable to occupational risk factors

To estimate the number of incident cases of UEMSD attributable to occupational risk factors in the PdL region, the calculation procedure was implemented in two steps. First, the study sample was weighted to provide estimates of incident UEMSD cases which were representative of the PdL working population, using data from the 2007 population census of the PdL region [conducted by the French National Institute of Statistics and Economic Studies (INSEE)]. A calibration on margins, proposed by Deville et al (44, 45), was used to take the characteristics of the PdL working population into account. The new weights were calculated using the following auxiliary variables (also called calibration variables): age, sex, occupational class and economic sector. These auxiliary variables were measured in both the COSALI cohort and the 2007 French population census, ie, their population distribution was known, and were correlated with the variable of interest, ie, incident UEMSD (according to Spearman's correlation test). The "*linear*" calibration method was used to calculate the new weights from the "*Calmar*" macro (*calibration on margins*) developed by Sautory (46). With the calibration method, weights are assigned to all survey respondents in order to make the sample as representative as possible of the (inference) population. Over-represented groups then had a small weight and under-represented groups a large weight. The weighted sample (ie, with the new weights) is more representative of the working population of the PdL region, resulting in estimates with a lower bias than those that are unweighted. Furthermore, through the calibration method, potential improvements in the accuracy of the estimates can be expected (47).

At the second step, the estimated number of incident cases of UEMSD (and the variation range) attributable to risk factor was obtained by multiplying the PAF (and the 95% CI) by the projected number of incident UEMSD in the PdL region in 2007.

All statistical analyses were performed using the SAS software, version 9.4 (SAS Institute Inc, Cary, NC, USA).

Results

Study sample characteristics

Of the 1385 eligible participants with a standardized clinical examination at follow-up, a total of 1246 participants (734 (59%) men and 512 (41%) women) with a mean age of 38.2 (standard deviation 8.7) years at baseline were included in current analyses (figure 1). A comparison of characteristics and working conditions at baseline between the eligible participants included in the analyses and those excluded is provided in an additional file [see supplementary material, www.sjweh.fi/show_abstract.php?abstract_id=3911]. Excluded participants did not differ in terms of BMI, diabetes mellitus and rheumatoid arthritis, but were significantly older than those included in analyses (P<0.001). They were more likely to: be women (P=0.036) and lower-grade white-collar workers (P<0.001), work in trade and services sectors (P<0.001), be temporarily employed (P=0.006) or have a higher seniority level in their current job (P=0.041). No difference was observed in working conditions under study. However, borderline differences exist for perceived physical exertion, repetitiveness of task, and use of vibrating tools.

Incident UEMSD diagnosed at follow-up

At least one of the six UEMSD was diagnosed at follow-up in 139 workers free from UEMSD at baseline (74 men and 65 women) corresponding to a projected number of 129 320 new UEMSD cases in the PdL region in 2007 (table 1). The incidence proportion of UEMSD observed in the PdL region did not significantly differ between sexes (10.3% for men versus 12.4% for women; P=0.287). The most common diagnoses at follow-up were rotator cuff syndrome (incidence proportion 6.5%), lateral epicondylar tendinopathy (incidence proportion 2.2%) and CTS (incidence proportion 2.0%). The estimate of the projected number of workers in the PdL with two or more UEMSD at follow-up was 19 404 (1.7%) workers.

Incident UEMSD risk factors

The RR for incident UEMSD associated with occupational risk factors in the multivariable model after adjustment for personal risk factors are shown in table 2. The following occupational exposures were positively associated with incident UEMSD: high perceived physical exertion (RR 1.52, 95% CI 1.06–2.17), working with arms above shoulder level (RR 1.57, 95% CI 1.04–2.39) and low social support at work (RR 1.41, 95% CI 1.03–1.92).

Concerning personal factors, age was associated with the incident UEMSD while the RR for female sex was at the limit of statistical significance.

PAF and estimated number of incident UEMSD attributable to risk factors

PAF associated with the incidence of UEMSD in the multivariable model were 20.4% (95% CI -1.1–40.1)

Table 1. Distribution of the six upper-extremity musculoskeletal disorders (UEMSD) among the study population and its projection.

	Study sample							Projection of the study sample at the level of the PdL region						
	Overall (N=1246)		Men (N=734)		Women (N=512)		P-value [a]	Overall (N=1141 324) [b]		Men (N=582 950) [b]		Women (N=558 373) [b]		P-value [c]
	N	%	N	%	N	%		N	%	N	%	N	%	
Rotator cuff syndrome	78	6.3	41	5.6	37	7.2	0.242	73 858	6.5	32 827	5.6	41 032	7.3	0.259
Lateral epicondylar tendinopathy	28	2.3	22	3.0	6	1.2	0.032	24 767	2.2	18 117	3.1	6650	1.2	0.033
Carpal tunnel syndrome	24	1.9	7	1.0	17	3.3	0.003	22 456	2.0	7228	1.2	15 228	2.7	0.084
Ulnar tunnel syndrome	12	1.0	7	1.0	5	1.0	1.000 [d]	12 022	1.1	7796	1.3	4227	0.8	0.332
De Quervain tenosynovitis	10	0.8	4	0.6	6	1.2	0.334 [d]	7878	0.7	2159	0.4	5719	1.0	0.138
Flexor-extensor peritendinitis or tenosynovitis of the forearm-wrist region	9	0.7	5	0.7	4	0.8	1.000 [d]	9399	0.8	3988	0.7	5410	1.0	0.625
≥1 of 6 UEMSD	139	11.2	74	10.1	65	12.7	0.149	129 320	11.3	60 133	10.3	69 187	12.4	0.287
≥2 of 6 UEMSD	20	1.6	11	1.5	9	1.8	0.720	19 404	1.7	10 921	1.9	8483	1.5	0.652

[a] P-value of Chi-square test;
[b] Weighted.
[c] P-value of the Rao-Scott Chi-square test for weighted samples.
[d] Fisher's exact test.

Table 2. Multivariable models for risk factors of incident upper-extremity musculoskeletal disorders (UEMSD) in the COSALI cohort. [RR=relative risk; 95% CI=95% confidence interval]

	Overall study sample (N=1246; incident UEMSD=139)			Men (N=734; incident UEMSD=74)			Women (N=512; incident UEMSD=65)		
	N (%)	RR (95% CI)	P-value [a]	N (%)	RR (95% CI)	P-value [a]	N (%)	RR (95% CI)	P-value [a]
Biomechanical factors [b]									
High perceived physical exertion (≥13) [c]	571 (45.8)	1.52 (1.06–2.17)	0.022	365 (49.7)	2.38 (1.41–4.04)	0.001	206 (40.2)	0.74 (0.41–1.33)	0.319
High repetitiveness of tasks (>4 hrs/day)	267 (21.4)	1.15 (0.81–1.64)	0.421				128 (25.0)	1.33 (0.86–2.08)	0.201
Repeated/sustained posture with arms above shoulder level (≥2 hrs/day)	126 (10.1)	1.57 (1.04–2.39)	0.033	76 (10.4)	1.28 (0.71–2.33)	0.412	50 (9.8)	1.70 (0.97–2.98)	0.066
Repeated/sustained posture with shoulder abduction [d]	373 (29.9)	1.26 (0.88–1.81)	0.201				126 (24.6)	1.75 (1.05–2.93)	0.032
Repeated/sustained elbow movements (flexion/extension) (≥2 hrs/day)	355 (28.5)	1.00 (0.69–1.46)	0.994	213 (29.0)	1.26 (0.79–2.00)	0.327			
Wrist twisting movements (≥2 hrs/day)	386 (31.0)	0.99 (0.67–1.46)	0.970				148 (28.9)	1.41 (0.82–2.41)	0.214
Psychosocial factors [e]									
Low social support	444 (35.6)	1.41 (1.03–1.92)	0.032	279 (38.0)	1.42 (0.92–2.17)	0.109	165 (32.2)	1.36 (0.85–2.17)	0.196
High psychological demands				348 (47.4)	1.29 (0.84–1.99)	0.244			
Personal factors									
Female sex	512 (41.1)	1.33 (0.97–1.81)	0.075						
Age: 35–44 years (ref: <35 years)	451 (36.2)	1.54 (1.03–2.29)	0.034	268 (36.5)	1.80 (1.02–3.16)	0.041	183 (35.7)	1.37 (0.77–2.42)	0.286
Age: ≥45 years (ref: <35 years)	335 (26.9)	2.13 (1.44–3.16)	<0.001	186 (25.3)	2.77 (1.59–4.83)	<0.001	149 (29.1)	1.60 (0.92–2.78)	0.098
Overweight/obesity [f]							124 (24.2)	1.70 (1.07–2.72)	0.025

[a] P-value of Wald test.
[b] Binary variables assessed using exposure criteria from the European consensus criteria to diagnose work-related UEMSD (32).
[c] Assessed using the Borg RPE scale (35).
[d] Workers who responded "rarely (<2 hours/day)", "often (2–4 hours/day)" or "always (≥4 hours/day)" were defined as being at risk of this posture (30).
[e] Binary variables assessed using assessed using the French JCQ (38).
[f] Binary variable assessed using the World Health Organization criteria (33).

for high physical exertion (Borg RPE scale ≥13), 6.6% (-3.5–16.4) for working with arms above shoulder level (≥2 hours/day), and 12.9% (0.3–25.1) for low social support (table 3). Of the projected estimate of 129 320 incident UEMSD cases in PdL in 2007, an estimated 26 381 (variation range: 0–51 857) new UEMSD cases were attributable to high physical exertion, 16 682 (388–32 459) to low social support, and 8535 (0–21 208) new cases to working with arms above shoulder level. A high number of incident UEMSD [10 863 cases (0–30 778)] could be attributed to working with shoulder abduction despite the associated RR failing to reach the 5% statistical significance level. The projected number of incident UEMSD attributable to all occupational factors in the multivariable model was estimated at 53 021 (0–98 671) cases, representing 41.0% of all new UEMSD in the PdL region.

Sex-stratified analyses

Results from sex-stratified analyses suggest that the observed relationship between incident UEMSD and high physical exertion or low social support were primarily observed among men. The relationship observed between incident UEMSD and sustained or repetitive shoulder abduction or working with arms above shoulder level were primarily observed among women. Thus, the association of high physical exertion with incident UEMSD was only statistically significant (RR 2.38, 95% CI 1.41–4.04)] among men, while the association with low social support approached statistical significance (RR 1.42, 95% CI 0.92–2.17). Occupational exposure with shoulder abduction was only found to be positively associated with incident UEMSD (RR 1.75, 95% CI 1.05–2.93) among women, and the RR associated with working with arms above shoulder level approached statistical significance (RR 1.70, 95% CI 0.97–2.98) (table 2).

Of the projected total estimate of 60 133 UEMSD incident cases among male workers in the PdL region in 2007, 25 015 were attributable to high physical exertion, representing 41.6% of all new cases, while 8599 (14.3%) could be attributed to low social support (table 3). Similarly, of the projected 69 187 new UEMSD cases among women estimated in 2007, 12 315 cases (17.8% of all new UEMSD) were attributable to working with shoulder abduction while 5258 cases (7.6%) could be attributed to working with arms above shoulder level. In addition, the PAF among women for being overweight/obese (a potentially modifiable factor) was 15.3% corresponding to 10 586 new UEMSD cases in the PdL region in 2007.

The PAF attributable to all occupational factors was estimated to be 59.7% among men and 42.5% among women, corresponding to 35 899 and 29 411 projected incident cases of UEMSD in the PdL region, respectively.

Table 3. Population-attributable fraction (PAF) and estimated number (EN) of incident upper-extremity musculoskeletal disorders (UEMSD) attributable to risk factors. PAF was adjusted for all factors in the model and calculated using the lowest risk group for each factor as the reference group, with all other factors remaining unchanged. EN was calculated by multiplying the PAF by the projected number of incident UEMSD cases in the Pays de la Loire region in 2007.

	Overall population				Men				Women			
	PAF [a]	95% CI	EN	EN variation range	PAF [a]	95% CI	EN	EN variation range	PAF [a]	95% CI	EN	EN variation range
Biomechanical factors												
High perceived physical exertion (≥13) [a, b]	20.4	-1.1–40.1	26 381	0–51 857	41.6	14.2–63.1	25 015	8539–37 944				
High repetitiveness of tasks (>4 hrs/day)	3.7	-6.7–14.0	4785	0–18 105					8.9	-8.6–25.8	6158	0–17 850
Repeated/sustained posture with arms above shoulder level (≥2 hrs/day)	6.6	-3.5–16.4	8535	0–21 208	3.9	-7.2–14.8	2345	0–8900	7.6	-5.7–20.6	5258	0–14 253
Repeated/sustained posture with shoulder abduction	8.4	-7.4–23.8	10 863	0–30 778					17.8	-7.5–41.0	12 315	0–28 367
Elbow flexion/extension movements (≥2 hrs/day)	0.1	-12.6–12.7	129	0–16 424	7.8	-9.2–24.4	4690	0–14 672				
Wrist twisting movements (≥2 hrs/day) [b]									12.4	-13.0–36.4	8579	0–25 184
Psychosocial factors												
Low social support	12.9	0.3–25.1	16 682	388–32 459	14.3	-4.3–32.0	8599	0–19 243	10.6	-6.7–27.2	7334	0–18 819
High psychological demands					11.9	-8.3–31.2	7156	0–18 761				
Personal factors												
Female sex	11.5	-1.0–23.6	14 872	0–30 520								
Age: 35–44 years	12.6	2.7–22.3	16 294	3492–28 838	16.8	2.7–30.3	10 102	1624–18 220	9.1	-5.1–22.8	6296	0–15 775
Age: ≥45 years	19.9	11.6–27.8	25 735	15 001–35 951	24.2	14.4–33.5	14 552	8659–20 145	13.8	-1.9–28.9	9548	0–19 995
Overweight/obesity									15.3	-1.7–31.4	10 586	0–21 725
All occupational factors	41.0	-13.0–76.3	53 021	0–98 671	59.7	4.4–87.0	35 899	2646–52 316	42.5	-20.8–80.7	29 411	0–55 834

[a] Assessed using the Borg RPE scale (35).
[b] Relative risk <1 and the PAF was not calculated.

Discussion

Main findings

This study has estimated the number of incident cases of UEMSD attributable to occupational exposure factors in the working population of the French PdL region in 2007.

Considering occupational risk factors for incident UEMSD, our results showed that an estimated 26 381 incident cases, representing 20.4% of all new projected UEMSD cases in the PdL region in 2007, were attributable to high physical exertion, 8535 incident cases (6.6%) to working with arms above shoulder level, and 16 682 incident cases (12.9%) to low social support from coworkers and supervisors. Furthermore, a significant number of new UEMSD cases (N=10 863) could be attributed to working with shoulder abduction despite the associated RR did not reach the 5% statistical significance level.

Comparison with previous literature

To our knowledge, this is the first cohort study estimating the number of potential cases of UEMSD attributable to occupational risk factors in an entire working population.

The main occupational factor likely to lead to the highest number of incident cases of UEMSD was high physical exertion, associated with 26 381 cases (about 20.4% of incident UEMSD in the PdL working population). Approximately one in five incident UEMSD could theoretically be prevented by reducing exposure to physical exertion in the workplace. Previous studies carried out in Italy and the Netherlands (22, 23) reported that 28% of CTS cases and 25% of lateral epicondylar tendinopathy cases respectively, could be attributable to high physical exertion. Moreover, a recent narrative review showed that forceful exertion was a significant risk factor for all UEMSD (48). Meta-analyses have also revealed a significant relationship between shoulder disorders and hand force exertion, but with moderate evidence (11), and between CTS and force (10). In addition, a summary study based on three longitudinal MSD studies provided strong evidence for a relationship between lateral epicondylalgia and occupational exposure to high hand force (49).

Our study indicated the important contribution of awkward shoulder postures with a projected estimate of 8535 (6.6%) and 10 863 (8.4%) incident UEMSD attributable to working with arms above shoulder level and working with shoulder abduction respectively. This result is consistent with recent PAF estimates (15% for lateral epicondylar tendinopathy and 9% for shoulder disorders) associated with awkward postures in the working population (22) and a recent meta-analysis showing moderate evidence of a positive association between shoulder disorders and exposure to arm-hand elevation (11).

The present study estimated the projected number of incident UEMSD related to low social support at 16 682, representing 12.9% of all incident cases. Our PAF estimates are in line with the findings from the 2001 US National Research Council extensive review (27), which concluded that improving low social support of coworkers and supervisors in exposed workers could potentially reduce the risk for UEMSD by 28–52%. A multitude of psychosocial factors in the workplace, including poor social support, activate psychosocial stress. Stress then appears to initiate a sequence of physiological reactions, including biochemical reactions, which in the short term may increase muscle tension and, in the long term, may increase the risk of MSD (50). Therefore, an improvement in social support from superiors and colleagues may contribute to the reduction of this risk. Moreover, workers with low social support may be exposed to higher levels of biomechanical risk factors (51). Conversely, high social support may facilitate the cooperation between coworkers in performing strenuous manual tasks to minimize biomechanical exposure (52). In a previous meta-analysis, exposure to low social support in the workplace was positively associated with the onset of UEMSD (9). A systematic literature review showed that low social support at work may result in an increased occurrence of specific disorders at the elbow (12). Another systematic review by Kraatz et al (53) showed strong evidence for adverse effects of low social support on the onset of shoulder disorders. A meta-analysis of Lang et al (54) found positive associations between psychosocial work stressors, including low social support at work, and shoulder symptoms and upper-extremity symptoms, while another found low-quality evidence of no association for social support (11). However, this finding has been inconsistent with some previous studies. A prospective study found no associations between social support and incident UEMSD (lateral epicondylitis, rotator cuff tendinitis, CTS, tendinitis of forearm–wrist extensors and flexors) (55). Recently, a review reported limited evidence for a positive association between psychosocial factors including low social support and CTS in the workplace (56).

Concerning personal risk factors, sex and age are not modifiable factors. Among the potentially personal modifiable risk factors, the present study suggests that (in women) an important number of projected incident UEMSD could be attributed to high BMI (15.3% of all projected new cases) in the PdL female working population. This result is in line with a prospective cohort study of Italian workers reporting that about 30% of CTS cases may be attributable to being overweight/obese (23). These differences may reflect the gender division of work where men are more often exposed to jobs requiring high physical work load and forceful exertion (eg, in the construction sector) and women more often exposed to highly repetitive tasks with lower force exertion (eg, in assembly line work) (39, 40). Moreover, highly physically demanding jobs (eg, manual handling of heavy loads) require mutual help and social support from coworkers to collectively cope with job tasks and minimize biomechanical exposure (52).

Strengths and limitations

The present study has some limitations. Approximately 57% of workers included at baseline did not have a follow-up clinical examination. Within this participant group, 58% were no longer being monitored by any OP of the network because they had left their baseline jobs without informing their OP. In some cases, their OP refused to participate in the follow-up period. Moreover, the follow-up period coincided with the major economic crisis in the PdL region in 2008–2009, during which the regional salaried workforce declined by 3.4% (33.7% in temporary employment agencies) (57). The lowest participation rate in this study was among young or temporary workers or those with a short length of service at baseline (29). According to a study on the effects of drop out in a longitudinal study of MSD (58), the differences between the participants and the drop out subjects had a very modest influence on the RR for effects of occupational exposures. We therefore believe that there was no major selection bias associated with the quality of the follow-up.

Another limitation is the exposure assessment, which was based only on workers self-reporting. In spite of that, the use of standardized and validated questions may have ensured better quality of the self-reported exposure measures. Non-differential misclassification of exposures may have occurred due to workers' inability to precisely recall or describe their current work exposures among workers without symptoms. Nevertheless, due to the prospective design of the study, exposure information gathered prior to UEMSD diagnosis resulted in low risk of differential recall bias. To the extent that the risk of UEMSD is increased by cumulative physical exposures, our analyses may have underestimated the true contribution of work exposures to the incidence of UEMSD in our study population. This may be particularly the case for rotator cuff syndrome, since studies of work-related risk factors for shoulder pain have identified the length of time employed as a risk factor (59). The single and short window of follow-up in this study after a long follow-up period is another potential limitation. Workers may have had a UEMSD in the period between the first and second clinical examinations, but recover and do not have the UEMSD at follow-up. This may have resulted in an underestimation of the number of cases diagnosed.

The computation of the combined PAF assumes independence and the absence of interaction between individual risk factors. However, there may be an interaction between certain occupational risk factors. In such cases, the calculation of the combined PAF may lead to its over- or underestimation. Nevertheless, none of the interactions between occupational exposures explored previously was statistically significant (29). It should also be noted that the choice of thresholds used to define exposure levels can have an effect on PAF estimates (60). However, to avoid bias, we chose exposure definitions as close as possible to public health recommendations and those recommended in the scientific literature. The concept of PAF supposes a causal relationship between exposure and UEMSD (19). Moreover, a strong association between a risk factor and UEMSD, ie, a high RR, may correspond to a low or high PAF depending on the prevalence of exposure. This leads to very different public health consequences as the prevalence of exposure can vary considerably within populations that are separated in time and space (61). Thus, we assume that a reduction in occupational exposure at the working population level would lead to a reduction in the incidence of WRUEMSD and PAF estimates should therefore be interpreted with caution. Finally, it is possible that the 95% CI of the PAF includes the null value, despite the significance of the RR due to the use of nonlinear transformations to compute the 95% CI of the PAF (62). Even so, zero should be close to the 95% CI.

The use of a prospective cohort including a representative sample of the working population at baseline is a major strength of the present study (31). Secondly, outcomes were clinically assessed by trained OP using standardized procedures (31, 32). In addition, this study strictly applied the definitions of exposures proposed by the European consensus criteria document (32), except for the measure of exposure to forceful exertion which was assessed according to the rating of perceived exertion (35) and the INRS cut-offs (36).

Another strength is the formula used to estimate the PAF from multivariable regression models, allowing a non-biased computation of PAF estimates adjusted for covariates (19). Lastly, sophisticated weighting adjustment methods (44–46) for enhancing estimate accuracy were used to extrapolate the number of cases observed in the study sample to the whole working population. Furthermore, the "*linear*" calibration method used to calculate the new weights was the one that gave the lowest variance and range of weight ratios (new weights / initial weights). Indeed, it was chosen by considering the following criteria: lowest dispersion, smallest extent and general appearance of the distribution of the new weight distribution; the other calibration methods give calibrated estimators with the same asymptotic accuracy (44, 46).

Finally, estimating the number of incident cases of UEMSD in the working population of the PdL region is useful for comparing the population-level impacts of various risk factors on the incidence of UEMSD. Furthermore, these estimates provide additional input for the implementation of prevention programs that target and prioritize the modifiable risk factors with the greatest impact for more effective interventions to reduce the medical, economic and social impact of UEMSD in the workplace.

Concluding remarks

Following adjustment for personal factors, we have been able to estimate the proportion and projected number of new UEMSD cases attributable to occupational risk factors in the working population of the French PdL region. According to our findings, an important proportion and a large number of incident UEMSD in the workplace in the PdL region could potentially be prevented by reducing occupational exposures such as physical exertion, working with shoulder abduction, and improving social support from coworkers and supervisors. These findings highlight the magnitude of potentially modifiable and preventable occupational exposures in the incidence of UEMSD in the workplace.

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Ethics approval and consent to participate

Each worker provided informed written consent to participate in this study, and the study received the approval of the French Advisory Committee on the Processing of Information in Health Research ("CCTIRS") and the National Committee for Data Protection ("CNIL").

References

1. Storheim K, Zwart JA. Musculoskeletal disorders and the Global Burden of Disease study. Ann Rheum Dis 2014 Jun;73(6):949–50. https://doi.org/10.1136/annrheumdis-2014-205327.

2. Summers K, Jinnett K, Bevan S. Musculoskeletal Disorders, Workforce Health and Productivity in the United States. Musculoskelet Disord. 2015;41.

3. Bevan S. Economic impact of musculoskeletal disorders (MSDs) on work in Europe. Best Pract Res Clin Rheumatol 2015 Jun;29(3):356–73. https://doi.org/10.1016/j.berh.2015.08.002.

4. Roquelaure Y. Musculoskeletal disorders: a major challenge for occupational risk prevention in Europe. ETUI, Brussels [Internet]. 2015; Available from: https://www.etui.org/Publications2/Policy-Briefs/European-Economic-Employment-and-Social-Policy/Musculoskeletal-disorders-a-major-challenge-for-occupational-risk-prevention-in-Europe

5. Eurostat. Health and safety at work in Europe (1999-2007): a statistical portrait. Luxembourg: Publications Office of the European Union; 2010.

6. Cnam. Direction des Risques Professionnels : Mission statistiques & Département tarification. Rapport annuel 2018 : L'Assurance Maladie – Risques professionnels [Internet]. Caisse nationale de l'Assurance Maladie, Paris Cedex 20; 2019 Dec p. 174. Available from: http://www.risquesprofessionnels.ameli.fr/fileadmin/user_upload/document_PDF_a_telecharger/brochures/Rapport%20annuel%202018%20AMRP%20-%20web.pdf.

7. da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: A systematic review of recent longitudinal studies. Am J Ind Med 2010 Mar;53(3):285–323.

8. Descatha A, Albo F, Leclerc A, Carton M, Godeau D, Roquelaure Y et al. Lateral Epicondylitis and Physical Exposure at Work? A Review of Prospective Studies and Meta-Analysis. Arthritis Care Res (Hoboken) 2016 Nov;68(11):1681–7. https://doi.org/10.1002/acr.22874.

9. Hauke A, Flintrop J, Brun E, Rugulies R. The impact of work-related psychosocial stressors on the onset of musculoskeletal disorders in specific body regions: A review and meta-analysis of 54 longitudinal studies. Work Stress 2011;25(3):243–56. https://doi.org/10.1080/02678373.2011.614069.

10. Kozak A, Schedlbauer G, Wirth T, Euler U, Westermann C, Nienhaus A. Association between work-related biomechanical risk factors and the occurrence of carpal tunnel syndrome: an overview of systematic reviews and a meta-analysis of current research [Internet]. BMC Musculoskelet Disord 2015 Sep;16(1):231. [cited 2018 Nov 17] Available from: http://bmcmusculoskeletdisord.biomedcentral.com/articles/10.1186/s12891-015-0685-0 https://doi.org/10.1186/s12891-015-0685-0.

11. van der Molen HF, Foresti C, Daams JG, Frings-Dresen MH, Kuijer PP. Work-related risk factors for specific shoulder disorders: a systematic review and meta-analysis. Occup Environ Med 2017 Oct;74(10):745–55. https://doi.org/10.1136/oemed-2017-104339.

12. van Rijn RM, Huisstede BM, Koes BW, Burdorf A. Associations between work-related factors and specific disorders at the elbow: a systematic literature review. Rheumatology (Oxford) 2009 May;48(5):528–36. https://doi.org/10.1093/rheumatology/kep013.

13. Feltner C, Peterson K, Palmieri Weber R, Cluff L, Coker-Schwimmer E, Viswanathan M et al. The Effectiveness of Total Worker Health Interventions: A Systematic Review for a National Institutes of Health Pathways to Prevention Workshop. Ann Intern Med 2016 Aug;165(4):262–9. https://doi.org/10.7326/M16-0626.

14. Stock SR, Nicolakakis N, Vézina N, Vézina M, Gilbert L, Turcot A et al. Are work organization interventions effective in preventing or reducing work-related musculoskeletal disorders? A systematic review of the literature. Scand J Work Environ Health 2018 Mar;44(2):113–33. https://doi.org/10.5271/sjweh.3696.

15. Van Eerd D, Munhall C, Irvin E, Rempel D, Brewer S, van der Beek AJ et al. Effectiveness of workplace interventions

in the prevention of upper extremity musculoskeletal disorders and symptoms: an update of the evidence. Occup Environ Med 2016 Jan;73(1):62–70. https://doi.org/10.1136/oemed-2015-102992.

16. Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. J Electromyogr Kinesiol 2004 Feb;14(1):13–23. https://doi.org/10.1016/j.jelekin.2003.09.015

17. Roquelaure Y, Fouquet N, Chazelle E, Descatha A, Evanoff B, Bodin J et al. Theoretical impact of simulated workplace-based primary prevention of carpal tunnel syndrome in a French region. BMC Public Health 2018 Apr;18(1):426. https://doi.org/10.1186/s12889-018-5328-6.

18. Levin ML. The occurrence of lung cancer in man. Acta Unio Int Contra Cancrum 1953;9(3):531–41.

19. Rockhill B, Newman B, Weinberg C. Use and misuse of population attributable fractions. Am J Public Health 1998 Jan;88(1):15–9. https://doi.org/10.2105/AJPH.88.1.15.

20. Melchior M, Roquelaure Y, Evanoff B, Chastang JF, Ha C, Imbernon E et al.; Pays de la Loire Study Group. Why are manual workers at high risk of upper limb disorders? The role of physical work factors in a random sample of workers in France (the Pays de la Loire study). Occup Environ Med 2006 Nov;63(11):754–61. https://doi.org/10.1136/oem.2005.025122.

21. Roquelaure Y, Ha C, Fouquet N, Descatha A, Leclerc A, Goldberg M et al. Attributable risk of carpal tunnel syndrome in the general population: implications for intervention programs in the workplace. Scand J Work Environ Health 2009 Oct;35(5):342–8. https://doi.org/10.5271/sjweh.1342.

22. van der Molen HF, Hulshof CT, Kuijer PP. How to improve the assessment of the impact of occupational diseases at a national level? The Netherlands as an example. Occup Environ Med 2019 Jan;76(1):30–2. https://doi.org/10.1136/oemed-2018-105387.

23. Violante FS, Farioli A, Graziosi F, Marinelli F, Curti S, Armstrong TJ et al. Carpal tunnel syndrome and manual work: the OCTOPUS cohort, results of a ten-year longitudinal study. Scand J Work Environ Health 2016 Jul;42(4):280–90. https://doi.org/10.5271/sjweh.3566.

24. Balogh I, Arvidsson I, Björk J, Hansson GÅ, Ohlsson K, Skerfving S et al. Work-related neck and upper limb disorders - quantitative exposure-response relationships adjusted for personal characteristics and psychosocial conditions. BMC Musculoskelet Disord 2019 Apr;20(1):139. https://doi.org/10.1186/s12891-019-2491-6.

25. Dalbøge A, Frost P, Andersen JH, Svendsen SW. Cumulative occupational shoulder exposures and surgery for subacromial impingement syndrome: a nationwide Danish cohort study. Occup Environ Med 2014 Nov;71(11):750–6. https://doi.org/10.1136/oemed-2014-102161.

26. Hagberg M, Morgenstern H, Kelsh M. Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome. Scand J Work Environ Health 1992 Dec;18(6):337–45. https://doi.org/10.5271/sjweh.1564.

27. National Research Council (U.S.), Institute of Medicine. (U.S.), editors. Musculoskeletal disorders and the workplace: low back and upper extremities. Washington, D.C: National Academy Press; 2001.

28. Rossignol M, Stock S, Patry L, Armstrong B. Carpal tunnel syndrome: what is attributable to work? The Montreal study. Occup Environ Med 1997 Jul;54(7):519–23. https://doi.org/10.1136/oem.54.7.519.

29. Nambiema A, Bertrais S, Bodin J, Fouquet N, Aublet-Cuvelier A, Evanoff B et al. Proportion of upper extremity musculoskeletal disorders attributable to personal and occupational factors: results from the French Pays de la Loire study. BMC Public Health 2020 Apr;20(1):456. https://doi.org/10.1186/s12889-020-08548-1.

30. Bodin J, Ha C, Petit Le Manac'h A, Sérazin C, Descatha A, Leclerc A et al. Risk factors for incidence of rotator cuff syndrome in a large working population. Scand J Work Environ Health 2012 Sep;38(5):436–46. https://doi.org/10.5271/sjweh.3285.

31. Roquelaure Y, Ha C, Leclerc A, Touranchet A, Sauteron M, Melchior M et al. Epidemiologic surveillance of upper-extremity musculoskeletal disorders in the working population. Arthritis Rheum 2006 Oct;55(5):765–78. https://doi.org/10.1002/art.22222.

32. Sluiter JK, Rest KM, Frings-Dresen MH. Criteria document for evaluating the work-relatedness of upper-extremity musculoskeletal disorders. Scand J Work Environ Health. 2001;27 Suppl 1:1–102.

33. WHO. Obesity: preventing and managing the global epidemic: report of a WHO consultation. Geneva: World Health Organization; 2000.

34. Halpern M, Hiebert R, Nordin M, Goldsheyder D, Crane M. The test-retest reliability of a new occupational risk factor questionnaire for outcome studies of low back pain. Appl Ergon 2001 Feb;32(1):39–46. https://doi.org/10.1016/S0003-6870(00)00045-4.

35. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc 1982;14(5):377–81. https://doi.org/10.1249/00005768-198205000-00012.

36. INRS. Méthode d'analyse de la charge physique de travail - ED 6161 2ème édition. 2019 Mar;43.

37. Karasek R, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B. The Job Content Questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. J Occup Health Psychol 1998 Oct;3(4):322–55. https://doi.org/10.1037/1076-8998.3.4.322.

38. Niedhammer I, Chastang JF, Gendrey L, David S, Degioanni S. Propriétés psychométriques de la version française des echelles de la demande psychologique, de la latitude décisionnelle et du soutien social du 4 Job Content Questionnaire [Psychometric properties of the French version of Karasek's "Job Content Questionnaire" and its scales measuring psychological pressures, decisional latitude and social support: the results of the SUMER]. Sante Publique 2006 Sep;18(3):413–27. https://doi.org/10.3917/

spub.063.0413

39. Messing K, Stock SR, Tissot F. Should studies of risk factors for musculoskeletal disorders be stratified by gender? Lessons from the 1998 Québec Health and Social Survey. Scand J Work Environ Health 2009 Mar;35(2):96–112. https://doi.org/10.5271/sjweh.1310.

40. Silverstein B, Fan ZJ, Smith CK, Bao S, Howard N, Spielholz P et al. Gender adjustment or stratification in discerning upper extremity musculoskeletal disorder risk? Scand J Work Environ Health. 2009 Mar;35(2):113-26. https://doi.org/10.5271/sjweh.1309.

41. Dwivedi AK, Mallawaarachchi I, Lee S, Tarwater P. Methods for estimating relative risk in studies of common binary outcomes. J Appl Stat 2014 Mar;41(3):484–500. https://doi.org/10.1080/02664763.2013.840772.

42. Spiegelman D, Hertzmark E, Wand HC. Point and interval estimates of partial population attributable risks in cohort studies: examples and software. Cancer Causes Control 2007 Jun;18(5):571–9. https://doi.org/10.1007/s10552-006-0090-y.

43. Wong BH, Peskoe SB, Spiegelman D. The effect of risk factor misclassification on the partial population attributable risk. Stat Med 2018 Apr;37(8):1259–75. https://doi.org/10.1002/sim.7559.

44. Deville JC, Särndal CE. Calibration Estimators in Survey Sampling. J Am Stat Assoc 1992 Jun;87(418):376–82. https://doi.org/10.1080/01621459.1992.10475217.

45. Deville JC, Särndal CE, Sautory O. Generalized Raking Procedures in Survey Sampling. J Am Stat Assoc 1993 Sep;88(423):1013–20. https://doi.org/10.1080/01621459.1993.10476369.

46. Sautory O. La macro Calmar. Redressement d'un échantillon par calage sur marges [Internet]. Paris: Insee, Unité Méthodes Statistiques; 1993. Available from: https://www.insee.fr/fr/information/2021908.

47. Szymkowiak M. Weighting and Estimation - Calibration. Memobust Handb. Methodol. Mod Bus Stat. [Internet]. 2014. Available from: https://ec.europa.eu/eurostat/cros/content/calibration-method_en.

48. Keir PJ, Farias Zuniga A, Mulla DM, Somasundram KG. Relationships and Mechanisms Between Occupational Risk Factors and Distal Upper Extremity Disorders. Hum. Factors J Hum Factors Ergon Soc. [Internet]. 2019 Jul 17 [cited 2019 Dec 2]; Available from: http://journals.sagepub.com/doi/10.1177/0018720819860683

49. Descatha A, Dale AM, Silverstein BA, Roquelaure Y, Rempel D. Lateral epicondylitis: new evidence for work relatedness. Joint Bone Spine 2015 Jan;82(1):5–7. https://doi.org/10.1016/j.jbspin.2014.10.013.

50. Roquelaure Y. Musculoskeletal Disorders and Psychosocial Factors at Work. SSRN Electron J. [Internet]. 2018 [cited 2020 Feb 20]; Available from: https://www.ssrn.com/abstract=3316143.

51. Bodin J, Garlantézec R, Costet N, Descatha A, Viel J-F, Roquelaure Y. Risk Factors for Shoulder Pain in a Cohort of French Workers: A Structural Equation Model. Am J Epidemiol. Oxford Academic; 2018 Feb 1;187(2):206–13.

52. Roquelaure Y, Garlantézec R, Evanoff BA, Descatha A, Fassier JB, Bodin J. Personal, biomechanical, psychosocial, and organizational risk factors for carpal tunnel syndrome: a structural equation modeling approach. Pain 2020 Apr;161(4):749–57. https://doi.org/10.1097/j.pain.0000000000001766.

53. Kraatz S, Lang J, Kraus T, Münster E, Ochsmann E. The incremental effect of psychosocial workplace factors on the development of neck and shoulder disorders: a systematic review of longitudinal studies. Int Arch Occup Environ Health 2013 May;86(4):375–95. https://doi.org/10.1007/s00420-013-0848-y.

54. Lang J, Ochsmann E, Kraus T, Lang JW. Psychosocial work stressors as antecedents of musculoskeletal problems: a systematic review and meta-analysis of stability-adjusted longitudinal studies. Soc Sci Med 2012 Oct;75(7):1163–74. https://doi.org/10.1016/j.socscimed.2012.04.015.

55. Bugajska J, Żołnierczyk-Zreda D, Jędryka-Góral A, Gasik R, Hildt-Ciupińska K, Malińska M et al. Psychological factors at work and musculoskeletal disorders: a one year prospective study. Rheumatol Int 2013 Dec;33(12):2975–83. https://doi.org/10.1007/s00296-013-2843-8.

56. Mansfield M, Thacker M, Sandford F. Psychosocial Risk Factors and the Association With Carpal Tunnel Syndrome: A Systematic Review. Hand (N Y) 2018 Sep;13(5):501–8. https://doi.org/10.1177/1558944717736398.

57. Hautbois L. Crise en Pays de la Loire : industrie et intérim dans la tourmente [Internet]. Insee Pays de la Loire; 2010 p. 4. Available from: https://www.epsilon.insee.fr/jspui/handle/1/2836

58. Bildt C, Alfredsson L, Punnett L, Theobald H, Torgén M, Wikman A. Effects of drop out in a longitudinal study of musculoskeletal disorders. Occup Environ Med 2001 Mar;58(3):194–9. https://doi.org/10.1136/oem.58.3.194.

59. van der Windt DA, Thomas E, Pope DP, de Winter AF, Macfarlane GJ, Bouter LM et al. Occupational risk factors for shoulder pain: a systematic review. Occup Environ Med 2000 Jul;57(7):433–42. https://doi.org/10.1136/oem.57.7.433.

60. Rockhill B, Weinberg CR, Newman B. Population attributable fraction estimation for established breast cancer risk factors: considering the issues of high prevalence and unmodifiability. Am J Epidemiol 1998 May;147(9):826–33. https://doi.org/10.1093/oxfordjournals.aje.a009535.

61. Benichou J. Biostatistics and epidemiology: measuring the risk attributable to an environmental or genetic factor. C R Biol 2007 Apr;330(4):281–98. https://doi.org/10.1016/j.crvi.2007.02.015.

62. Hertzmark E, Wand H, Spiegelman D. The SAS PAR Macro. Harv Sch Public Health Boston [Internet]. 2012 Mar 8; Available from: https://www.hsph.harvard.edu/donna-spiegelman/software/par/.

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4. Paper3: Proportion and number of upper extremity musculoskeletal disorders attributable to the combined effect of biomechanical and psychosocial risk factors in a working population

Submitted for publication

Key Findings and Messages

As part of a prevention strategy to reduce the incidence of UEMSD among workers in the French PdL region exposed to both high physical exertion and low social support from coworkers and supervisors, it was estimated that:

- 8664 new cases could potentially be prevented by improving social support only, representing 6.7% of all the projected estimate of 129 320 incident UEMSD cases in the PdL region in 2007
- 19 010 new cases (14.7%) could potentially be prevented by reducing exposure to high physical exertion only,
- and 20 443 new cases (15.8%) could potentially be prevented by acting on both factors.

In conclusion, this study showed that a multidimensional prevention intervention that would combine both a reduction of exposure to high physical exertion and an improvement of social support at work could reduce the incidence of UEMSD, thereby preventing a large number of cases.

Proportion and number of upper-extremity musculoskeletal disorders attributable to the combined effect of biomechanical and psychosocial risk factors in a working population

Aboubakari Nambiema, MSc, MPH[1*], Julie Bodin, PhD[1], Susan Stock, MD, MSc, FRCPC[2,3], Agnès Aublet-Cuvelier, MD[4], Alexis Descatha, MD, PhD[1,5], Bradley Evanoff, MD, MPH[6], Yves Roquelaure, MD, PhD[1]

[1]Univ Angers, CHU Angers, Univ Rennes, Inserm, EHESP, Irset (Institut de recherche en santé, environnement et travail) - UMR_S 1085, F-49000 Angers, France

[2]INSPQ - Institut National de Santé Publique du Québec, Montréal, QC, Canada

[3]Department of Social & Preventive Medicine, University of Montréal, QC, Canada

[4]INRS, Département Homme au travail, 1 rue du Morvan CS60027, 54519 Vandœuvre, France

[5]Inserm, UMS 011, unité cohortes épidémiologiques en population, Villejuif, France

[6]Division of General Medical Sciences, Washington University School of Medicine, St. Louis, MO 63310, USA, Saint-Louis, USA

***Corresponding author**
Aboubakari Nambiema, MSc, MPH

Irset - Inserm UMR 1085 - Equipe Ester
Faculté de santé - Département Médecine
28 Rue Roger Amsler, 49100 Angers, France

Tel: +33 24 17 35 907

www.ester.univ-angers.fr / www.irset.org

Email: aboubakari.nambiema@univ-angers.fr

ORCID iD: https://orcid.org/0000-0002-4258-3764

Key messages

What is already known about this subject?

- Several epidemiological studies have shown an increased risk of upper-extremity musculoskeletal disorders (UEMSD) associated with multiple occupational factors among the working population.

What are the new findings?

- As part of a prevention strategy to reduce the incidence of UEMSD among workers in the French Pays de la Loire (PdL) region exposed to both high physical exertion at work and low social support from coworkers and supervisors, it was estimated that:
  - 8664 new cases could potentially be prevented by improving social support only, representing 6.7% of all the projected estimate of 129 320 incident UEMSD cases in the PdL region in 2007,
  - 19 010 new cases (14.7%) could potentially be prevented by reducing exposure to high occupational physical exertion only,
  - and 20 443 new cases (15.8%) could potentially be prevented by acting on both risk factors.

How might this impact on policy or clinical practice in the foreseeable future?

- Estimating the potential theoretical impact of multidimensional workplace prevention programs may help occupational and public health practitioners and policy makers guide prevention strategies that reduce exposure to occupational risk factors with the greatest effect in the working population.

Abstract

Objective: To assess the combined effect of occupational biomechanical and psychosocial risk factors on the incidence of work-related upper-extremity musculoskeletal disorders (UEMSD) and estimate the proportion and number of incident cases attributable to these risk factors in a working population.

Methods: This study used data from the COSALI cohort. A total of 3710 workers from the French Pays de la Loire (PdL) region were randomly included between 2002−2005 and followed-up between 2007−2010. All participants underwent a standardized clinical examination at inclusion and 1611 workers were re-examined at follow-up. A complete case analysis including 1246 workers (59% of men, mean age: 38 years ± 8.6 at baseline) was conducted by excluding workers with baseline UEMSD and those with missing values for at least one covariate. Population attributable fractions and numbers of attributable cases of UEMSD to occupational risk factors in the PdL working population in 2007 were calculated.

Results: During the follow-up, 139 cases of UEMSD were diagnosed, representing an estimated 129 320 projected cases of incident UEMSD in PdL in 2007. After adjusting for personal factors, 8664 (6.7% of all projected incident UEMSD) cases were attributable to low social support only, 19 010 (14.7%) to high physical exertion only and 20 443 (15.8%) to co-exposure to both factors.

Conclusions: This study’s findings suggest that a large number of UEMSD cases may be prevented by multidimensional interventions aimed at reducing exposure to high physical exertion and improving social support at work.

Keywords: Cohort study; France; upper-extremity MSD; occupational risk factor; combined effect; preventable cases; prevention.

Introduction

Throughout the world, upper-extremity musculoskeletal disorders (UEMSD) (e.g. carpal tunnel syndrome, shoulder tendinopathy) are an important health problem in the working population, with a major impact on work-related disabilities, quality of life and years lost due to disability [1–3]. Besides their consequences on the health of workers, UEMSD also have a serious impact on workers' careers, absenteeism from work, and on the economic health of the companies they work for, particularly in terms of costs related to production loss, work performance and the sustainability of workers' activities [1,4]. In France, according to 2018 social health insurance data, the costs related to all work-related MSD (mainly UEMSD, which comprise 91% of all MSD) were estimated at €2 billion for companies [5].

Previous studies have provided estimates of prevalence and/or incidence of UEMSD. A systematic review [6] of worldwide incidence and prevalence studies in the working population showed a 12-month prevalence of UEMSD ranging from 2.3 to 41.0%. A recent review [7] found that the annual incidence and the prevalence worldwide ranged from 0.08 to 6.3% and from 0.14 to 21.9% in the working population, respectively. Furthermore, a large amount of literature documented that UEMSD are associated with multiple risk factors including personal factors (e.g. age), biomechanical factors (e.g. repetitiveness of tasks), psychosocial factors (e.g. low social support) and organizational factors (e.g. machine-paced work) which commonly interact with each other in creating the overall risk [8–12].

With regard to UEMSD prevention, occupational and public health practitioners and policy makers should prioritize interventions based on modifiable risk factors or on a combination of risk factors with the greatest effect in the working population and which prevent the greatest number of incident cases. In a previous study [13], population attributable fractions (PAFs) and the number of incident UEMSD attributable separately to each identified risk factor were estimated for French workers in the Pays de la Loire (PdL) region. Based on the results of this previous study, this paper aims to (i) assess the combined effect of occupational biomechanical (e.g. high physical exertion) and psychosocial (e.g. low social support) risk factors on the incidence of UEMSD among the French workers in the PdL region and (ii) estimate the proportion and number of incident cases attributable to these risk factors in two prevention scenarios in the PdL region.

Methods

Data from the COSALI cohort [13], which was based on data from a prospective study of MSD and their risk factors in the working population from the French PdL region [14], were re-analyzed. Briefly, a total of 3710 workers were included by the 83 occupational physicians (OP) (18% of OP in the region) volunteered to take part in the study between 2002–2005. They completed a self-administered questionnaire and underwent a standardized clinical examination performed by the OP. Between 2007–2010, 1611 workers were re-examined by their OP. From the 1611 workers re-examined at follow-up, a complete case analysis including 1246 workers was conducted by excluding workers with baseline UEMSD and those with missing values for at least one covariate.

The study received approval from France's Advisory Committee on the Processing of Information in Health Research ("CCTIRS") and the National Committee for Data Protection ("CNIL"), initially in 2001 and again in 2006. Each worker provided written informed consent prior to inclusion.

Outcome definition

The outcome was defined as incident cases of six main clinically diagnosed UEMSD among workers free of any of the six main clinically diagnosed UEMSD at baseline and who met the criteria for at least one of the disorders at follow-up (based on the European consensus criteria to diagnose work-related UEMSD for health surveillance of epidemiologic studies) [13]. These UEMSD were carpal tunnel syndrome (CTS), ulnar tunnel syndrome, De Quervain's disease, flexor-extensor peritendinitis or tenosynovitis of the forearm-wrist region, rotator cuff syndrome (RCS), and lateral epicondylar tendinopathy (LET).

Covariates

Previously identified risk factors for UEMSD [13] were included in this study: high perceived physical exertion (Borg RPE scale ≥13) (yes/no), posture with arms above shoulder level (≥2 hours/day) (yes/no), low social support (yes/no), age (<35 years, 35-44 years, and ≥45 years) and female sex. In addition, two combined factors were created: ***"High perceived physical exertion + low social support" (HPPELSS)*** was categorized into four groups: no factor, low social support only, high physical exertion only, and both factors and "***posture with arms above shoulder level (≥2 hours/day) + low social support" (PAASLSS)*** was categorized into four groups: no factor, low social support only, posture with arms above shoulder level, and both factors.

Statistical analysis

To identify a hypothetical prevention scenario that would prevent more UEMSD from occurring by addressing the modifiable occupational risk factor(s) with the greatest impact on the working population, two multivariate models, each including one of the two combinations of factors mentioned above, were tested, as described below.

a) Model 1: HPPELSS + posture with arms above shoulder level + female sex + age.
b) Model 2: PAASLSS + high perceived physical exertion + female sex + age.

As in the previous study [13], relative risks, PAFs and population estimated numbers of UEMSD cases attributable to risk factors were computed for each model. To facilitate the comprehension and interpretation of the PAF estimate, the lower limit of its 95% CI was set to zero when this lower limit was negative. All statistical analyses were performed using SAS software, version 9.4 TS Level 1M6.

Results

Of the 1246 workers (59% men, mean age: 38 years ± 8.6 at baseline), 139 (11.2%) developed UEMSD during follow-up, amounting to a projected number of 129 320 new UEMSD cases in the PdL region working population in 2007 13. Table 1 gives the results of RR for incident UEMSD, PAFs and population estimated numbers of UEMSD cases attributable to risk factors, with the lowest risk group as a reference. In model 1: of the 129 320 new

UEMSD cases estimated in the PdL region in 2007, low social support at work only led to an estimate of 8664 new cases representing 6.7% of all new cases, high perceived physical exertion at work only led to 19 010 (14.7%), and the combination of both factors led to 20 433 (15.8%) new UEMSD cases. In model 2, 16 294 new cases (12.6% of all new cases in the PdL region) were attributable to low social support at work only, 6983 (5.4%) to working posture with arms above shoulder level at work only and only 5043 (3.9%) were attributable to the combination of both factors.

Discussion

This cohort study analyzed two prevention models of work-related UEMSD and supports the need for prevention programs to adopt a multidimensional approach aims to reduce both biomechanical (particularly for high physical exertion) and psychosocial factors, as this would potentially prevent the occurrence of a larger number of UEMSD cases [16].

The reduction of exposure to occupational high physical exertion in combination with the improvement of social support at work may theoretically prevent 20 443 new cases; i.e. 16% of all the 129 320 UEMSD cases projected in the PdL region in 2007 among workers. To the best of our knowledge, this is the first study estimating the number of cases that could be potentially prevented by multidimensional interventions acting on both biomechanical (i.e. high physical exertion) and psychosocial (i.e. low social support) exposure. Several studies have estimated the combined effect of biomechanical factors on the occurrence of UEMSD [14,17–20], but only one study [21] evaluated the combined effect of biomechanical and psychosocial factors. The study showed an increased risk of neck/shoulders symptoms with the combination of awkward or tiring position + awkward grip or hand movements + work stress. However, PAFs and numbers of cases of UEMSD attributable to the risk factors were not evaluated [21].

In the model of reducing exposure to working postures with arms above the shoulders combined with improved social support, around 5000 new cases of UEMSD (3.9% of all new UEMSD) could theoretically be avoided. The lower number of potentially preventable cases when acting upon these two risk factors can be explained by the low proportion of workers exposed to the combination of both risk factors (joint prevalence), and the low number of UEMSD cases corresponding to the combination of both risk factors among these exposed workers. Indeed, these two key indicators (prevalence and number of UEMSD cases) that are taken into account in the calculation of the PAF [22] are lower among workers exposed to the combined factors than among those exposed to only one of these risk factors.

The main strength of this study was the use of a prospective cohort which included a representative sample of the working population at baseline. Furthermore, information on exposures were collected based on literature definitions or public health recommendations [15,23]. In addition, outcomes were clinically assessed by trained OP using standardized procedures [15]. This study examined the potential impact on UEMSD cases prevented of two multidimensional preventive intervention strategies, one acting on occupational exposure to both high physical exertion and low social support, and the other acting on working posture with arms above the shoulders and low social support. The prevalence of certain risk factors (e.g. working with arms above the shoulders, low social

Table 1. Proportion and population estimated number (PEN) of incident UEMSD attributable to exposure to occupational risk factors in the working population in the PdL region

	Estimates in the COSALI cohort			Estimates at the level of the PdL region
Model 1	**Prev* (%)**	**Adjusted RR (95% CI)**	**Adjusted PAF (95% CI)**	**PEN (variation range)**
Occupational factors				
HPPELSS: High perceived physical exertion (Borg RPE scale ≥13) + Low social support				
No factor	37.2	1.00	Reference	Reference
Low social support only	17.0	1.64 (1.00 to 2.70)	6.7 (0.7 to 12.7)	8664 (905 to 16 424)
High perceived physical exertion only	27.2	1.83 (1.18 to 2.82)	14.7 (5.4 to 23.7)	19 010 (6983 to 30 649)
Both factors	18.6	2.37 (1.51 to 3.70)	15.8 (8.9 to 22.5)	20 433 (11 509 to 29 097)
Posture with arms above shoulder level (≥2 hours/day)	10.1	1.72 (1.14 to 2.57)	7.5 (0.5 to 14.4)	9699 (647 to 18 622)
All occupational factors			**41.1 (14.7 to 62.1)**	**53 151 (19 010 to 80 308)**
Personal factors				
Female gender	41.1	1.32 (0.97 to 1.80)	11.4 (0 to 23.8)	14 742 (0 to 30 778)
Age: 35-44 years	36.2	1.51 (1.01 to 2.25)	12.1 (1.5 to 22.5)	15 648 (1940 to 29 097)
Age: ≥45 years	26.9	2.09 (1.41 to 3.10)	19.5 (10.3 to 28.4)	25 217 (13 320 to 36 727)
	Estimates from the COSALI cohort			Estimates at the level of the PdL region
Model 2	**Prev* (%)**	**Adjusted RR (95% CI)**	**Adjusted PAF (95% CI)**	**PEN (variation range)**
Occupational factors				
PAASLSS: Posture with arms above shoulder level (≥2 hours/day) + Low social support				
No factor	58.4	1.00	Reference	Reference
Low social support only	31.5	1.51 (1.07 to 2.14)	12.6 (2.7 to 22.3)	16 294 (3492 to 28 838)
Posture with arms above shoulder level only	6.0	2.00 (1.18 to 3.37)	5.4 (0 to 10.8)	6983 (0 to 13 967)
Both factors	4.1	2.17 (1.17 to 4.03)	3.9 (0.3 to 7.4)	5043 (388 to 9570)
High perceived physical exertion (Borg RPE scale ≥13)	45.8	1.63 (1.17 to 2.28)	23.2 (6.0 to 39.0)	30 002 (7759 to 50 435)
All occupational factors			**38.9 (8.1 to 63.0)**	**50 306 (10 475 to 81 472)**
Personal factors				
Female gender	41.1	1.32 (0.97 to 1.80)	11.4 (0 to 23.7)	14 742 (0 to 30 649)
Age: 35-44 years	36.2	1.50 (1.01 to 2.23)	12.0 (1.2 to 22.5)	15 518 (1552 to 29 097)
Age: ≥45 years	26.9	2.09 (1.41 to 3.09)	19.5 (10.4 to 28.3)	25 217 (13 449 to 36 598)

UEMSD: Upper-extremity musculoskeletal disorders. Prev*: Prevalence of risk factor. RR: relative risk; 95% CI: 95% confidence interval. The PAF, adjusted for all factors in the model, was calculated using the lowest risk group for each factor as the reference group, with all other factors remaining unchanged. PAF: Population attributable fraction. PEN: Population estimated number of UEMSD. The PEN factor was calculated by multiplying the PAF by the projected number of incident UEMSD cases in the Pays de la Loire region in 2007.

support) or their combination or the small number of UEMSD cases related to the risk factors led to low PAFs and therefore of numbers of attributable cases in this work. This was particularly the case with the combination of reducing working with arms above the shoulders and improving social support, which would prevent fewer UEMSD than if only one of the two factors was acted upon in this study. Given to the above mentioned limitations, future research on estimating preventable UEMSD attributable to work should be carried out in longitudinal studies with larger sample sizes in order to obtain a solid scientific basis to confirm our conclusions and also to conduct similar analyses in different occupations and industrial sectors with a high risk of UEMSD. Future studies should evaluate the effectiveness and cost-effectiveness of such interventions.

In conclusion, this study demonstrated the potential relevance of multidimensional preventive interventions acting on several occupational factors at the same time. The findings suggest that an intervention that would both reduce exposure to high physical exertion and improve social support at work could potentially reduce the incidence of work-related UEMSD, thereby preventing a large number of cases. These conclusions support the implementation of interventions that target a combination of occupational risk factors in order to maximize the number of potentially preventable cases whose effectiveness should be evaluated in future studies.

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Authors' contributions

YR participated to the design of the study. AN analyzed the data, performed the statistical analysis and wrote the manuscript. YR had full access to all of the data in the study and takes responsibility for the integrity of the data. JB, SS, AAC, AD, BE, and YR reviewed and commented on the final manuscript. All authors read and approved the final manuscript to be published.

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Conflicts of interest

The authors have none to declare.

Ethics approval and consent to participate

Each worker provided informed written consent to participate in this study, and the study received the approval of the French Advisory Committee on the Processing of Information in Health Research ("CCTIRS") and the National Committee for Data Protection ("CNIL").

References

1 Bureau of Labor Statistics. Nonfatal occupational injuries and illnesses requiring days away from work, 2015 2016:28.

2 Roquelaure Y. Musculoskeletal disorders: a major challenge for occupational risk prevention in Europe. ETUI Policy Brief 2015;9:2015.

3 Sebbag E, Felten R, Sagez F, Sibilia J, Devilliers H, Arnaud L. The world-wide burden of musculoskeletal diseases: a systematic analysis of the World Health Organization Burden of Diseases Database. Ann Rheum Dis 2019;78:844–8. https://doi.org/10.1136/annrheumdis-2019-215142.

4 Bevan S. Economic impact of musculoskeletal disorders (MSDs) on work in Europe. Best Pract Res Clin Rheumatol 2015;29:356–73. https://doi.org/10.1016/j.berh.2015.08.002.

5 Cnam. Direction des Risques Professionnels. L'Essentiel 2018 – Santé et sécurité au travail. 2019.

6 Huisstede BM, Bierma-Zeinstra SM, Koes BW, Verhaar JA. Incidence and prevalence of upper-extremity musculoskeletal disorders. A systematic appraisal of the literature. BMC Musculoskelet Disord 2006;7:7. https://doi.org/10.1186/1471-2474-7-7..

7 da Costa JT, Baptista JS, Vaz M. Incidence and prevalence of upper-limb work related musculoskeletal disorders: A systematic review. Work 2015 ;51 :635–44. https ://doi.org/10.3233/WOR-152032.

8 Descatha A, Albo F, Leclerc A, Carton M, Godeau D, Roquelaure Y, et al. Lateral Epicondylitis and Physical Exposure at Work? A Review of Prospective Studies and Meta-Analysis: Work Exposure and Lateral Epicondylitis. Arthritis Care Res 2016;68:1681–7. https://doi.org/10.1002/acr.22874.

9 Hauke A, Flintrop J, Brun E, Rugulies R. The impact of work-related psychosocial stressors on the onset of musculoskeletal disorders in specific body regions: A review and meta-analysis of 54 longitudinal studies. Work Stress 2011;25:243–56. https://doi.org/10.1080/02678373.2011.614069.

10 Kozak A, Schedlbauer G, Wirth T, Euler U, Westermann C, Nienhaus A. Association between work-related biomechanical risk factors and the occurrence of carpal tunnel syndrome: an overview of systematic reviews and a meta-analysis of current research. BMC Musculoskelet Disord 2015;16:. https://doi.org/10.1186/s12891-015-0685-0.

11 Roquelaure Y, Garlantézec R, Evanoff BA, Descatha A, Fassier J-B, Bodin J. Personal, biomechanical, psychosocial, and organizational risk factors for carpal tunnel syndrome: a structural equation modeling approach. PAIN 2020;161:749–757. https://doi.org/10.1097/j.pain.0000000000001766.

12 van der Molen HF, Foresti C, Daams JG, Frings-Dresen MHW, Kuijer PPFM. Work-related risk factors for specific shoulder disorders: a systematic review and meta-analysis. Occup Environ Med 2017;74:745–55. https://doi.org/10.1136/oemed-2017-104339.

13 Nambiema A, Bodin J, Fouquet N, Bertrais S, Stock S, Aublet-Cuvelier A, et al. Upper-extremity musculoskeletal disorders: how many cases can be prevented? Estimates from the COSALI cohort. Scand J Work Environ Health 2020. https ://doi.org/10.5271/sjweh.3911.

14 Bodin J, Ha C, Petit Le Manac'h A, Sérazin C, Descatha A, Leclerc A, et al. Risk factors for incidence of rotator cuff syndrome in a large working population. Scand J Work Environ Health 2012;38:436–46. https://doi.org/10.5271/sjweh.3285.

15 Sluiter JK, Rest KM, Frings-Dresen MH. Criteria document for evaluating the work-relatedness of upper-extremity musculoskeletal disorders. Scand J Work Environ Health 2001;27:1–30 & 43–5. https://doi.org/10.5271/sjweh.637.

16 Kennedy CA, Amick III BC, Dennerlein JT, Brewer S, Catli S, Williams R, et al. Systematic Review of the Role of Occupational Health and Safety Interventions in the Prevention of Upper Extremity Musculoskeletal Symptoms, Signs, Disorders, Injuries, Claims and Lost Time. J Occup Rehabil 2010;20:127–62. https://doi.org/10.1007/s10926-009-9211-2.

17 Haahr JP, Andersen JH. Physical and psychosocial risk factors for lateral epicondylitis: a population based case-referent study. Occup Environ Med 2003;60:322–9.

18 National Research Council and Institute of Medicine. Musculoskeletal disorders and the workplace: low back and upper extremities. Washington, D.C: National Academy Press; 2001.

19 Silverstein BA, Bao SS, Fan ZJ, Howard N, Smith C, Spielholz P, et al. Rotator Cuff Syndrome: Personal, Work-Related Psychosocial and Physical Load Factors. J Occup Environ Med 2008;50:1062–76. https://doi.org/10.1097/JOM.0b013e31817e7bdd.

20 Harris-Adamson C, Eisen EA, Neophytou A, Kapellusch J, Garg A, Hegmann KT, et al. Biomechanical and psychosocial exposures are independent risk factors for carpal tunnel syndrome: assessment of confounding using causal diagrams. Occup Environ Med 2016;73:727–34. https://doi.org/10.1136/oemed-2016-103634.

21 Widanarko B, Legg S, Devereux J, Stevenson M. The combined effect of physical, psychosocial/84rganizational and/or environmental risk factors on the presence of work-related musculoskeletal symptoms and its consequences. Appl Ergon 2014;45:1610–21. https://doi.org/10.1016/j.apergo.2014.05.018.

22 Spiegelman D, Hertzmark E, Wand HC. Point and interval estimates of partial population attributable risks in cohort studies: examples and software. Cancer Causes Control 2007 ;18 :571–9. https ://doi.org/10.1007/s10552-006-0090-y.

23 INRS. Méthode d'analyse de la charge physique de travail – ED 6161 2ème édition 2019 :43. Available online at: http://www.inrs.fr/media.html?refINRS=ED%206161

General discussion

This section presents a summary of the key findings and conclusions that can be drawn from the research.

In this PhD thesis, we investigated the impact of various biomechanical (e.g. physical exertion, repetitiveness of tasks) and psychosocial exposures (e.g. low social support) on the incidence of UEMSD at the level of the working population. Several epidemiological studies have shown an increased risk of UEMSD associated with multiple exposure factors in the workplace. However, few have quantified the impact of these exposures on the incidence of UEMSD in the working population. Furthermore, most of them were based on cross-sectional designs and assessed only one type of MSD as an outcome (e.g. CTS).

In this research work, we specifically estimated 1) the proportion of incident UEMSD that could be attributed to risk factors (article 1); 2) the proportion and the number of UEMSD that could be potentially avoidable through prevention actions at the working population level (article 2); and 3) the relationship between incident UEMSD and co-exposure to risk factors and the impact of these risk factors at the working population level (article 3). All research for this thesis used data from the COSALI cohort, a prospective study of MSD and their risk factors in the working population conducted in the French PdL region. Moreover, sophisticated weighting adjustment methods for enhancing estimate accuracy were used to extrapolate the number of cases observed in the study sample to the whole working population.

1. Key findings

The first part of the current thesis (article 1) was the first prospective study in France to estimate the PAF of work-related exposures for the incidence of six main UEMSD in the working population. Based on a standardized clinical diagnosis of cases, the overall incidence proportion was of 11.2% and did not significantly differ between genders (10.1% for men vs 12.9% for women; p=0.122), although female workers were more affected than male workers. We found that the main occupational risk factor with a high impact on the incident of UEMSD was exposure to high perceived physical exertion (PAF: 30%), followed by exposure to low social support from supervisor and co-workers (PAF: 12%), and working with arms above shoulder level (PAF: 7%). The findings concerning biomechanical factors were consistent with previous studies carried out in Italy (OCTOPUS study) (Violante et al., 2016) and the Netherlands (van der Molen et al., 2019) which reported that 28% of CTS cases and 25% of LE cases respectively, could be attributable to high physical exertion. Furthermore, the study in the Netherlands reported that 15% of LE were attributable to posture, 10% and 9% of shoulder soft tissue disorders were attributable to force and posture, respectively (van der Molen et al., 2019). Several systematic reviews and meta-analyses also support our results (da Costa and Vieira, 2010; Descatha et al., 2016; Kozak et al., 2015; Kraatz et al., 2013; National Research Council and Institute of Medicine, 2001). Moreover, recent meta-analyses revealed with moderate evidence that arm-hand elevation (OR=1.9 [1.47–2.47]) and shoulder load (OR=2.0 [1.90–2.10]) were associated with the risk of shoulder disorders (van der Molen et al., 2017), and that working with the shoulder above 90 degrees was associated with an increased risk of rotator cuff tendinopathy (Leong et al., 2019). Regarding psychosocial risk factors, the meta-analysis by Hauke et al. (Hauke et al., 2011) found an effect of low social support at work on the onset of UEMSD (OR=1.18 [1.06–1.32]). The results of another meta-analysis showed that specific psychosocial risk factors such as low social support were relevant risk factors for the development of shoulder symptoms (Lang et al., 2012).

Besides these work-related risk factors, we also found that with respect to personal risk factors, female gender (PAF: 12%), age [age group 35–44 (PAF: 13%) and age group ≥45 (PAF: 20%)], and a high BMI (only for women) (PAF: 17%) had a significant impact on the incidence of UEMSD in the French working population in the PdL region. The OCTOPUS study (Violante et al., 2016) found that a BMI ≥25km/m^2, female gender and age >35 years contributed to 30%, 34%, and 54% of CTS, respectively. A recent meta-analysis provided strong evidence that age above 50 years (pooled OR=3.3) was associated with an increased risk of rotator cuff tendinopathy (Leong et al., 2019). Another recent meta-analysis revealed that female gender and older age were associated with LE (Sayampanathan et al., 2020).

Using the same data as for the first study, the main objective of the second part of the thesis was to estimate the proportion and number of UEMSD cases attributable to occupational risk factors (potentially preventable) in the working population at the level of the PdL region. Like the first study, this second part was the first cohort study to estimate the number of potential cases of UEMSD attributable to occupational risk factors in an entire working population. The results from this study highlight the magnitude of the impact of potentially modifiable and preventable occupational exposures on the incidence of UEMSD in the workplace. Specifically, of the projected estimate of 129 320 incident UEMSD cases in PdL in 2007, it is estimated that 26 381 (representing 20.4% of all new projected UEMSD cases), 16 682 (12.9%), and 8535 (6.6%) incident cases were due to high physical exertion, low social support from coworkers and supervisors, and working posture with shoulder abduction, respectively. Therefore, these estimated numbers of attributable cases could potentially be prevented by reducing occupational exposures to physical risk factors, working posture with shoulder abduction, and by improving social support from coworkers and supervisors if fully efficient interventions were implemented.

Concerning the potentially personal modifiable risk factors, our results suggest that an important number of projected incident UEMSD (10 586 cases) could be attributed to high BMI (15.3% of all projected new cases) in female workers.

The third study, based on the same data as the previous ones, (a) investigated the association between incident UEMSD and occupational co-exposure factors, and (b) estimated the proportion and number of UEMSD cases that were attributable to these risk factors under two models of prevention and therefore potentially avoidable by modifying workplace risk factors. Two (potential) multidimensional UEMSD prevention scenarios were analyzed using two statistical models, each including a combination of a biomechanical and psychosocial factor ("high physical exertion + low social support" in model 1, and "working posture with arms above shoulder level + low social support" in model 2).

Results of model 1 showed that 8664 new cases could potentially be prevented by improving social support only, representing 6.7% of all the projected estimate of 129 320 incident UEMSD cases in the PdL region in 2007, 19 010 new cases (14.7%) could potentially be prevented by reducing exposure to high physical exertion only, and 20 443 new cases (15.8%) could potentially be prevented by acting on both. With the model 2, 19 010 new cases (12.6%) could potentially be prevented by improving social support only, 6983 new cases (5.4%) could potentially be prevented by reducing exposure to working posture with arms above shoulder level only, and only 5043 new cases (3.9%) could potentially be prevented by acting on both factors. The lower number of potentially preventable cases when acting upon the two risk factors rather than just one was unexpected. Nevertheless, this could be explained by, on the one hand, the low proportion of workers exposed to the combination of the two risk factors (joint prevalence) and, on the other hand, the low number of UEMSD cases corresponding to the combination the two risk factors among these exposed workers. Indeed, these two key measures (prevalence and number of UEMSD cases) that are taken into account in the calculation of the PAF (Benichou, 2007; Spiegelman et al., 2007) are lower among workers exposed to the combined factors than among those exposed to only one of these risk factors.

In summary, this dissertation found that some occupational exposures to biomechanical (e.g. high physical exertion, awkward shoulder postures) and psychosocial (e.g. low social support) factors were independently associated with the incidence of UEMSD and lead to a large number of these disorders in the working population. When these single independent factors were combined, the risk of incident UEMSD and the number of attributable cases changed. Combined exposure to "high physical exertion + low social support" or "working with arms above shoulder level + low social support" increased the risk of developing of UEMSD and therefore its consequences. These findings indicate that in order to reduce the incidence of UEMSD, prevention programs must adopt a multi-dimensional approach: focus on reducing exposure to biomechanical factors (e.g. physical exertion or working with arms above shoulder level) as well as psychosocial factors (e.g. improving social support at work).

2. Strengths and limitations

The interpretation of the results of this PhD thesis must take into account the limitations of the analyses, particularly with respect to data availability, the estimation method used for PAFs as well as the calibration method used to compute the study sample weights in order to provide estimates of UEMSD incident cases at the PdL region level.

Some potential limitations related to the data used or the analyses performed in the current PhD thesis may have affected the results. The current thesis used data from the COSALI cohort, a prospective study based on two successive surveys of workers in only one French region, the PdL which contained 5.6% of the French working population in 2002. However, the socioeconomic structure of this region is diversified and close to that of France as a whole (Ha et al., 2009). Another limitation is the age of the data with inclusion between 2002 and 2005 and follow-up between 2007 and 2010. The structure of the working population has since changed. According to a report by the PdL Regional Economic and Social Observatory (ORES) (ORES Pays de la Loire, 2016), a decline in jobs was observed between 2008 and 2014 in some sectors at high-risk of UEMSD such as industry with 17 000 jobs lost (representing 6.4% of its workforce), construction with 8200 jobs lost (7.1%) and agriculture sectors with 1800 jobs lost (2.9%). At the same time, the tertiary sector (trade and services sectors) recorded an increase of 38 100 jobs. However, due to the economic growth in the region the number of jobs is increasing by an average of 5500 a year over the same period. In addition, a positive trend in the number of jobs has been observed since 2010 according to the PdL ORES (ORES Pays de la Loire, 2016) with a 2.6% increase in the working population over five years (between 2012- and 2017) and a 5.5% increase in the number of jobs (78 000 jobs) over the same period (ORES Pays de la Loire, 2020).

The physicians who volunteered to participate in the study were representative of the region's OPs in terms of medical practice, work time and geographic and economic sectors covered. More than 90% of the selected workers at inclusion participated in this study (<10%: no shows, refusals, duplications). Women were slightly underrepresented in the sample (42% vs. 47% in the region, P<0.001) (Roquelaure et al., 2006). Overall, the distribution of occupations in the final sample was close to that of the regional workforce and of France, except for the occupations not surveyed by OPs (e.g. farmers, shopkeepers, and self-employed workers) (Ha et al., 2009; Roquelaure et al., 2006). During the follow-up period (between 2007 and 2010), a total of 1611 clinical examinations were carried out, for an overall response rate of 43% and 65%, considering all workers initially included and only those whose OP was known at the time of follow up, respectively (Sérazin et al., 2014). This period coincided with a major economic crisis in the PdL region in 2008–2009, during which the regional salaried workforce declined by 3.4% (33.7% in temporary employment agencies) (Hautbois, 2010). Workers usually surveilled by a non-participant OP, people on parental or long-term sick leave, retired people, and those who had lost their jobs were excluded from the follow-up.

The population considered in the COSALI cohort was a population selected only from the working population. Indeed, OPs performed the clinical examination only for employees. This could be a source of "healthy worker effect" leading to a probable under-representation of subjects suffering from MSD (Pearce et al., 2007) and therefore a dilution of the effects of the expected associations, or even a loss of these associations. However, this effect may have been limited according to a study published by Roquelaure et al. (Y. Roquelaure et al., 2012) workers lost to follow-up suffered from UEMSD of the wrist/hand region more often than permanent workers but not in other anatomical regions of the upper extremities.

Concerning the clinical examination at follow-up, approximately 57% of workers included at baseline did not have a follow-up. However, within these non-followed participants, 58% were no longer being monitored by any OP of the network because they had left their baseline job without informing their OP. In some cases, their OP refused to participate in the follow-up period. Furthermore, the follow-up period coincided with the major economic crisis in the PdL region in 2008–2009, during which the regional salaried workforce declined by 3.4% (33.7% in temporary employment agencies) (Hautbois, 2010). The lowest participation rate in this study was among young workers, temporary workers or workers with a short length of service at baseline. According to a study on the effects of drop out in a longitudinal study of MSD (Bildt et al., 2001), the differences between participants and drop out individuals had a very modest influence on the RR for the effects of occupational exposures. We therefore believe that there was no major selection bias associated with the quality of follow-up. Furthermore, the comparison of baseline characteristics and working conditions of workers with follow-up and those without follow-up (see appendix 3A) showed that follow-up participants did not differ in terms of BMI and rheumatoid arthritis but were significantly older than those who did not participate in the follow-up. They were more likely to work in trade and services sectors, to be in temporary employment or have a higher seniority level in their current job. They were less likely to be exposed to working with arms above shoulder level, elbow movements (flexion/extension), and low social support at work, but no difference was observed in other working conditions under study. Moreover, in order to minimize the number of subjects lost to follow-up after major changes in the cohort (OP in charge of workers from other companies, change of work and of OP for a few workers), the investigators made a concerted effort to find each participant's new OP. This contributed to a high mobilization of the regional OPs (only 9 refused to participate among 157 new OPs contacted because they were now responsible for the medical surveillance of at least one individual); so the proportion of workers followed by an OP known by the investigators was relatively correct.

Another potential limitation was the lack of medical information between baseline and follow-up, so cases that may have occurred between the two clinical examinations and were negative at follow-up could not be considered as "incident cases" in our analyses. The single and short window of follow-up in this study after a long follow-up period is another potential limitation. Workers may have had a UEMSD in the period between the first and second clinical examination but recovered and not had a UEMSD at follow-up. This may have resulted in an underestimation of the number of cases diagnosed. In this study, there were many participants, but few events. This led to a lack of statistical power and thus to potential and/or known associations (e.g. association of UEMSD risk and high repetitiveness of tasks) that could not be detected (Bouyer et al., 2009b).

Another limitation is the exposure assessment, which was based only on workers self-reporting. In spite of that, the use of standardized and validated questions may have ensured better quality of the self-reported exposure measures. Non-differential misclassification of exposures may have occurred due to workers' inability to precisely recall or describe their current work exposures among workers without symptoms. Nevertheless, due to the prospective design of the study, exposure information gathered prior to UEMSD diagnosis resulted in low risk of differential recall bias. To the extent that the risk of UEMSD is increased by cumulative physical exposures, our analyses may have underestimated the true contribution of work exposures to the incidence of UEMSD in our study population.

Lack of measurement precision may also have occurred when quantifying exposures due to the 1 to 4 point ordinal scale used in exposure questions, except for physical exertion which was assessed using the RPE Borg Scale (Borg, 1982). To the extent that the risk of UEMSD is increased by cumulative or chronic physical exposures, our analyses may have underestimated the true contribution of work exposures to the incidence of UEMSD in our study population. This may be especially true for RCS, as studies of occupational risk factors for shoulder pain have consistently identified duration of employment as a risk factor (van der Windt et al., 2000).

A complete case analysis was conducted in this thesis, which could potentially induce a bias in our estimates. However, a previous doctoral thesis (Herquelot, 2015) using the same data as in the present thesis showed that analyses on the complete data gave similar results to analyses on the imputed data. We therefore believe that there was a very modest influence on our estimates. The computation of the combined PAF assumes independence and the absence of interaction between individual risk factors. However, there may be an interaction between certain occupational risk factors. In such cases, the calculation of the combined PAF may lead to its over- or underestimation. Nevertheless, none of the interactions between occupational exposures explored was statistically significant (Nambiema et al., 2020). In this situation, the joint impact of multiple exposures on the incidence of UEMSD estimated in this study would potentially not be multiplicative. According to Walter's demonstration (Walter, 1983), this situation would not be additive either. Therefore, the joint impact of multiple exposures estimated would be more than additive. In addition, the lack of statistical power in this study may have led to the non-detection of potential interactions between occupational risk factors (Bouyer et al., 2009b). It should also be noted that the choice of thresholds used to define exposure levels can have an effect on PAF estimates (B. Rockhill et al., 1998). However, to avoid bias, we chose exposure definitions as close as possible to public health recommendations and those recommended in the scientific literature. The concept of PAF assumes a causal relationship between exposure and UEMSD (Sluiter et al., 2001). Thus, we assume that a reduction in occupational exposure at the working population level would lead to a reduction in the incidence of UEMSD and PAF estimates should therefore be interpreted with caution. The accuracy of the PAF and the number of UEMSD cases attributable to investigated risk factors depends on the precision of the exposure data collected, the relative risk estimates, and the UEMSD incidence data studied. Furthermore, the PAF estimates did not take into account potential protective effects of uninvestigated factors such as regular breaks, physical activity in relation to the risk of UEMSD in the exposed population.

The proportion as well as the number of UEMSD cases attributable to the various occupational risk factors presented in this doctoral thesis, i.e. that would not have occurred if exposure to these modifiable risk factors would have been at an optimal or low level, depends on the variables included in the analyses, their definitions and the reference groups that were chosen. It would therefore be important, for a more objective interpretation of our results, to remember that a number of risk factors for UEMSD (Roquelaure, 2018) could not be included in the analyses due to the very low number of UEMSD cases or prevalence of exposure that could lead to a statistical non-association with UEMSD. This was particularly the case for occupational factors (e.g. vibration exposure, working in very cold temperatures) for which the prevalence of exposure or number of UEMSD cases was very low. The estimated number of potentially preventable UEMSD cases therefore does not take into account all the modifiable risk factors to which the working population in the French region of PdL is actually exposed. The estimates did also not take into account certain personal risk factors such as diabetes or rheumatoid arthritis.

All these limitations may in some cases lead to an over- or underestimation of the PAF. Therefore, the findings of this thesis work should be interpreted in light of the available data and the limitations of the methods used to estimate PAFs and the number of potentially preventable UEMSD cases. Finally, it is possible that the 95% CI of the PAF includes the null value, despite the significance of the RR due to the use of nonlinear transformations to compute the 95% CI of the PAF (Hertzmark et al., 2012). Even so, zero should be close to the 95% CI. Furthermore, it's important to note that the PAF associated with single risk factors cannot be added to obtain a combined PAF associated with a combination of risk factors and that a combined PAF cannot be subtracted from 100% to determine the "unexplained" proportion of cases (B Rockhill et al., 1998). It is also important to note that there is currently a lack of research intervention studies in the literature that have clearly demonstrated a reduction in exposure to biomechanical (Hoe et al., 2018; Kennedy et al., 2019; Rodrigues Ferreira Faisting and de Oliveira Sato, 2019; Van Eerd et al., 2016; van Niekerk et al., 2012), psychosocial (Stock et al., 2018; Van Eerd et al., 2016), or organizational (Hoe et al., 2018; Luger et al., 2019; Stock et al., 2018) risk factors with a strong level of evidence. This could be partly explained by the existence of gaps in the adequate conversion of scientific knowledge into intervention programs that can minimize exposure to ergonomic risk factors associated with a work situation, or to limitations that may exist in the scientific understanding of the effectiveness of some interventions.

This work has also several strengths. To the best of our knowledge today, no prospective study has estimated the proportion and number of incident cases of the six major UEMSD attributable occupational and personal risk factors at the population level.

The use of a prospective cohort including a representative sample of the working population at baseline is a major strength of the present study (Roquelaure et al., 2006). Furthermore, over 90% of workers randomly selected by the OPs accepted to participate. Secondly, outcomes were clinically assessed by trained OPs using standardized procedures (Roquelaure et al., 2006; Sluiter et al., 2001). In addition, this study strictly applied the definitions of exposures proposed by the European consensus criteria document (Sluiter et al., 2001), except for the measurement of exposure to forceful exertion which was assessed according to the rating of perceived exertion (Borg, 1982) and the INRS cut-offs (INRS, 2019). Due to the prospective design of the study, exposure information gathered prior to UEMSD diagnosis resulted in low risk of recall bias.

Another strength is the formula used to estimate the PAF from multivariable regression models, allowing a non-biased computation of PAF estimates adjusted for covariates (B Rockhill et al., 1998). This regression-based PAF estimation method enables to control for confounding and interaction, and can be used for the main epidemiologic designs (Benichou, 2007). Lastly, sophisticated weighting adjustment methods (Deville et al., 1993; Deville and Särndal, 1992; Sautory, 1993) for enhancing estimate accuracy were used to extrapolate the number of cases observed in the study sample to the whole working population. Furthermore, the "linear" calibration method used to calculate the new weights was the one that gave the lowest variance and range of weight ratios (new weights / initial weights). Indeed, it was chosen by considering the following criteria: lowest dispersion, smallest extent and general appearance of the distribution of the new weight distribution; the other calibration methods give calibrated estimators with the same asymptotic accuracy (Deville and Särndal, 1992).

Finally, estimating the number of incident cases of UEMSD in the working population of the PdL region is useful for comparing the population-level impacts of various risk factors on the incidence of UEMSD. Furthermore, these estimates provide additional input for the implementation of prevention programs that target and prioritize the modifiable risk factors with the greatest impact for more effective interventions to reduce the medical, economic and social impact of UEMSD in the working population.

Conclusions and recommendations

This section outlines the contributions of the current thesis to the fields of occupational and public health in general and UEMSD prevention in particular, provides recommendations for future research and conclusions that can be drawn from the research.

1. Contributions of the current thesis

This dissertation focused on analyzing data from a prospective cohort of the working population with the aim of providing new and relevant information for occupational hazard prevention and UEMSD burden reduction by improving knowledge of the topic and identifying the modifiable risk factors that have the greatest impact on these MSD. Sophisticated multivariate methods were used to estimate the fraction and number of incident UEMSD cases attributable to various occupational and personal risk factors, and hence the number of cases that would not have occurred if the exposure to a risk factor was reduced or eliminated in the workplace.

Findings from the present doctoral thesis, based on a prospective cohort study of MSD in the French working population of the PdL region, contribute to the literature on the burden of UEMSD risk factors and are of occupational and public health significance in assisting practitioners and policy makers to implement UEMSD prevention programs in the working population. These findings should help to better target and prioritize the modifiable risk factors that have the greatest impact on the onset of UEMSD for more effective interventions to reduce the medical, economic and social impact of these disorders.

More specifically, this thesis points to the importance of modifiable occupational exposures such as high physical exertion, awkward arm posture and low social support in the incidence of UEMSD in the workplace. Indeed, two incident cases of UEMSD out of five projected in 2007 in the working population of the PdL region, i.e. approximately 50 000 incident UEMSD, were attributable to these occupational exposures. Therefore, preventing UEMSD by reducing exposure to high physical exertion, awkward arm posture, and by improving the quality of working relationships where workers receive little support from supervisors or their coworkers, can be an effective intervention strategy for UEMSD prevention in the working population. Furthermore, the findings of this thesis work regarding the combined effect of biomechanical and psychosocial risk factors i.e. combined exposure to "high physical exertion + low social support" or "working with arms above shoulder level + low social support" increased the risk of developing UEMSD, provide valuable information on different prevention intervention strategies within a working population exposed jointly to biomechanical and psychosocial factors. Indeed, the effect of low social support as an additional exposure to high physical exertion increased the risk of UEMSD and led to many cases. Likewise, exposure to working with arms above shoulder level combined with low social support from co-workers and supervisors increased the risk of UEMSD. These findings show that for prevention interventions aimed at reducing the incidence of UEMSD in companies where workers are exposed to high physical exertion (or working with arms above shoulder level) combined with low social support, other exposures remaining constant, public health practitioners should give priority to the reduction of exposure to physical exertion (or working with arms above shoulder level) over improving low social support when they need to act on only one of these two factors. This is the model that would reduce the greatest number of incident cases. However, by acting jointly on both factors, an even higher number of cases could be prevented.

Besides occupational risk factors, the work presented here indicates that there are also potentially modifiable personal risk factors, especially overweight and obesity. These findings regarding personal factors are also clinically relevant, as obesity is a known strong risk factor for UEMSD, particularly CTS, and efforts should be made to promote healthy weights in the working population. Finally, since the diverse socio-economic structure of the PdL region is similar to that of France as a whole (Ha et al., 2009), the results of this work may also lead to similar UEMSD prevention strategies for the rest of the country.

Using a prospective cohort data and sophisticated statistical methods, this research work provides valuable new information to the limited epidemiological knowledge available on the proportion and number of incident UEMSD cases that could potentially be avoided by preventive actions that target and prioritize exposure to modifiable risk factors and, thus reduce the medical, economic and social impact of UEMSD. This work also highlights both public health and clinical significance for the prevention of UEMSD in the working population. Therefore, this work also contributes to the literature on the burden of UEMSD risk factors. More specifically, it increases knowledge on two relatively under-studied topics regarding UEMSD, namely the PAF and the number of potentially preventable cases. The main contributions are as follows:

- an increase in the body of epidemiological knowledge available on the proportion of UEMSD cases attributable to different risk factors;
- a quantification of the proportions and numbers of incident UEMSD cases that could potentially be prevented by modifying risk factors in the workplace;
- appropriate recommendations based on the findings and limitations of this work with suggestions for future research.

The findings could be useful to public health practitioners and policy makers in designing prevention programs to improve the reduction of exposures to occupational risk factors with a significant impact on the incidence of UEMSD among the working population of the PdL region and possibly throughout France. These stakeholders must continue to prioritize efforts in the primary prevention of UEMSD in order to reduce the incidence of UEMSD among the working population. However, primary prevention policies for UEMSD should not only concentrate on reducing occupational exposures that have a major impact on the occurrence of these MSD, but also on collective health promotion efforts.

In conclusion, this thesis made it possible to estimate the potential impact of UEMSD prevention interventions on the number of potentially preventable cases in a working population, and thus to quantify the expected benefits of the prevention measures that could be implemented. It provides evidence that to be effective, UEMSD prevention cannot be limited to reducing exposure to biomechanical risk factors but requires a comprehensive approach that also takes into account psychosocial risks. For example, for preventive actions targeting the upper extremities, it should be necessary to combine the prevention of static workload (e.g. shoulders) and repetitive work (e.g. elbow), while for the lower extremities actions could focus mainly on preventing the effects of static workload due to prolonged standing. More specifically, this thesis showed that an intervention that would combine both a reduction of exposure to high physical exertion (or working with arms above shoulder level) and improving social support at work would reduce the incidence of UEMSD, thereby preventing a large number of cases. However, some known occupational exposures or personal risk factors could not be included in our analyses either because the data were not available or because the prevalence of these exposures or the incidence of UEMSD was low for these exposures. In the latter case, the results of the risk models concluded that there was no association with these MSD. Therefore, further studies are needed to corroborate our findings.

2. Recommendations for future research

The main objective of this dissertation was to estimate and compare the potential effects of reducing work-related exposures to the main biomechanical and psychosocial risk factors on the incidence of UEMSD.

Several epidemiological studies conducted in working populations have shown that UEMSD are multifactorial and can be caused by organizational, psychosocial, biomechanical and personal factors, with these factors interacting with each other most of the time. Due to these multiple risk factors, it is becoming increasingly clear that prevention efforts to reduce the incidence of UEMSD must be based on a combined approach to be effective. Furthermore, research indicated that workplace interventions based on single actions appear unlikely to prevent UEMSD. Interventions addressing a single risk factor are likely to be less effective than a combination of interventions targeting multiple factors. Efforts to prevent UEMSD need to target different levels (micro: in the clinical setting, meso: in the workplace, and macro: at the national level) of the determinants chain. Changes in work situations based on interventions at the level of individual services and companies in primary prevention are still needed to reduce the biomechanical and psychosocial risk factors that exist prior to the onset of UEMSD, but they need to be complemented by more widespread efforts to improve working conditions and management practices at the level of regions, industries or economic sectors. This broad approach to UEMSD prevention is essential to guarantee long-term socio-economic success. Furthermore, clinical trials are needed to determine the effectiveness of interventions that may be implemented based on the results of this thesis.

Certain risk factors (e.g. vibration exposure, working in very cold temperatures) were not included in our analyses due to their low prevalence. Estimating fractions and numbers of preventable UEMSD in future studies with larger samples would be necessary to support our conclusions and provide additional evidence for more effective prevention strategies. Furthermore, it would also be interesting and very useful to conduct similar analyses, i.e. to estimate the proportion and number of cases related to exposure to occupational risk factors in high-risk occupations and economic sectors. This will provide additional information to better guide UEMSD prevention interventions in the workplace. Therefore, future research on the issue of UEMSD through longitudinal studies with larger samples is needed in order to obtain a solid scientific basis to confirm our results and to conduct similar analyses in different occupations and economic sectors as well as to investigate the "dose-response" relationships and interactions between the different factors. For example, data from the French "CONSTANCES" cohort (Zins et al., 2015, 2010), a large population-based longitudinal study, could be analyzed together with health data from the French National Health Data System (SNDS) matched for each participant. The CONSTANCES cohort used the same inclusion questions as the COSALI cohort for data collection on musculoskeletal symptoms and biomechanical factors. Research should also be warranted on methods to better identify workers with a high risk of occupational marginalization and to intervene at an earlier stage.

3. Conclusion

Findings from this dissertation are informative, relevant and useful, particularly for prioritizing and targeting future prevention efforts. This information could assist public health practitioners and policy makers in implementing UEMSD prevention programs, as well as help researchers planning to conduct prevention intervention research on these MSD in the working population. Nevertheless, they must be interpreted by taking into consideration the available data used, in particular the variables included in the analyses and the limitations of the statistical methods used. Finally, it should be noted that, despite the consideration of adjustment factors, the analyses may in some cases have led to an under- or over-estimation of the number of attributable cases. Despite the limitations, estimates from this work highlight that a large number of UEMSD could be avoided if the working population were optimally exposed to the modifiable risk factors studied that have a high impact on the incidence of UEMSD, such as physical exertion, awkward shoulder postures, and social support from coworkers and supervisors. Moreover, this thesis has shown that, to be effective, the prevention of UEMSD in the workplace should not be limited to reducing exposure to biomechanical risk factors but requires a comprehensive approach that also takes into account other occupational factors, in particular psychosocial factors.

TAKE HOME MESSAGE

1. This dissertation is the first study to estimate the proportion and number of incident UEMSD cases that could be potentially prevented by potential multidimensional preventive interventions;
2. Combined exposure to occupational a high physical exertion or an awkward shoulder posture with a low social support at work increased the risk of developing UEMSD;
3. A large number and important proportion of UEMSD cases (more than 50 000 cases; 41%) could be prevented in the working population;
4. Prevention programs must adopt a multi-dimensional approach including biomechanical ans psychosocial risk factors;
5. Not all cases of UEMSD can be prevented by multidimensional preventive interventions ➔ need for an integrated occupational health policy.

Résumé en français

1. Introduction

Les troubles musculo-squelettiques (TMS) sont regroupe un ensemble de lésions et de troubles des tissus mous qui affectent l'appareil locomoteur (c'est-à-dire les muscles, les tendons, les articulations, les nerfs, les cartilages). Ces affections se traduisent principalement par des douleurs et des gênes dans le travail et la vie quotidienne. Elles sont provoquées ou aggravées par une exposition répétée ou soutenue à des activités liées au travail, telles que les postures inconfortables pendant de longues périodes, les tâches répétitives, les efforts excessifs pour porter et soulever des objets lourds, les vibrations du corps et un manque de temps de récupération (Aublet-Cuvelier et al., 2015; da Costa and Vieira, 2010; Kozak et al., 2015; Roquelaure, 2015; Sluiter et al., 2001). L'Organisation internationale du travail (ILO, 2015) a estimé qu'environ 160 millions de cas de maladies non mortelles liées au travail se produisent chaque année dans le monde, parmi lesquels un nombre élevé de TMS. Selon des données récentes de l'Organisation mondiale de la santé sur la charge mondiale de morbidité, les TMS se classent parmi les cinq premières maladies au monde (4ème) en termes de charge de morbidité (Roser and Ritchie, 2020).

Dans la présente thèse de doctorat, l'accent est mis sur les TMS les plus fréquemment retrouvés sur le lieu du travail, c'est-à-dire les TMS affectant le membre supérieur (TMS-MS) (Sluiter et al., 2001). Ces troubles concernent les zones du corps suivantes : épaule/bras, coude/avant-bras et main/poignet.

Plusieurs études épidémiologiques menées à travers le monde ont fourni des estimations de prévalence et d'incidence des TMS-MS (da Costa et al., 2015; Dale et al., 2018; Descatha et al., 2016; Huisstede et al., 2006; Leclerc et al., 2004; Roquelaure et al., 2009b; Spahn et al., 2012; Thygesen et al., 2016; van der Molen et al., 2016). Ces estimations varient selon les pays, la conception de l'étude (transversale, de cohorte, revue systématique et méta-analyse) et la population concernée (générale/active). La revue systématique de Luime et al. (Luime et al., 2004) réalisée dans la population générale a retrouvé une prévalence comprise entre 4,7 % et 46,7 % et une incidence cumulée comprise entre 0,1 % et 2,5 %. En ce qui concerne la population active, une étude systématique menée par Huisstede et al. (Huisstede et al., 2006) a retrouvé une prévalence variant entre 9,3 et 26,9 % pour les TMS-MS diagnostiqué cliniquement et une prévalence variant entre 2,3 et 41,0 % pour les douleurs au cours des 12 derniers mois. La méta-analyse de Spahn et al. (Spahn et al., 2012) a révélé une prévalence comprise entre 8,2 % et 10,9 %, et un taux d'incidence compris entre 1,8 et 17,3 cas/1000 personnes-années.

Dans de nombreux pays, les TMS-MS représentent une proportion importante de l'ensemble des maladies professionnelles (enregistrées ou indemnisables, ou les deux) (Roquelaure, 2018). Selon le Bureau of Labor Statistics des États-Unis, en 2015, il y a eu 358 890 nouveaux cas de TMS-MS (taux d'incidence : 3,2 cas/1000 travailleurs à temps plein) pour des accidents du travail et des maladies professionnelles non mortels impliquant des jours d'arrêt de travail (Bureau of Labor Statistics, 2016). Dans l'ensemble du Québec, le taux d'incidence a été estimé à 15,4 cas/1000 travailleurs à temps plein en 2006, soit une diminution de 4,5 % par rapport à 2001 (Michel et al., 2010). En France, une étude de surveillance épidémiologique du TMS-MS d'origine professionnelle dans la région des Pays de la Loire (PdL) a révélé une prévalence d'environ 13 % (11 % chez les hommes et 15 % chez les femmes) des TMS-MS cliniquement diagnostiqués (Roquelaure et al., 2006). Selon les estimations de la cohorte française CONSTANCES (Carton et al., 2016), la prévalence des douleurs persistantes (≥30 jours au cours des 12 derniers mois) variait entre 11,6 % (au niveau du coude), 19,8 % (au niveau du poignet) et 20,7 % (au niveau de l'épaule) chez les femmes, 9,4 %, 12,0 % et 15,5 % chez les hommes (respectivement pour les mêmes localisations). En outre, selon le dernier Rapport annuel de l'Assurance Maladie en France, les TMS-MS représentaient 80 % (39 555 cas) de toutes les maladies professionnelles en 2018, soit une hausse d'environ 3 % par rapport à 2017 (Cnam. Direction des Risques Professionnels : Mission statistiques & Département tarification, 2019).

Aujourd'hui les TMS-MS constituent l'une des questions les plus préoccupantes en santé au travail et santé publique du fait d'un coût humain et socioprofessionnel considérable en termes de douleurs et gênes dans le travail et la vie quotidienne, de réduction d'aptitude au travail et de risque de rupture de carrière (Bevan, 2015; Roquelaure, 2015; Summers et al., 2015). Ces TMS représentent également l'un des problèmes professionnels les plus graves en raison de leur impact sur le fonctionnement et l'économique des entreprises (absentéisme, remplacement de salariés, coûts liés à la perte de production) (Bevan, 2015; de Kok et al., 2019; Lang et al., 2018; Roquelaure, 2015; Storheim and Zwart, 2014; Summers et al., 2015; Weinstein, 2016). Les TMS-MS touchent les travailleurs de tous les secteurs et de toutes les professions et constituent la principale cause de morbidité, d'incapacités liées au travail et d'absentéisme au travail dans de nombreux pays développés tels que les États-Unis, le Canada et les pays de l'Union européenne (UE) (Côté et al., 2013; de Kok et al., 2019; GBD 2017 Disease and Injury Incidence and Prevalence Collaborators, 2018; Roquelaure, 2018; Storheim and Zwart, 2014; Summers et al., 2015). Entre 1997 et 2005, 127 885 demandes d'indemnisation des travailleurs ont été acceptées pour les TMS-MS dans l'État de Washington, ce qui représentait 10,3 % de l'ensemble des demandes, avec 36,9 % des demandes indemnisables entraînant des coûts directs de 1,49 milliard de dollars (Silverstein and Adams, 2007). Selon le Bureau of Labor Statistics des Etats-Unis (Bureau of Labor Statistics, 2016), en 2015, un tiers des accidents et maladies professionnels avec arrêt de travail étaient dû aux TMS-MS. Entre 1998 et 2007 au Québec, les TMS-MS ont représenté en moyenne 27 % de l'ensemble des TMS indemnisés annuellement (Michel et al., 2010). En outre, ces TMS-MS étaient ceux qui étaient compensés pour des périodes plus longues avec une période de compensation moyenne de 81,1 jours (médiane de 20 jours). Une étude menée par Buckle et Devereux (Buckle and Devereux, 2002) a conclu que les TMS constituent un problème majeur dans l'UE en termes de santé et de coûts. En France, selon les données de l'Assurance Maladie, le montant des coûts facturés liés à l'ensemble des TMS (principalement des TMS-MS, soit 91 % de l'ensemble des TMS) a été estimé à 2 milliards d'euros liés aux TMS-MS pour les entreprises en 2018 (Cnam. Direction des Risques Professionnels, 2019).

En résumé, les TMS restent très répandus dans la population active avec un coût humain et socioprofessionnel considérable (douleurs et gênes dans le travail et la vie quotidienne) et coûtent cher aux entreprises (absentéisme, baisse de production). L'écrasante majorité des cas de ces TMS concerne par ailleurs le membre supérieur (Aptel et al., 2002; Aublet-Cuvelier et al., 2015; Michel et al., 2010).

2. Objectifs

L'impact modéré des plans de prévention mis en œuvre au cours des dernières décennies nécessite des études supplémentaires sur les stratégies de prévention au niveau de la population active. Afin de mieux concevoir les programmes de prévention, il est essentiel de connaître les facteurs de risque (FdR) modifiables qui ont le plus grand impact sur la population active salariée pour améliorer l'efficacité des interventions.

L'objectif principal de ce travail de thèse de doctorat était d'estimer et de comparer les effets potentiels de la réduction des expositions professionnelles aux principaux FdR biomécaniques et psychosociaux sur l'incidence des TMS-MS en utilisant les données de la cohorte française COSALI (COhorte des SAlariés LIgériens). Trois études correspondant à trois articles de recherche, ont été menées.

(a) la première étude a examiné les associations entre les FdR potentiels et l'incidence des TMS-MS, et a estimé la proportion de cas de TMS-MS pouvant être attribués à chacun de ces FdR par le calcul de fraction attribuable dans la population (FRAP) ;

(b) la deuxième étude a estimé la proportion et le nombre de cas de TMS-MS incidents qui pourraient être potentiellement évités dans la population active salariée de la région française des Pays de la Loire (PdL) ;

(c) la troisième étude a évalué l'effet combiné des FdR biomécaniques et psychosociaux sur l'incidence de TMS-MS, et a estimé la proportion et le nombre de cas de TMS-MS attribuables à ces FdR dans la population active salariée de la région des PdL.

3. Matériel et méthodes

Population d'étude

La cohorte COSALI est une étude prospective des TMS et de leurs FdR dans la population active basée sur deux enquêtes successives auprès des salariés de la région française des PdL (centre-ouest de la France, 3 305 000 habitants et 1 247 839 salariés en 2002) (Bodin et al., 2012a; Roquelaure et al., 2006). Cette région représentait 5,5 % de la population française et 5,6 % de la population active française en 2002, et sa structure socio-économique diversifiée était similaire à celle de la France dans son ensemble (Ha et al., 2009).

Entre 2002 et 2005, 83 médecins du travail (MT) (18 % des MT de la région) se sont portés volontaires pour participer à l'étude. A l'occasion de la visite médicale périodique des salariés, ces MT ont inclus aléatoirement 3 710 salariés (2 161 hommes, 1 549 femmes) correspondant à 2 % des 184 600 salariés sous la surveillance des 83 MT. Plus de 90 % des salariés sélectionnés ont participé à cette étude (<10 % : absences, refus, doubles emplois). Les femmes étaient légèrement sous-représentées dans l'échantillon (42 % contre 47 % dans la région, $p<0,001$). Dans l'ensemble, la répartition des professions dans l'échantillon était proche de celle de la main-d'œuvre régionale, sauf pour les professions non examinées par les MT (agriculteurs, commerçants et travailleurs indépendants). Les données sur les caractéristiques personnelles et les conditions de travail ont été recueillies au moyen d'un auto-questionnaire. Le MT procédait à un examen clinique standardisé des participants en appliquant strictement la démarche diagnostique des TMS-MS (méthodologie et tests cliniques) du groupe de consensus européen SALTSA (Sluiter et al., 2001). Chaque MT participant, chargé de la surveillance médicale des travailleurs salariés, a reçu des documents décrivant le protocole clinique (comprenant les tableaux des critères de diagnostic et les photographies des tests cliniques) et a suivi un programme de formation de 3 heures visant à standardiser les examens cliniques. Entre 2007 et 2010, les MT ont réexaminé 1 611 travailleurs en utilisant la même procédure qu'à l'inclusion [voir (Bodin et al., 2012a; Roquelaure et al., 2006) pour plus de détails sur la cohorte COSALI].

L'étude COSALI a reçu l'approbation du Comité consultatif sur le traitement de l'information dans le domaine de la recherche en santé (CCTIRS) et de la Commission nationale de l'informatique et des libertés (CNIL), d'abord en 2001, puis en 2006. Chaque salarié a donné son consentement éclairé par écrit avant de participer à l'étude.

Les cas incidents de TMS-MS ont été définis comme des salariés exempts des six principaux TMS-MS cliniquement diagnostiqués à l'inclusion et qui ont eu un diagnostic d'au moins un des six au suivi. Les six principaux TMS-MS étaient : 1-syndrome de la coiffe des rotateurs (SCR), 2-épicondylite latérale (EPI), 3-syndrome du tunnel cubital, 4-tendinite des extenseurs/fléchisseurs de la main et des doigts, 5-ténosynovite de De Quervain et 6-syndrome du canal carpien (SCC).

Analyse statistique

Pour les analyses dans le cadre de cette thèse, seuls les salariés ayant participé à l'examen clinique standardisé de suivi ont été pris en compte (1611 salariés sur les 3 710 présents à l'inclusion).

Les risques relatifs (RR) et leurs intervalles de confiance (CI) à 95 % ont été estimés à partir des modèles de régression multivariée de Cox avec une variance robuste et un temps de suivi constant pour chaque sujet (Dwivedi et al., 2014). Pour quantifier la proportion de cas de TMS-MS attribuables à chaque FdR, une FRAP a été estimée pour chaque FdR ou combinaison de FdR dans le modèle multivarié. Les estimations des FRAP et leur IC à 95 % de la FRAP ont été calculées en utilisant la méthode décrite par Spiegelman et al. (Spiegelman et al., 2007a). L'estimation de la FRAP prend en compte la prévalence de l'exposition et le RR du TMS-MS associé à cette exposition (Spiegelman et al., 2007a).

Pour estimer le nombre de cas de TMS-MS incidents attribuables aux FdR professionnels dans la région des PdL, le nombre total de TMS-MS (NT) dans la population active salariée dans la région a d'abord été estimé après redressement de l'échantillon (calcul de pondération) en utilisant les données du recensement de 2007 de la région des PdL. Ensuite, le nombre de TMS-MS attribuables aux FdR a été obtenu en multipliant la FRAP par le NT.

Toutes les analyses statistiques ont été réalisées à l'aide du logiciel SAS version 9.4.

4. Résultats principaux

Au cours du suivi, au moins un des six TMS-MS a été diagnostiqué chez 143 salariés (soit 11,2 % de l'échantillon d'étude ; 10,1 % des hommes vs 12,9 % des femmes ; p=0,122) sur les 1 275 suivis exempts de TMS-MS à l'inclusion (étude 1 : article 1). En ce qui concerne les études 2 et 3, il y a eu 139 cas de TMS-MS (11,2 % de l'échantillon d'étude), ce qui correspond à un nombre prévu de 129 320 nouveaux cas de TMS-MS projetés dans la population active salariée de la région des PdL en 2007. Les diagnostics de TMS-MS les plus fréquents au suivi étaient le SCR (6,5 %), l'EPI (2,2 %) et le SCC (2,0 %).

La première partie de la présente thèse a estimé la proportion de cas de TMS-MS incidents attribuables aux FdR personnels et professionnels. L'incidence cumulée globale était de 11,2 % et ne différait pas significativement entre les sexes (10,1 % pour les hommes contre 12,9 % pour les femmes ; p=0,122). Le principal FdR professionnel ayant un impact élevé sur l'incidence des TMS-MS était l'exposition aux efforts physiques perçus élevés (FRAP : 30 %), suivi d'un faible soutien social de la part des collègues et de la hiérarchie (FRAP : 12 %), et du travail avec les bras au-dessus des épaules (FRAP : 7 %).

Outre ces FdR liés au travail, les résultats ont montré aussi que les FdR personnels tels que le genre féminin (FRAP : 12 %), l'âge [groupe d'âge 35-44 ans (FRAP : 13 %) et groupe d'âge ≥45 (FRAP : 20 %)], et le surpoids/obésité (uniquement pour les femmes) (FRAP : 17 %) avaient un impact significatif sur l'incidence des TMS-MS dans la population active salariée.

Concernant la deuxième étude, les résultats ont mis en évidence l'ampleur des expositions professionnelles potentiellement modifiables et évitables dans l'apparition des TMS-MS. Plus précisément, sur l'estimation projetée de 129 320 cas de TMS-MS dans les PdL en 2007, on a estimé que 26 381 (représentant 20,4 % de tous les nouveaux cas de TMS-MS prévus), 16 682 (12,9 %) et 8 535 (6,6 %) cas incidents de TMS-MS étaient attribuables respectivement aux efforts physiques élevés, au faible soutien social de la part des collègues et de la hiérarchie, et aux postures de travail avec les bras au-dessus des épaules. Par conséquent, ces nombres estimés de cas attribuables pourraient potentiellement être évités en réduisant les expositions professionnelles aux efforts physiques élevés, au travail avec les bras au-dessus des épaules, et en améliorant le soutien social des collègues et de la hiérarchie si des interventions efficaces étaient mises en œuvre.

En ce qui concerne les FdR personnels potentiellement modifiables, les résultats suggèrent qu'un nombre important de TMS-MS incidents (10 586 cas) pourrait être attribué au surpoids/obésité (15,3 % de tous les nouveaux cas projetés) chez les femmes actives.

Dans la troisième étude, deux scénarios potentiels de prévention multidimensionnelle des TMS-MS ont été analysés à l'aide de deux modèles statistiques, comprenant chacun une combinaison d'un FdR biomécanique et d'un FdR psychosocial (« efforts physiques élevés + faible soutien social » dans le modèle 1, et « posture de travail avec les bras au-dessus des épaules + faible soutien social » dans le modèle 2). Les résultats du scénario 1 ont montré que 8 664 nouveaux cas pourraient potentiellement être évités en améliorant le soutien social uniquement, ce qui représente 6,7 % des 129 320 cas de TMS-MS projetées dans la population active salariée de la région des PdL en 2007, 19 010 nouveaux cas (14,7 %) en réduisant l'exposition aux efforts physiques élevés uniquement, et 20 443 nouveaux cas (15,8 %) en agissant sur les deux facteurs. Avec le scénario 2, 19 010 nouveaux cas (12,6 %) pourraient potentiellement être évités en améliorant le soutien social uniquement, 6983 nouveaux cas (5,4 %) en réduisant l'exposition à la posture de travail avec les bras au-dessus des épaules uniquement et 5 043 nouveaux cas (3,9 %) en agissant sur les deux facteurs. Le faible nombre de cas de TMS-MS, qui serait potentiellement évités (5 043 cas) en agissant sur les deux FdR plutôt que sur un seul, était inattendu. Néanmoins, cela pourrait s'expliquer, d'une part, par la faible proportion de salariés exposée aux deux FdR en même temps (prévalence conjointe) et, d'autre part, par le faible nombre de cas de TMS-MS correspondant à la combinaison des deux FdR chez ces salariés exposés. En effet, ces deux mesures clés (prévalence et nombre de cas de TMS-MS), qui sont prises en compte dans le calcul de la FRAP (Benichou, 2007; Spiegelman et al., 2007), sont plus faibles chez les salariés exposés aux facteurs combinés comparées aux salariés exposés à un seul de ces FdR.

5. Conclusions et perspectives

En résumé, cette thèse a montré que certaines expositions professionnelles à des FdR biomécaniques (par exemple, les efforts physiques élevés, les postures contraignantes de l'épaule) et psychosociaux (par exemple, le faible soutien social) étaient indépendamment associées à l'incidence des TMS-MS et entraîneraient un grand nombre de ces TMS dans la population active salariée. Lorsque ces facteurs indépendants étaient combinés, le risque d'apparition des TMS-MS augmentait ainsi le nombre de cas attribuables. Ainsi, l'exposition combinée aux « efforts physiques perçus élevés + faible soutien social au travail » ou aux « travail avec les bras au-dessus de l'épaule + faible soutien social au travail » augmentait le risque d'apparition des TMS-MS et donc ses conséquences. Ces résultats indiquent que la réduction des niveaux d'exposition aux différentes catégories de FdR professionnels biomécaniques (par exemple, les efforts physiques élevés) combinée à une amélioration des pratiques managériales (amélioration du soutien social au travail) permettrait de beaucoup plus réduire l'incidence des TMS-MS comparé à l'action sur un seul facteur (exemple : les efforts physiques perçus uniquement).

Cette thèse a permis d'estimer l'impact potentiel des interventions de prévention des TMS-MS sur le nombre de cas potentiellement évitables dans une population active salariée, et donc de quantifier les bénéfices attendus des mesures de prévention qui pourraient être mises en œuvre. Les résultats de cette thèse sont informatifs, pertinents et utiles, notamment pour prioriser et améliorer le ciblage des interventions sur les expositions professionnelles conduisant à un nombre de cas évitables de TMS-MS potentiellement élevé. Ils permettront entre autres d'enrichir la réflexion sur les politiques nationales et régionales de prévention des TMS-MS qui sont actuellement principalement basées sur des données de sinistralité. Ces résultats pourront aussi aider les chercheurs qui prévoient de mener des recherches sur les interventions de prévention de ces TMS-MS dans la population active salariée. Cependant, ces conclusions doivent être interprétées en tenant compte des données disponibles utilisées, notamment des variables incluses dans les analyses ainsi que des limites liées aux calculs de la FRAP. Malgré cela, les estimations issues de ces travaux soulignent qu'un grand nombre de TMS-MS pourrait être évité si la population active salariée était faiblement exposée aux FdR modifiables étudiés qui ont un impact élevé sur l'incidence des TMS-MS (efforts physiques élevés, travail avec les bras au-dessus des épaules et le faible soutien social). En outre, cette thèse a montré que, pour être efficace, la prévention des TMS-MS sur le lieu de travail ne doit pas se limiter à la réduction de l'exposition aux FdR biomécaniques, mais nécessite une approche multidimensionnelle qui prend également en compte d'autres FdR professionnels, en particulier les FdR psychosociaux.

Certains FdR de TMS-MS (par exemple, l'exposition aux vibrations, le travail à des températures très froides) n'ont pas pu être inclus dans les analyses en raison de leur faible prévalence. L'estimation des FRAP et du nombre de TMS-MS évitables dans de futures études portant sur des échantillons plus importants serait nécessaire pour appuyer nos conclusions et fournir des preuves supplémentaires en vue de stratégies de prévention plus efficaces. En outre, il serait également intéressant et très utile de mener des analyses similaires, c'est-à-dire d'estimer la proportion et le nombre de cas liés à l'exposition aux FdR professionnels dans les professions et les secteurs économiques à haut risque tels que l'industrie et la construction. Ces analyses permettront d'obtenir des informations supplémentaires pour mieux orienter les interventions de prévention des TMS-MS (sur le lieu de travail) dans ces secteurs d'activité. Par conséquent, les futures recherches sur la question des TMS-MS par le biais d'études longitudinales avec des échantillons plus importants sont nécessaires afin d'obtenir une base scientifique solide pour confirmer nos résultats. De plus, l'analyse de données d'enquêtes de grande taille permettront aussi le calcul des estimations de fractions et de nombres cas attribuables dans différentes professions et différents secteurs économiques, ainsi que l'étude des relations « dose-réponse » et interactions entre les différents facteurs. Par exemple, les données de la cohorte française CONSTANCES (Zins et al., 2015, 2010) pourraient être analysées avec les données de santé du Système National de Données de Santé (SNDS) appariées pour chaque participant.

References

Álvarez, P.C., Mercado, M.E., 2017. postweight or calibrate? Survey post-adjustments in Stata 16.

Anact, Inserm, INRS, Dares, CCMSA, 1996. Affections périarticulaires des membres supérieurs et organisation du travail. Résultats de l'enquête épidémiologique.

Andorsen, O.F., Ahmed, L.A., Emaus, N., Klouman, E., 2014. High prevalence of chronic musculoskeletal complaints among women in a Norwegian general population: the Tromsø study. BMC Res. Notes 7, 506. https://doi.org/10.1186/1756-0500-7-506

Aptel, M., Aublet-Cuvelier, A., Claude Cnockaert, J., 2002. Work-related musculoskeletal disorders of the upper limb. Joint Bone Spine 69, 546–555. https://doi.org/10.1016/S1297-319X(02)00450-5

Aptel, M., Vézina, N., 2008. Quels modèles pour comprendre et prévenir les TMS ? Pour une approche holistique et dynamique. Actes 2ème Congrès Francoph. Sur TMS 27.

Armstrong, T.J., Buckle, P., Fine, L.J., Hagberg, M., Jonsson, B., Kilbom, A., Kuorinka, I.A., Silverstein, B.A., Sjogaard, G., Viikari-Juntura, E.R., 1993. A conceptual model for work-related neck and upper-limb musculoskeletal disorders. Scand. J. Work. Environ. Health 19, 73–84. https://doi.org/10.5271/sjweh.1494

Aublet-Cuvelier, A., Claudon, L., Gautier, M.-A., Kerlo-Brusset, M., 2018. Pratique d'exercices physiques au travail et prévention des TMS : que dit la littérature ? Arch. Mal. Prof. Environ. 79, 344–345. https://doi.org/10.1016/j.admp.2018.03.303

Aublet-Cuvelier, A., Gaudez, C., Cail, F., 2015. Troubles musculosquelettiques des membres supérieurs d'origine professionnelle. Wwwem-Premiumcomdatatraitesin16-63068 11.

Aude, J., 2010. Calage sur marges de la base des cliniques privées pour améliorer l'estimation de la situation économique. Direction de la recherche, des études, de l'évaluation et des statistiques DREES, Paris.

Azimi, S.S., Khalili, D., Hadaegh, F., Yavari, P., Mehrabi, Y., Azizi, F., 2014. Calculating Population Attributable Fraction for Cardiovascular Risk Factors Using Different Methods in a Population Based Cohort Study. J. Res. Health Sci. 15, 22–27.

Balogh, I., Arvidsson, I., Björk, J., Hansson, G.-Å., Ohlsson, K., Skerfving, S., Nordander, C., 2019. Work-related neck and upper limb disorders – quantitative exposure–response relationships adjusted for personal characteristics and psychosocial conditions. BMC Musculoskelet. Disord. 20, 139. https://doi.org/10.1186/s12891-019-2491-6

Bao, S.S., Kapellusch, J.M., Merryweather, A.S., Thiese, M.S., Garg, A., Hegmann, K.T., Silverstein, B.A., Marcum, J.L., Tang, R., 2016. Impact of Work Organizational Factors on Carpal Tunnel Syndrome and Epicondylitis. J. Occup. Environ. Med. 58, 760–764. https://doi.org/10.1097/JOM.0000000000000790

Barros, A.J., Hirakata, V.N., 2003. Alternatives for logistic regression in cross-sectional studies: an empirical comparison of models that directly estimate the prevalence ratio. BMC Med. Res. Methodol. 3, 21. https://doi.org/10.1186/1471-2288-3-21

Becker, J., Nora, D.B., Gomes, I., Stringari, F.F., Seitensus, R., Panosso, J.S., Ehlers, J.A.C., 2002. An evaluation of gender, obesity, age and diabetes mellitus as risk factors for carpal tunnel syndrome. Clin. Neurophysiol. 113, 1429–1434. https://doi.org/10.1016/S1388-2457(02)00201-8

Bellemare, M., Marier, M., Montreuil, S., Allard, D., Prévost, J., 2002. La transformation des situations de travail par une approche participative en ergonomie : une recherche intervention pour la prévention des troubles musculo-squelettiques 124.

Benichou, J., 2007. Biostatistics and epidemiology: measuring the risk attributable to an environmental or genetic factor. C. R. Biol. 330, 281–298. https://doi.org/10.1016/j.crvi.2007.02.015

Benichou, J., 2001. A review of adjusted estimators of attributable risk. Stat. Methods Med. Res. 10, 195–216. https://doi.org/10.1177/096228020101000303

Benichou, J., 2000. Attributable risk, in: M.H. Gail, Encyclopedia of Epidemiologic Methods. Wiley, Chichester, UK, pp. 50–63.

Benichou, J., 1991. Methods of adjustment for estimating the attributable risk in case-control studies: A review. Stat. Med. 10, 1753–1773. https://doi.org/10.1002/sim.4780101113

Bernal, D., Campos-Serna, J., Tobias, A., Vargas-Prada, S., Benavides, F.G., Serra, C., 2015. Work-related psychosocial risk factors and musculoskeletal disorders in hospital nurses and nursing aides: A systematic review and meta-analysis. Int. J. Nurs. Stud. 52, 635–648. https://doi.org/10.1016/j.ijnurstu.2014.11.003

Bethlehem, J.G., 2009. Weighting Adjustment, in: Applied Survey Methods: A Statistical Perspective, Wiley Series in Survey Methodology. Wiley, Hoboken, N.J, pp. 249–275.

Bevan, S., 2015. Economic impact of musculoskeletal disorders (MSDs) on work in Europe. Best Pract. Res. Clin. Rheumatol., Occupation and Musculoskeletal Disorders 29, 356–373. https://doi.org/10.1016/j.berh.2015.08.002
Bhattacharya, A., 2014. Costs of occupational musculoskeletal disorders (MSDs) in the United States. Int. J. Ind. Ergon. 44, 448–454. https://doi.org/10.1016/j.ergon.2014.01.008
Bildt, C., Alfredsson, L., Punnett, L., Theobald, H., Torgén, M., Wikman, A., 2001. Effects of Drop out in a Longitudinal Study of Musculoskeletal Disorders. Occup. Environ. Med. 58, 194–199.
Bodin, J., 2017. Déterminants professionnels des troubles musculo-squelettiques de l'épaule : intérêt de la prise en compte des facteurs organisationnels (phdthesis). Université d'Angers, Angers.
Bodin, J., Garlantézec, R., Costet, N., Descatha, A., Fouquet, N., Caroly, S., Roquelaure, Y., 2017. Forms of work organization and associations with shoulder disorders: Results from a French working population. Appl. Ergon. 59, 1–10. https://doi.org/10.1016/j.apergo.2016.07.019
Bodin, J., Garlantézec, R., Costet, N., Descatha, A., Viel, J.-F., Roquelaure, Y., 2020. Shoulder pain among male industrial workers: Validation of a conceptual model in two independent French working populations. Appl. Ergon. 85, 103075. https://doi.org/10.1016/j.apergo.2020.103075
Bodin, J., Garlantézec, R., Costet, N., Descatha, A., Viel, J.-F., Roquelaure, Y., 2018. Risk Factors for Shoulder Pain in a Cohort of French Workers: A Structural Equation Model. Am. J. Epidemiol. 187, 206–213. https://doi.org/10.1093/aje/kwx218
Bodin, J., Ha, C., Petit Le Manac'h, A., Sérazin, C., Descatha, A., Leclerc, A., Goldberg, M., Roquelaure, Y., 2012a. Risk factors for incidence of rotator cuff syndrome in a large working population. Scand. J. Work. Environ. Health 38, 436–446. https://doi.org/10.5271/sjweh.3285
Bodin, J., Ha, C., Sérazin, C., Descatha, A., Leclerc, A., Goldberg, M., Roquelaure, Y., 2012b. Effects of individual and work-related factors on incidence of shoulder pain in a large working population. J. Occup. Health 54, 278–288.
Bongers, P.M., Ijmker, S., van den Heuvel, S., Blatter, B.M., 2006. Epidemiology of work related neck and upper limb problems: psychosocial and personal risk factors (part I) and effective interventions from a bio behavioural perspective (part II). J. Occup. Rehabil. 16, 279–302. https://doi.org/10.1007/s10926-006-9044-1
Bongers, P.M., Kremer, A.M., Laak, J. ter, 2002. Are psychosocial factors, risk factors for symptoms and signs of the shoulder, elbow, or hand/wrist?: A review of the epidemiological literature. Am. J. Ind. Med. 41, 315–342. https://doi.org/10.1002/ajim.10050
Boocock, M.G., McNair, P.J., Larmer, P.J., Armstrong, B., Collier, J., Simmonds, M., Garrett, N., 2007. Interventions for the prevention and management of neck/upper extremity musculoskeletal conditions: a systematic review. Occup. Environ. Med. 64, 291–303. https://doi.org/10.1136/oem.2005.025593
Borg, G.A.V., 1982. Psychophysical bases of perceived exertion. Med. Sci. Sports Exerc. 14, 377–381. https://doi.org/10.1249/00005768-198205000-00012
Bouyer, J., Hémon, D., Cordier, S., Derriennic, F., Stücker, I., Stengel, B., Clavel, J., 2009a. Analyse multivariée - Principes généraux, in: Epidémiologie: principes et méthodes quantitatives. Editions INSERM, Paris, pp. 240–265.
Bouyer, J., Hémon, D., Cordier, S., Derriennic, F., Stücker, I., Stengel, B., Clavel, J., 2009b. Epidémiologie: principes et méthodes quantitatives, Lavoisier. ed. Editions INSERM, Paris.
Brenner, D.R., Friedenreich, C.M., Ruan, Y., Poirier, A.E., Walter, S.D., King, W.D., Franco, E.L., Demers, P.A., Villeneuve, P.J., Grevers, X., Nuttall, R., Smith, L.M., Volesky, K.D., O'Sullivan, D.E., De, P., 2019. The burden of cancer attributable to modifiable risk factors in Canada: Methods overview. Prev. Med., Burden of Cancer in Canada 122, 3–8. https://doi.org/10.1016/j.ypmed.2019.03.007
Brooks-Pollock, E., Danon, L., 2017. Defining the population attributable fraction for infectious diseases. Int. J. Epidemiol. 46, 976–982. https://doi.org/10.1093/ije/dyx055
Bruzzi, P., Green, S.B., Byar, D.P., Brinton, L.A., Schairer, C., 1985. Estimating the population attributable risk for multiple risk factors using case-control data. Am. J. Epidemiol. 122, 904–914.
Buckle, P.W., Devereux, J.J., 2002. The nature of work-related neck and upper limb musculoskeletal disorders. Appl. Ergon. 33, 207–217.
Bureau of Labor Statistics, 2016. Nonfatal occupational injuries and illnesses requiring days away from work, 2015 28.
Cail, F., Aptel, M., 2006. Facteurs de risque pour le membre supérieur dans le travail sur écran : synthèse bibliographique. Trav. Hum. Vol. 69, 229–268.

Carayon, P., Smith, M.J., Haims, M.C., 1999. Work Organization, Job Stress, and Work-Related Musculoskeletal Disorders. Hum. Factors J. Hum. Factors Ergon. Soc. 41, 644–663. https://doi.org/10.1518/001872099779656743
Carton, M., Santin, G., Leclerc, A., Gueguen, A., Goldberg, M., Roquelaure, Y., Zins, M., Descatha, A., 2016. Prévalence des troubles musculo-squelettiques et des facteurs biomécaniques d'origine professionnelle : premières estimations à partir de Constances. Bull Epidémiol Hebd 10.
Cassou, B., Derriennic, F., Monfort, C., Norton, J., Touranchet, A., 2002. Chronic neck and shoulder pain, age, and working conditions: longitudinal results from a large random sample in France. Occup. Environ. Med. 59, 537–544.
Cazares-Manríquez, M.A., Wilson, C.C., Vardasca, R., García-Alcaraz, J.L., Olguín-Tiznado, J.E., López-Barreras, J.A., García-Rivera, B.R., 2020. A Review of Carpal Tunnel Syndrome and Its Association with Age, Body Mass Index, Cardiovascular Risk Factors, Hand Dominance, and Sex. Appl. Sci. 10, 3488. https://doi.org/10.3390/app10103488
Chen, L., 2014. 'paf': Attributable Fraction Function for Censored Survival Data, R package version 1.0.
Cnam. Direction des Risques Professionnels, 2019. L'Essentiel 2018 - Santé et sécurité au travail.
Cnam. Direction des Risques Professionnels : Mission statistiques & Département tarification, 2019. Rapport annuel 2018 : L'Assurance Maladie – Risques professionnels. Paris.
Cole, D., Rivilis, I., Van Eerd, D., Cullen, K., Irvin, E., Kramer, D., 2005. Effectiveness of participatory ergonomic interventions: a systematic review, in: Database of Abstracts of Reviews of Effects (DARE): Quality-Assessed Reviews [Internet]. Centre for Reviews and Dissemination (UK).
Cole, P., MacMahon, B., 1971. Attributable risk percent in case-control studies. Br. J. Prev. Soc. Med. 25, 242–244. https://doi.org/10.1136/jech.25.4.242
Côté, J.N., Ngomo, S., Stock, S., Messing, K., Vézina, N., Antle, D., Delisle, A., Bellemare, M., Laberge, M., St-Vincent, M., 2013. Quebec Research on Work-related Musculoskeletal Disorders: Deeper Understanding for Better Prevention. Relat. Ind. 68, 643–660. https://doi.org/10.7202/1023009ar
Cox, C., 2006. Model-based estimation of the attributable risk in case-control and cohort studies. Stat. Methods Med. Res. 15, 611–625. https://doi.org/10.1177/0962280206071930
Cox, C., Li, X., 2012. Model-Based Estimation of the Attributable Risk: A Loglinear Approach. Comput. Stat. Data Anal. 56, 4180–4189. https://doi.org/10.1016/j.csda.2012.04.017
Crowson, C.S., Therneau, T.M., O'fallon, W.M., 2009. Attributable Risk Estimation in Cohort Studies.
da Costa, B.R., Vieira, E.R., 2010. Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. Am. J. Ind. Med. 53, 285–323.
da Costa, J.T., Baptista, J.S., Vaz, M., 2015. Incidence and prevalence of upper-limb work related musculoskeletal disorders: A systematic review. Work 51, 635–644. https://doi.org/10.3233/WOR-152032
Dahlqwist, E., Sjölander, A., 2017. 'AF': Model-Based Estimation of Confounder-Adjusted Attributable Fractions, R package version 0.1.4.
Dahlqwist, E., Zetterqvist, J., Pawitan, Y., Sjölander, A., 2016. Model-based estimation of the attributable fraction for cross-sectional, case–control and cohort studies using the R package AF. Eur. J. Epidemiol. 31, 575–582. https://doi.org/10.1007/s10654-016-0137-7
Dalbøge, A., Frost, P., Andersen, J.H., Svendsen, S.W., 2014. Cumulative occupational shoulder exposures and surgery for subacromial impingement syndrome: a nationwide Danish cohort study. Occup. Environ. Med. 71, 750–756. https://doi.org/10.1136/oemed-2014-102161
Dale, A.M., Ekenga, C.C., Buckner-Petty, S., Merlino, L., Thiese, M.S., Bao, S., Meyers, A.R., Harris-Adamson, C., Kapellusch, J., Eisen, E.A., Gerr, F., Hegmann, K.T., Silverstein, B., Garg, A., Rempel, D., Zeringue, A., Evanoff, B.A., 2018. Incident CTS in a large pooled cohort study: associations obtained by a Job Exposure Matrix versus associations obtained from observed exposures. Occup. Environ. Med. 75, 501–506. https://doi.org/10.1136/oemed-2017-104744
Dale, A.M., Harris-Adamson, C., Rempel, D., Gerr, F., Hegmann, K., Silverstein, B., Burt, S., Garg, A., Kapellusch, J., Merlino, L., Thiese, M.S., Eisen, E.A., Evanoff, B., 2013. Prevalence and incidence of carpal tunnel syndrome in US working populations: pooled analysis of six prospective studies. Scand. J. Work. Environ. Health 39, 495–505. https://doi.org/10.5271/sjweh.3351
Dares, 2003. Surveillance médicale des expositions aux risques professionnels (Sumer) : édition 2003. Ministère du Travail, Paris.
Dartois, L., Fagherazzi, G., Baglietto, L., Boutron-Ruault, M.-C., Delaloge, S., Mesrine, S., Clavel-Chapelon, F., 2016. Proportion of premenopausal and postmenopausal breast cancers attributable to known risk factors: Estimates from the E3N-EPIC cohort. Int. J. Cancer 138, 2415–2427. https://doi.org/10.1002/ijc.29987

Davies, G., 2018. Examination of approaches to calibration in survey sampling (Ph.D.). Cardiff University.
de Kok, J., Vroonhof, P., Snijders, J., Roullis, G., Clarke, M., Peereboom, K., van Dorst, P., Isusi, I., 2019. Work-related musculoskeletal disorders: prevalence, costs and demographics in the EU. Safety and health at work - EU-OSHA.
Deming, W.E., Stephan, F.F., 1940. On a Least Squares Adjustment of a Sampled Frequency Table When the Expected Marginal Totals are Known. Ann. Math. Stat. 11, 427–444. https://doi.org/10.1214/aoms/1177731829
Descatha, A., Albo, F., Leclerc, A., Carton, M., Godeau, D., Roquelaure, Y., Petit, A., Aublet-Cuvelier, A., 2016. Lateral Epicondylitis and Physical Exposure at Work? A Review of Prospective Studies and Meta-Analysis: Work Exposure and Lateral Epicondylitis. Arthritis Care Res. 68, 1681–1687. https://doi.org/10.1002/acr.22874
Descatha, A., Dale, A.M., Jaegers, L., Herquelot, E., Evanoff, B., 2013. Self-reported physical exposure association with medial and lateral epicondylitis incidence in a large longitudinal study. Occup. Environ. Med. 70, 670–673. https://doi.org/10.1136/oemed-2012-101341
Descatha, A., Dale, A.M., Silverstein, B.A., Roquelaure, Y., Rempel, D., 2015. Lateral epicondylitis: New evidence for work relatedness. Joint Bone Spine 82, 5–7. https://doi.org/10.1016/j.jbspin.2014.10.013
Deville, J.-C., Särndal, C.-E., 1992. Calibration Estimators in Survey Sampling. J. Am. Stat. Assoc. 87, 376–382. https://doi.org/10.1080/01621459.1992.10475217
Deville, J.-C., Särndal, C.-E., Sautory, O., 1993. Generalized Raking Procedures in Survey Sampling. J. Am. Stat. Assoc. 88, 1013–1020. https://doi.org/10.1080/01621459.1993.10476369
Di Maso, M., Bravi, F., Polesel, J., Negri, E., Decarli, A., Serraino, D., La Vecchia, C., Ferraroni, M., 2020. Attributable fraction for multiple risk factors: Methods, interpretations, and examples. Stat. Methods Med. Res. 29, 854–865. https://doi.org/10.1177/0962280219848471
D'Souza, J., 2011. CALIBRATE: Stata module to calibrate survey datasets to population totals, Statistical Software Components. Boston College Department of Economics.
D'Souza, J., 2010. A Stata program for calibration weighting (No. 02), United Kingdom Stata Users' Group Meetings 2010, United Kingdom Stata Users' Group Meetings 2010. Stata Users Group.
Dwivedi, A.K., Mallawaarachchi, I., Lee, S., Tarwater, P., 2014. Methods for estimating relative risk in studies of common binary outcomes. J. Appl. Stat. 41, 484–500. https://doi.org/10.1080/02664763.2013.840772
Eide, G.E., 2008. Attributable fractions for partitioning risk and evaluating disease prevention: a practical guide: A practical guide to attributable fractions. Clin. Respir. J. 2, 92–103. https://doi.org/10.1111/j.1752-699X.2008.00091.x
Engmann, N.J., Golmakani, M.K., Miglioretti, D.L., Sprague, B.L., Kerlikowske, K., for the Breast Cancer Surveillance Consortium, 2017. Population-Attributable Risk Proportion of Clinical Risk Factors for Breast Cancer. JAMA Oncol. 3, 1228. https://doi.org/10.1001/jamaoncol.2016.6326
Estevao, V., Hidiroglou, M.A., Särndal, C.-E., 1995. Methodological principles for a generalized estimation system at Statistics Canada. J. Off. Stat.-Stockh.- 11, 181–181.
Etuknwa, A.B., Humpheries, S., 2018. A Systematic Review on the Effectiveness of Ergonomic Training Intervention in Reducing the Risk of Musculoskeletal Disorder. J. Nurs. Health Stud. 3. https://doi.org/10.21767/2574-2825.1000032
Fan, Z.J., Harris-Adamson, C., Gerr, F., Eisen, E.A., Hegmann, K.T., Bao, S., Silverstein, B., Evanoff, B., Dale, A.M., Thiese, M.S., Garg, A., Kapellusch, J., Burt, S., Merlino, L., Rempel, D., 2015. Associations between workplace factors and carpal tunnel syndrome: A multi-site cross sectional study: Workplace Factors and Prevalence of Carpal Tunnel Syndrome. Am. J. Ind. Med. 58, 509–518. https://doi.org/10.1002/ajim.22443
Fan, Z.J., Silverstein, B.A., Bao, S., Bonauto, D.K., Howard, N.L., Smith, C.K., 2014. The association between combination of hand force and forearm posture and incidence of lateral epicondylitis in a working population. Hum. Factors 56, 151–165. https://doi.org/10.1177/0018720813492327
Flegal, K.M., Panagiotou, O.A., Graubard, B.I., 2015. Estimating population attributable fractions to quantify the health burden of obesity. Ann. Epidemiol. 25, 201–207. https://doi.org/10.1016/j.annepidem.2014.11.010
Franceschi, F., Papalia, R., Paciotti, M., Franceschetti, E., Di Martino, A., Maffulli, N., Denaro, V., 2014. Obesity as a Risk Factor for Tendinopathy: A Systematic Review. Int. J. Endocrinol. 2014, 1–10. https://doi.org/10.1155/2014/670262
Gassama, M., Bénichou, J., Dartois, L., Thiébaut, A.C.M., 2017. Comparison of methods for estimating the attributable risk in the context of survival analysis. BMC Med. Res. Methodol. 17, 10. https://doi.org/10.1186/s12874-016-0285-1

GBD 2017 Disease and Injury Incidence and Prevalence Collaborators, 2018. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet Lond. Engl. 392, 1789–1858. https://doi.org/10.1016/S0140-6736(18)32279-7
Gilg Soit Ilg, A., Fouquet, N., 2017. Fraction attribuable et risques professionnels.
Greenland, S., Robins, J.M., 1988. Conceptual problems in the definition and interpretation of attributable fractions. Am. J. Epidemiol. 128, 1185–1197. https://doi.org/10.1093/oxfordjournals.aje.a115073
Ha, C., Roquelaure, Y., Leclerc, A., Touranchet, A., Goldberg, M., Imbernon, E., 2009. The French Musculoskeletal Disorders Surveillance Program: Pays de la Loire network. Occup. Environ. Med. 66, 471–479. https://doi.org/10.1136/oem.2008.042812
Hagberg, M., Morgenstern, H., Kelsh, M., 1992. Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome. Scand. J. Work. Environ. Health 337–345.
Hagberg, M., Silverstein, B., Wells, R., Smith, M.J., Hendrick, H.W., Carayon, P., Pérusse, M., 1995. Les Lésions attribuables au travail répétitif ouvrage de référence sur les lésions musculo-squelettiques liées au travail. MultiMondes, Sainte-Foy, Québec.
Halpern, M., Hiebert, R., Nordin, M., Goldsheyder, D., Crane, M., 2001. The test–retest reliability of a new occupational risk factor questionnaire for outcome studies of low back pain. Appl. Ergon. 32, 39–46. https://doi.org/10.1016/S0003-6870(00)00045-4
Hamel, J.-F., Fouquet, N., Ha, C., Goldberg, M., Roquelaure, Y., 2012. Software for Unbiased Estimation of Attributable Risk. Epidemiology 23, 646–647. https://doi.org/10.1097/EDE.0b013e318259c31c
Harris-Adamson, C., Eisen, E.A., Dale, A.M., Evanoff, B., Hegmann, K.T., Thiese, M.S., Kapellusch, J.M., Garg, A., Burt, S., Bao, S., Silverstein, B., Gerr, F., Merlino, L., Rempel, D., 2013. Personal and workplace psychosocial risk factors for carpal tunnel syndrome: a pooled study cohort. Occup. Environ. Med. 70, 529–537. https://doi.org/10.1136/oemed-2013-101365
Harris-Adamson, C., Eisen, E.A., Kapellusch, J., Garg, A., Hegmann, K.T., Thiese, M.S., Dale, A.M., Evanoff, B., Burt, S., Bao, S., Silverstein, B., Merlino, L., Gerr, F., Rempel, D., 2015. Biomechanical risk factors for carpal tunnel syndrome: a pooled study of 2474 workers. Occup. Environ. Med. 72, 33–41. https://doi.org/10.1136/oemed-2014-102378
Harris-Adamson, C., Eisen, E.A., Neophytou, A., Kapellusch, J., Garg, A., Hegmann, K.T., Thiese, M.S., Dale, A.M., Evanoff, B., Bao, S., Silverstein, B., Gerr, F., Burt, S., Rempel, D., 2016. Biomechanical and psychosocial exposures are independent risk factors for carpal tunnel syndrome: assessment of confounding using causal diagrams. Occup. Environ. Med. 73, 727–734. https://doi.org/10.1136/oemed-2016-103634
Hauke, A., Flintrop, J., Brun, E., Rugulies, R., 2011. The impact of work-related psychosocial stressors on the onset of musculoskeletal disorders in specific body regions: A review and meta-analysis of 54 longitudinal studies. Work Stress 25, 243–256. https://doi.org/10.1080/02678373.2011.614069
Hautbois, L., 2010. Crise en Pays de la Loire : industrie et interim dans la tourmente (Etude No. 88). Insee Pays de la Loire, Nantes.
Heeringa, S.G., Berglund, P.A., West, B.T., Mellipilán, E.R., Portier, K., 2014. Attributable fraction estimation from complex sample survey data. Ann. Epidemiol., Causes of Cancer 25, 174–178. https://doi.org/10.1016/j.annepidem.2014.11.007
Heilskov-Hansen, T., Mikkelsen, S., Svendsen, S.W., Thygesen, L.C., Hansson, G.-Å., Thomsen, J.F., 2016. Exposure–response relationships between movements and postures of the wrist and carpal tunnel syndrome among male and female house painters: a retrospective cohort study. Occup. Environ. Med. 73, 401–408. https://doi.org/10.1136/oemed-2015-103298
Herquelot, E., 2015. Facteurs de risque professionnels des troubles musculo- squelettiques aux coudes et aux genoux. Université de Versailles-Saint Quentin en Yvelines.
Hertzmark, E., Wand, H., Spiegelman, D., 2012. The SAS PAR Macro. Harv. Sch. Public Health Boston.
Hill, A.B., 2015. The environment and disease: association or causation? J. R. Soc. Med. 108, 32–37. https://doi.org/10.1177/0141076814562718
Hill, A.B., 1965. The Environment and Disease: Association or Causation? Proc. R. Soc. Med. 58, 295–300.
Hoe, V.C., Urquhart, D.M., Kelsall, H.L., Sim, M.R., 2012. Ergonomic design and training for preventing work-related musculoskeletal disorders of the upper limb and neck in adults, in: Cochrane Database of Systematic Reviews. John Wiley & Sons, Ltd. https://doi.org/10.1002/14651858.CD008570.pub2
Hoe, V.C., Urquhart, D.M., Kelsall, H.L., Zamri, E.N., Sim, M.R., 2018. Ergonomic interventions for preventing work-related musculoskeletal disorders of the upper limb and neck among office workers. Cochrane Database Syst. Rev. 2018. https://doi.org/10.1002/14651858.CD008570.pub3

Hooftman, W.E., van Poppel, M.N.M., van der Beek, A.J., Bongers, P.M., van Mechelen, W., 2004. Gender differences in the relations between work-related physical and psychosocial risk factors and musculoskeletal complaints. Scand. J. Work. Environ. Health 30, 261–278. https://doi.org/10.5271/sjweh.794

Huisstede, B.M., Bierma-Zeinstra, S.M., Koes, B.W., Verhaar, J.A., 2006. Incidence and prevalence of upper-extremity musculoskeletal disorders. A systematic appraisal of the literature. BMC Musculoskelet. Disord. 7, 7. https://doi.org/10.1186/1471-2474-7-7

ILO, 2015. Global trends on occupational accidents and diseases.

INRS, 2019. Méthode d'analyse de la charge physique de travail - ED 6161 2ème édition 43.

INRS, 2014. Méthode d'analyse de la charge physique de travail - ED 6161 1ère édition 43.

Jackson, J.A., Olsson, D., Burdorf, A., Punnett, L., Järvholm, B., Wahlström, J., 2019. Occupational biomechanical risk factors for radial nerve entrapment in a 13-year prospective study among male construction workers. Occup. Environ. Med. 76, 326–331. https://doi.org/10.1136/oemed-2018-105311

Kalton, G., Flores-Cervantes, I., 2003. Weighting methods. J. Off. Stat. 19, 81–97.

Kapellusch Jm, J.M., Gerr, F.E., Malloy, E.J., Garg, A., Harris-Adamson, C., Bao, S.S., Burt, S.E., Dale, A.M., Eisen, E.A., Evanoff, B.A., Hegmann, K.T., Silverstein, B.A., Theise, M.S., Rempel, D.M., 2014. Exposure-response relationships for the ACGIH threshold limit value for hand-activity level: results from a pooled data study of carpal tunnel syndrome. Scand. J. Work. Environ. Health 40, 610–620. https://doi.org/10.5271/sjweh.3456

Karasek, R.A., Brisson, C., Kawakami, N., Houtman, I., Bongers, P., Amick, B., 1998. The Job Content Questionnaire (JCQ): An instrument for internationally comparative assessments of psychosocial job characteristics. J. Occup. Health Psychol. 3, 322–355. https://doi.org/10.1037/1076-8998.3.4.322

Karsh, B.-T., 2006. Theories of work-related musculoskeletal disorders: Implications for ergonomic interventions. Theor. Issues Ergon. Sci. 7, 71–88.

Kennedy, C.A., Amick III, B.C., Dennerlein, J.T., Brewer, S., Catli, S., Williams, R., Serra, C., Gerr, F., Irvin, E., Mahood, Q., Franzblau, A., Van Eerd, D., Evanoff, B., Rempel, D., 2010. Systematic Review of the Role of Occupational Health and Safety Interventions in the Prevention of Upper Extremity Musculoskeletal Symptoms, Signs, Disorders, Injuries, Claims and Lost Time. J. Occup. Rehabil. 20, 127–162. https://doi.org/10.1007/s10926-009-9211-2

Kennedy, P., Joshi, R., Dhawan, A., 2019. The Effect of Psychosocial Factors on Outcomes in Patients With Rotator Cuff Tears: A Systematic Review. Arthrosc. - J. Arthrosc. Relat. Surg. 35, 2698–2706. https://doi.org/10.1016/j.arthro.2019.03.043

Kittusamy, N.K., Buchholz, B., 2004. Whole-body vibration and postural stress among operators of construction equipment: A literature review. J. Safety Res. 35, 255–261. https://doi.org/10.1016/j.jsr.2004.03.014

Koukoulaki, T., 2014. The impact of lean production on musculoskeletal and psychosocial risks: An examination of sociotechnical trends over 20 years. Appl. Ergon., Advances in Socio-Technical Systems Understanding and Design: A Festschrift in Honour of K.D. Eason 45, 198–212. https://doi.org/10.1016/j.apergo.2013.07.018

Kozak, A., Schedlbauer, G., Wirth, T., Euler, U., Westermann, C., Nienhaus, A., 2015. Association between work-related biomechanical risk factors and the occurrence of carpal tunnel syndrome: an overview of systematic reviews and a meta-analysis of current research. BMC Musculoskelet. Disord. 16. https://doi.org/10.1186/s12891-015-0685-0

Kozak, A., Wirth, T., Verhamme, M., Nienhaus, A., 2019. Musculoskeletal health, work-related risk factors and preventive measures in hairdressing: a scoping review. J. Occup. Med. Toxicol. 14, 24. https://doi.org/10.1186/s12995-019-0244-y

Kraatz, S., Lang, J., Kraus, T., Münster, E., Ochsmann, E., 2013. The incremental effect of psychosocial workplace factors on the development of neck and shoulder disorders: a systematic review of longitudinal studies. Int. Arch. Occup. Environ. Health 86, 375–395.

Kumar, S., 2001. Theories of musculoskeletal injury causation. Ergonomics 44, 17–47. https://doi.org/10.1080/00140130120716

Laaksonen, M., 2010. Population Attributable Fraction (PAF) in epidemiologic follow-up studies.

Lang, J., Ochsmann, E., Kraus, T., Lang, J.W.B., 2012. Psychosocial work stressors as antecedents of musculoskeletal problems: A systematic review and meta-analysis of stability-adjusted longitudinal studies. Soc. Sci. Med. 75, 1163–1174. https://doi.org/10.1016/j.socscimed.2012.04.015

Lang, J.J., Alam, S., Cahill, L.E., Drucker, A.M., Gotay, C., Kayibanda, J.F., Kozloff, N., Mate, K.K.V., Patten, S.B., Orpana, H.M., 2018. Global Burden of Disease Study trends for Canada from 1990 to 2016. CMAJ 190, E1296–E1304. https://doi.org/10.1503/cmaj.180698

Larsson, B., Søgaard, K., Rosendal, L., 2007. Work related neck-shoulder pain: a review on magnitude, risk factors, biochemical characteristics, clinical picture and preventive interventions. Best Pract. Res. Clin. Rheumatol. 21, 447–463. https://doi.org/10.1016/j.berh.2007.02.015
Leclerc, A., Chastang, J.-F., Niedhammer, I., Landre, M.-F., Roquelaure, Y., Work, S.G. on R., 2004. Incidence of Shoulder Pain in Repetitive Work. Occup. Environ. Med. 61, 39–44.
Leclerc, A., Franchi, P., Cristofari, M.F., Delemotte, B., Mereau, P., Teyssier-Cotte, C., Touranchet, A., 1998. Carpal tunnel syndrome and work organisation in repetitive work: a cross sectional study in France. Study Group on Repetitive Work. Occup. Environ. Med. 55, 180–187.
Leider, P.C., Boschman, J.S., Frings-Dresen, M.H.W., Molen, H.F. van der, 2015. Effects of job rotation on musculoskeletal complaints and related work exposures: a systematic literature review. Ergonomics 58, 18–32. https://doi.org/10.1080/00140139.2014.961566
Leong, H., Fu, S., He, X., Oh, J., Yamamoto, N., Yung, S., 2019. Risk factors for rotator cuff tendinopathy: A systematic review and meta-analysis. J. Rehabil. Med. 51, 627–637. https://doi.org/10.2340/16501977-2598
Levin, M.L., 1953. The occurrence of lung cancer in man. Acta - Unio Int. Contra Cancrum 9, 531–541.
Likert, R., 1932. A technique for the measurement of attitudes. Arch. Psychol.
Lloyd, C.J., 1996. Estimating Attributable Response as a Function of a Continuous Risk Factor. Biometrika 83, 563–573.
Lowe, B.D., Dick, R.B., 2015. Workplace Exercise for Control of Occupational Neck/Shoulder Disorders: A Review of Prospective Studies. Environ. Health Insights 8, 75–95. https://doi.org/10.4137/EHI.S15256
Luca, G.D., Rossetti, C., 2018. Stata program to compute calibrated weights from scientific usefile and additional database 32.
Luger, T., Maher, C.G., Rieger, M.A., Steinhilber, B., 2019. Work-break schedules for preventing musculoskeletal symptoms and disorders in healthy workers. Cochrane Database Syst. Rev. 7, CD012886. https://doi.org/10.1002/14651858.CD012886.pub2
Luime, J.J., Koes, B.W., Hendriksen, I.J.M., Burdorf, A., Verhagen, A.P., Miedema, H.S., Verhaar, J. a. N., 2004. Prevalence and incidence of shoulder pain in the general population; a systematic review. Scand. J. Rheumatol. 33, 73–81. https://doi.org/10.1080/03009740310004667
Lumley, T., 2020. Package 'survey' Version 4.0, 2014-04-06]. http://faculty. washington. edu/tlumley/survey.
Lund, C.B., Mikkelsen, S., Thygesen, L.C., Hansson, G.-Å., Thomsen, J.F., 2019. Movements of the wrist and the risk of carpal tunnel syndrome: a nationwide cohort study using objective exposure measurements. Occup. Environ. Med. 76, 519–526. https://doi.org/10.1136/oemed-2018-105619
Luttmann, A., Jäger, M., Griefahn, B., Caffier, G., Liebers, F., Steinberg, U., 2003. Preventing Musculoskeletal Disorders in the Workplace. WHO.
Macfarlane, G.J., Pallewatte, N., Paudyal, P., Blyth, F.M., Coggon, D., Crombez, G., Linton, S., Leino-Arjas, P., Silman, A.J., Smeets, R.J., van der Windt, D., 2009. Evaluation of work-related psychosocial factors and regional musculoskeletal pain: results from a EULAR Task Force. Ann. Rheum. Dis. 68, 885–891. https://doi.org/10.1136/ard.2008.090829
Malchaire, J., Cock, N., Vergracht, S., 2001. Review of the factors associated with musculoskeletal problems in epidemiological studies. Int. Arch. Occup. Environ. Health 74, 79–90. https://doi.org/10.1007/s004200000212
Mansfield, M., Thacker, M., Sandford, F., 2018. Psychosocial Risk Factors and the Association With Carpal Tunnel Syndrome: A Systematic Review. HAND 13, 501–508. https://doi.org/10.1177/1558944717736398
Mansournia, M.A., Altman, D.G., 2018. Population attributable fraction. BMJ k757. https://doi.org/10.1136/bmj.k757
Marant Micallef, C., Shield, K.D., Vignat, J., Baldi, I., Charbotel, B., Fervers, B., Gilg Soit Ilg, A., Guénel, P., Olsson, A., Rushton, L., Hutchings, S.J., Cléro, E., Laurier, D., Scanff, P., Bray, F., Straif, K., Soerjomataram, I., 2019. Cancers in France in 2015 attributable to occupational exposures. Int. J. Hyg. Environ. Health 222, 22–29. https://doi.org/10.1016/j.ijheh.2018.07.015
Marant-Micallef, C., 2018. Approche et méthodologie générale pour l'estimation des cancers attribuables au mode de vie et à l'environnement en France métropolitaine en 2015. Bull. Epidémiologique Hebd. 21, 432–42.
March, L., Smith, E.U.R., Hoy, D.G., Cross, M.J., Sanchez-Riera, L., Blyth, F., Buchbinder, R., Vos, T., Woolf, A.D., 2014. Burden of disability due to musculoskeletal (MSK) disorders. Best Pract. Res. Clin. Rheumatol., Preventing Musculoskeletal Disability 28, 353–366. https://doi.org/10.1016/j.berh.2014.08.002
Mattioli, S., Baldasseroni, A., Curti, S., Cooke, R.M.T., Mandes, A., Zanardi, F., Farioli, A., Buiatti, E., Campo, G., Violante, F.S., 2009. Incidence rates of surgically treated idiopathic carpal tunnel syndrome in blue- and

white-collar workers and housewives in Tuscany, Italy. Occup. Environ. Med. 66, 299–304. https://doi.org/10.1136/oem.2008.040212
Mayer, J., Kraus, T., Ochsmann, E., 2012. Longitudinal evidence for the association between work-related physical exposures and neck and/or shoulder complaints: a systematic review. Int. Arch. Occup. Environ. Health 85, 587–603. https://doi.org/10.1007/s00420-011-0701-0
Meems, M., Truijens, S., Spek, V., Visser, L.H., Pop, V.J.M., 2015. Prevalence, course and determinants of carpal tunnel syndrome symptoms during pregnancy: a prospective study. BJOG Int. J. Obstet. Gynaecol. 122, 1112–1118. https://doi.org/10.1111/1471-0528.13360
Melchior, M., Roquelaure, Y., Evanoff, B., Chastang, J.-F., Ha, C., Imbernon, E., Goldberg, M., Leclerc, A., and the Pays de la Loire Study Group, 2006. Why are manual workers at high risk of upper limb disorders? The role of physical work factors in a random sample of workers in France (the Pays de la Loire study). Occup. Environ. Med. 63, 754–761. https://doi.org/10.1136/oem.2005.025122
Mezzetti, M., Ferraroni, M., Decarli, A., La Vecchia, C., Benichou, J., 1996. Software for Attributable Risk and Confidence Interval Estimation in Case-Control Studies. Comput. Biomed. Res. 29, 63–75. https://doi.org/10.1006/cbmr.1996.0006
Michaelis, M., 2009. Identification and prioritisation of relevant prevention issues for work-related musculoskeletal disorders (MSDs) Work package 4 Prevention approaches: evidence-based effects and prioritised national strategies in other countries.
Michel, C., Institut national de santé publique du Québec, Direction des risques biologiques et de la santé au travail, 2010. Portrait national des troubles musculosquelettiques (TMS) 1998-2007: TMS sous surveillance. Direction des risques biologiques et de la santé au travail, Institut national de santé publique Québec : Agences de la santé et des services sociaux, Direction de santé publique, Montréal, Qué.
Miettinen, O.S., 1974. Proportion of disease caused or prevented by a given exposure, trait or intervention. Am. J. Epidemiol. 99, 325–332. https://doi.org/10.1093/oxfordjournals.aje.a121617
Miranda, H., Punnett, L., Viikari-Juntura, E., Heliövaara, M., Knekt, P., 2008. Physical work and chronic shoulder disorder. Results of a prospective population-based study. Ann. Rheum. Dis. 67, 218–223. https://doi.org/10.1136/ard.2007.069419
Miranda, H., Viikari-Juntura, E., Martikainen, R., Takala, E.P., Riihimäki, H., 2001. A prospective study of work related factors and physical exercise as predictors of shoulder pain. Occup. Environ. Med. 58, 528–534.
Moghtaderi, A., Izadi, S., Sharafadinzadeh, N., 2005. An evaluation of gender, body mass index, wrist circumference and wrist ratio as independent risk factors for carpal tunnel syndrome. Acta Neurol. Scand. 112, 375–379. https://doi.org/10.1111/j.1600-0404.2005.00528.x
Mohammadi, M., Mirzaei, M., 2017. Population-attributable fraction of hypertension associated with obesity, abdominal obesity, and the joint effect of both in the Central Provinces of Iran. J. Epidemiol. Glob. Health 7, 71–79. https://doi.org/10.1016/j.jegh.2016.11.002
Moradi-Lakeh, M., Forouzanfar, M.H., Vollset, S.E., Bcheraoui, C.E., Daoud, F., Afshin, A., Charara, R., Khalil, I., Higashi, H., Razek, M.M.A.E., Kiadaliri, A.A., Alam, K., Akseer, N., Al-Hamad, N., Ali, R., AlMazroa, M.A., Alomari, M.A., Al-Rabeeah, A.A., Alsharif, U., Altirkawi, K.A., Atique, S., Badawi, A., Barrero, L.H., Basulaiman, M., Bazargan-Hejazi, S., Bedi, N., Bensenor, I.M., Buchbinder, R., Danawi, H., Dharmaratne, S.D., Zannad, F., Farvid, M.S., Fereshtehnejad, S.-M., Farzadfar, F., Fischer, F., Gupta, R., Hamadeh, R.R., Hamidi, S., Horino, M., Hoy, D.G., Hsairi, M., Husseini, A., Javanbakht, M., Jonas, J.B., Kasaeian, A., Khan, E.A., Khubchandani, J., Knudsen, A.K., Kopec, J.A., Lunevicius, R., Razek, H.M.A.E., Majeed, A., Malekzadeh, R., Mate, K., Mehari, A., Meltzer, M., Memish, Z.A., Mirarefin, M., Mohammed, S., Naheed, A., Obermeyer, C.M., Oh, I.-H., Park, E.-K., Peprah, E.K., Pourmalek, F., Qorbani, M., Rafay, A., Rahimi-Movaghar, V., Shiri, R., Rahman, S.U., Rai, R.K., Rana, S.M., Sepanlou, S.G., Shaikh, M.A., Shiue, I., Sibai, A.M., Silva, D.A.S., Singh, J.A., Skogen, J.C., Terkawi, A.S., Ukwaja, K.N., Westerman, R., Yonemoto, N., Yoon, S.-J., Younis, M.Z., Zaidi, Z., Zaki, M.E.S., Lim, S.S., Wang, H., Vos, T., Naghavi, M., Lopez, A.D., Murray, C.J.L., Mokdad, A.H., 2017. Burden of musculoskeletal disorders in the Eastern Mediterranean Region, 1990–2013: findings from the Global Burden of Disease Study 2013. Ann. Rheum. Dis. 76, 1365–1373. https://doi.org/10.1136/annrheumdis-2016-210146
Muñoz-Poblete, C., Bascour-Sandoval, C., Inostroza-Quiroz, J., Solano-López, R., Soto-Rodríguez, F., 2019. Effectiveness of Workplace-Based Muscle Resistance Training Exercise Program in Preventing Musculoskeletal Dysfunction of the Upper Limbs in Manufacturing Workers. J. Occup. Rehabil. 29, 810–821. https://doi.org/10.1007/s10926-019-09840-7
Nambiema, A., Bertrais, S., Bodin, J., Fouquet, N., Aublet-Cuvelier, A., Evanoff, B., Descatha, A., Roquelaure, Y., 2020. Proportion of upper extremity musculoskeletal disorders attributable to personal and occupational

factors: results from the French Pays de la Loire study. BMC Public Health 20, 456. https://doi.org/10.1186/s12889-020-08548-1
Nastasia, I., Coutu, M.-F., Tcaciuc, R., 2014. Topics and trends in research on non-clinical interventions aimed at preventing prolonged work disability in workers compensated for work-related musculoskeletal disorders (WRMSDs): a systematic, comprehensive literature review. Disabil. Rehabil. 36, 1841–1856. https://doi.org/10.3109/09638288.2014.882418
National Research Council and Institute of Medicine, 2001. Musculoskeletal disorders and the workplace: low back and upper extremities. National Academy Press, Washington, D.C.
Newson, R., 2015. PUNAF: Stata module to compute population attributable fractions for cohort studies, Statistical Software Components.
Newson, R.B., 2013. Attributable and unattributable risks and fractions and other scenario comparisons. Stata J 13, 672–698.
Niedhammer, I., 2002. Psychometric properties of the French version of the Karasek Job Content Questionnaire: a study of the scales of decision latitude, psychological demands, social support, and physical demands in the GAZEL cohort. Int. Arch. Occup. Environ. Health 75, 129–144. https://doi.org/10.1007/s004200100270
Niedhammer, I., Chastang, J.-F., Gendrey, L., David, S., Degioanni, S., 2006. Psychometric properties of the French version of Karasek's "Job Content Questionnaire" and its scales measuring psychological pressures, decisional latitude and social support: the results of the SUMER. Santé Publique 18, 413–427.
Nieuwenbroek, N., Boonstra, H.J., 2002. Bascula 4.0 reference manual, BPA nr: 279-02-TMO. Stat. Neth. Heerlen.
Nilsen, T.I.L., Holtermann, A., Mork, P.J., 2011. Physical Exercise, Body Mass Index, and Risk of Chronic Pain in the Low Back and Neck/Shoulders: Longitudinal Data From the Nord-Trøndelag Health Study. Am. J. Epidemiol. 174, 267–273. https://doi.org/10.1093/aje/kwr087
Office For National Statistics. Social Survey Division, 2017. Labour Force Survey Five-Quarter Longitudinal Datasets, April 2012 - June 2013. 4th Edition. UK Data Service. SN: 7379. https://doi.org/10.5255/UKDA-SN-7379-4
Oh, I.-H., Yoon, S.-J., Seo, H.-Y., Kim, E.-J., Kim, Y.A., 2011. The economic burden of musculoskeletal disease in Korea: A cross sectional study. BMC Musculoskelet. Disord. 12, 157. https://doi.org/10.1186/1471-2474-12-157
Okunribido, O., Wynn, T., 2010. Ageing and work-related musculoskeletal disorders. Musculoskelet. Disord. 50.
ORES Pays de la Loire, 2020. Population active des Pays de la Loire [WWW Document]. URL http://ores.paysdelaloire.fr/1153-population-active.htm (accessed 7.23.20).
ORES Pays de la Loire, 2016. L'économie des Pays de la Loire - Chiffres-clés.
Padua, L., Pasquale, A.D., Pazzaglia, C., Liotta, G.A., Librante, A., Mondelli, M., 2010. Systematic review of pregnancy-related carpal tunnel syndrome. Muscle Nerve 42, 697–702. https://doi.org/10.1002/mus.21910
Palmer, K.T., Harris, E.C., Coggon, D., 2007. Carpal tunnel syndrome and its relation to occupation: a systematic literature review. Occup. Med. 57, 57–66. https://doi.org/10.1093/occmed/kql125
Paul, A., Salve, U.R., 2020. The Role of Organizational Factors in Development and Progression of Wrist Disorders: Psychosocial Aspects, in: Rebelo, F., Soares, M.M. (Eds.), Advances in Ergonomics in Design, Advances in Intelligent Systems and Computing. Springer International Publishing, Cham, pp. 783–793. https://doi.org/10.1007/978-3-030-20227-9_76
Pearce, N., Checkoway, H., Kriebel, D., 2007. Bias in occupational epidemiology studies. Occup. Environ. Med. 64, 562–568. https://doi.org/10.1136/oem.2006.026690
Petit, A., Ha, C., Bodin, J., Rigouin, P., Descatha, A., Brunet, R., Goldberg, M., Roquelaure, Y., 2015. Risk factors for carpal tunnel syndrome related to the work organization: A prospective surveillance study in a large working population. Appl. Ergon. 47, 1–10. https://doi.org/10.1016/j.apergo.2014.08.007
Pirani, N., Khiavi, F.F., 2017. Population Attributable Fraction for Cardiovascular Diseases Risk Factors in Selected Countries: A comparative study. Mater. Socio-Medica 29, 35–39. https://doi.org/10.5455/msm.2017.29.35-39
Pitblado, J., 2018. Calibrating Survey Weights in Stata. Canadian Stata Users Group Meeting, Vancouver, Canada.
Podniece, Z., Heuvel, S. van den, Blatter, B.M., 2008. Work-related musculoskeletal disorders : prevention report. European Agency for Safety and Health at Work.
Pourmemari, M.H., Shiri, R., 2016. Diabetes as a risk factor for carpal tunnel syndrome: a systematic review and meta-analysis. Diabet. Med. 33, 10–16. https://doi.org/10.1111/dme.12855

Proper, K.I., van Oostrom, S.H., 2019. The effectiveness of workplace health promotion interventions on physical and mental health outcomes - a systematic review of reviews. Scand. J. Work. Environ. Health 45, 546–559. https://doi.org/10.5271/sjweh.3833

Public Health Agency of Canada, 2018. Economic burden of illness in Canada, 2010.

Punnett, L., Cherniack, M., Henning, R., Morse, T., Faghri, P., Team, C.-N.R., 2009. A conceptual framework for integrating workplace health promotion and occupational ergonomics programs. Public Health Rep. 124, 16–25.

Punnett, L., Wegman, D.H., 2004. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. J. Electromyogr. Kinesiol. 14, 13–23. https://doi.org/10.1016/j.jelekin.2003.09.015

Rajaobelina, K., Dow, C., Mancini, F.R., Dartois, L., Boutron-Ruault, M.-C., Balkau, B., Bonnet, F., Fagherazzi, G., 2019. Population attributable fractions of the main type 2 diabetes mellitus risk factors in women: Findings from the French E3N cohort. J. Diabetes 11, 242–253. https://doi.org/10.1111/1753-0407.12839

Rämsch, C., Pfahlberg, A.B., Gefeller, O., 2009. Point and interval estimation of partial attributable risks from case–control data using the R-package 'pARccs.' Comput. Methods Programs Biomed. 94, 88–95. https://doi.org/10.1016/j.cmpb.2008.10.006

Rebecq, A., 2019. icarus: Calibrates and Reweights Units in Samples.

Rebecq, A., 2016. Icarus: un package r pour le calage sur marges et ses variantes, in: 9e Colloque Francophone Sur Les Sondages, Gatineau (Canada).

Riccò, M., Cattani, S., Signorelli, C., 2016. Personal risk factors for carpal tunnel syndrome in female visual display unit workers. Int. J. Occup. Med. Environ. Health 29, 927–936. https://doi.org/10.13075/ijomeh.1896.00781

Rivilis, I., Van Eerd, D., Cullen, K., Cole, D.C., Irvin, E., Tyson, J., Mahood, Q., 2008. Effectiveness of participatory ergonomic interventions on health outcomes: A systematic review. Appl. Ergon. 39, 342–358. https://doi.org/10.1016/j.apergo.2007.08.006

Robins, J.M., Greenland, S., 1989. Estimability and estimation of excess and etiologic fractions. Stat. Med. 8, 845–859. https://doi.org/10.1002/sim.4780080709

Robinson, J., 2014. Likert Scale, in: Michalos, A.C. (Ed.), Encyclopedia of Quality of Life and Well-Being Research. Springer Netherlands, Dordrecht, pp. 3620–3621. https://doi.org/10.1007/978-94-007-0753-5_1654

Rockhill, B, Newman, B., Weinberg, C., 1998. Use and misuse of population attributable fractions. Am. J. Public Health 88, 15–19. https://doi.org/10.2105/AJPH.88.1.15

Rockhill, B., Weinberg, C.R., Newman, B., 1998. Population Attributable Fraction Estimation for Established Breast Cancer Risk Factors: Considering the Issues of High Prevalence and Unmodifiability. Am. J. Epidemiol. 147, 826–833. https://doi.org/10.1093/oxfordjournals.aje.a009535

Rodrigues Ferreira Faisting, A.L., de Oliveira Sato, T., 2019. Effectiveness of ergonomic training to reduce physical demands and musculoskeletal symptoms - An overview of systematic reviews. Int. J. Ind. Ergon. 74, 102845. https://doi.org/10.1016/j.ergon.2019.102845

Roquelaure, Y., 2018. Musculoskeletal Disorders and Psychosocial Factors at Work, ETUI Research Paper-Report. ed, Report / European Trade Union Institute. Brussels.

Roquelaure, Y., 2017. L'organisation du travail et le management en question. Hygiène Sécurité Trav. 246, 22–28.

Roquelaure, Y., 2016. Promoting a Shared Representation of Workers' Activities to Improve Integrated Prevention of Work-Related Musculoskeletal Disorders. Saf. Health Work 7, 171–174. https://doi.org/10.1016/j.shaw.2016.02.001

Roquelaure, Y., 2015. Musculoskeletal disorders: a major challenge for occupational risk prevention in Europe. ETUI Policy Brief 9, 2015.

Roquelaure, Y., Fouquet, N., Chazelle, E., Descatha, A., Evanoff, B., Bodin, J., Petit, A., 2018. Theoretical impact of simulated workplace-based primary prevention of carpal tunnel syndrome in a French region. BMC Public Health 18. https://doi.org/10.1186/s12889-018-5328-6

Roquelaure, Y., Garlantézec, R., Evanoff, B.A., Descatha, A., Fassier, J.-B., Bodin, J., 2020. Personal, biomechanical, psychosocial, and organizational risk factors for carpal tunnel syndrome: a structural equation modeling approach. PAIN 161, 749–757. https://doi.org/10.1097/j.pain.0000000000001766

Roquelaure, Y., Ha, C., Fouquet, N., Descatha, A., Leclerc, A., Goldberg, M., Imbernon, E., 2009a. Attributable risk of carpal tunnel syndrome in the general population: implications for intervention programs in the workplace. Scand. J. Work. Environ. Health 35, 342–348.

Roquelaure, Y., Ha, C., Leclerc, A., Touranchet, A., Sauteron, M., Melchior, M., Imbernon, E., Goldberg, M., 2006. Epidemiologic surveillance of upper-extremity musculoskeletal disorders in the working population. Arthritis Care Res. 55, 765–778. https://doi.org/10.1002/art.22222
Roquelaure, Y., Ha, C., Nicolas, G., Pélier-Cady, M.-C., Mariot, C., Descatha, A., Leclerc, A., Raimbeau, G., Goldberg, M., Imbernon, E., 2008. Attributable risk of carpal tunnel syndrome according to industry and occupation in a general population. Arthritis Rheum. 59, 1341–1348. https://doi.org/10.1002/art.24002
Roquelaure, Y., Ha, C., Rouillon, C., Fouquet, N., Leclerc, A., Descatha, A., Touranchet, A., Goldberg, M., Imbernon, E., Members of Occupational Health Services of the Pays de la Loire Region, 2009b. Risk factors for upper-extremity musculoskeletal disorders in the working population. Arthritis Rheum. 61, 1425–1434. https://doi.org/10.1002/art.24740
Roquelaure, Yves, Leclerc, A., Coutarel, F., Brunet, R., Caroly, S., Daniellou, F., 2012. Comprendre et intervenir : enquêtes épidémiologiques et approches ergonomiques à propos des troubles musculosquelettiques des membres supérieurs, in: Risques du travail, la santé négociée. La Découverte, Paris, pp. 173–187.
Roquelaure, Y., LeManach, A.P., Ha, C., Poisnel, C., Bodin, J., Descatha, A., Imbernon, E., 2012. Working in temporary employment and exposure to musculoskeletal constraints. Occup. Med. 62, 514–518. https://doi.org/10.1093/occmed/kqs004
Roquelaure, Y., Mariel, J., Fanello, S., Boissiere, J., Chiron, H., Dano, C., Bureau, D., Penneau-Fontbonne, D., 2002. Active epidemiological surveillance of musculoskeletal disorders in a shoe factory. Occup. Environ. Med. 59, 452–458. https://doi.org/10.1136/oem.59.7.452
Roquelaure, Y., Petit, A., Fouquet, B., Descatha, A., 2014. Pathologies professionnelles musculo-squelettiques: priorité à la prévention et à la coordination des prises en charge. Rev. Prat. Paris 64, 350–357.
Roquelaure, Y., Touranchet, A., Ha, C., 2001. Réseau expérimental de surveillance épidémiologique des troubles musculo-squelettiques (TMS) d'origine professionnelle. Rapp. Final Pour L'Institut Veille Sanit. St.-Maurice.
Roser, M., Ritchie, H., 2020. Burden of disease. Publ. Online OurWorldInDataorg Retrieved Httpsourworldindataorgburden--Dis. Online Resour.
Rossignol, M., Stock, S., Patry, L., Armstrong, B., 1997. Carpal tunnel syndrome: what is attributable to work? The Montreal study. Occup. Environ. Med. 54, 519–523. https://doi.org/10.1136/oem.54.7.519
Rothman, K., Greenland, S., 1998. Modern Epidemiology. Lippincott-Raven Phila.
Roux, S., Armoogum, J., 2010. Redressement de l'Enquête Nationale sur les Transports et les Déplacements – 2007-08. Note Méthodologique Dép. Économie Sociol. Transp. - INRETS 54.
Roux, S., Armoogum, J., 2008. Mise en perspective des Enquêtes Nationales Transports 1973/74 - 1981/82 - 1993/94 - 2007/08 : Correction de la non-réponse dans l'Enquête Nationale sur les Transports et les Déplacements 2007-08. Note Méthodologique Dép. Économie Sociol. Transp. - INRETS 73.
Rückinger, S., von Kries, R., Toschke, A.M., 2009. An illustration of and programs estimating attributable fractions in large scale surveys considering multiple risk factors. BMC Med. Res. Methodol. 9, 7. https://doi.org/10.1186/1471-2288-9-7
Sauter, S., Moon, S.D., 1996. Beyond biomechanics: psychosocial aspects of musculoskeletal disorders in office work. CRC Press.
Sautory, O., 2018. Les méthodes de calage (Document No. Version n°1). Insee, Département des méthodes statistiques, Paris.
Sautory, O., 1993. La macro Calmar. Redressement d'un échantillon par calage sur marges (Document de travail n°F9310 de la DSDS). Insee, Unité Méthodes Statistiques, Paris.
Sayampanathan, A.A., Basha, M., Mitra, A.K., 2020. Risk factors of lateral epicondylitis: A meta-analysis. The Surgeon 18, 122–128. https://doi.org/10.1016/j.surge.2019.08.003
Schenck, L., Atkinson, E., Crowson, C., Therneau, T., 2014. 'Attribrisk': Population attributable risk, R package version 0.1.
Sérazin, C., Ha, C., Bidron, P., Gillard, A.-C., Tilliette, C., Tassy, V., Imbernon, E., Roquelaure, Y., 2014. Difficulties of a longitudinal epidemiological follow-up study in French occupational medicine. Santé Publique Vol. 26, 33–43.
Shield, K.D., Dossus, L., Fournier, A., Marant-Micallef, C., Rinaldi, S., Rogel, A., Heard, I., Pilleron, S., Bray, F., Soerjomataram, I., 2018. The impact of historical breastfeeding practices on the incidence of cancer in France in 2015. Cancer Causes Control 29, 325–332. https://doi.org/10.1007/s10552-018-1015-2
Shiri, R., 2016. Arthritis as a risk factor for carpal tunnel syndrome: a meta-analysis. Scand. J. Rheumatol. 45, 339–346. https://doi.org/10.3109/03009742.2015.1114141

Shiri, R., Pourmemari, M.H., Falah-Hassani, K., Viikari-Juntura, E., 2015. The effect of excess body mass on the risk of carpal tunnel syndrome: a meta-analysis of 58 studies: Obesity and carpal tunnel syndrome. Obes. Rev. 16, 1094–1104. https://doi.org/10.1111/obr.12324

Silverstein, B., Adams, D., 2007. Work-related musculoskeletal disorders of the neck, back, and upper extremity in Washington State, 1997–2005 (Technical Report No. 40-11–2007). Safety and Health Assessment and Research for Prevention (SHARP), Washington State Department of Labor and Industries, Olympia, WA 98504-4330.

Silverstein, B., Fan, Z.J., Smith, C.K., Bao, S., Howard, N., Spielholz, P., Bonauto, D.K., Viikari-Juntura, E., 2009. Gender adjustment or stratification in discerning upper extremity musculoskeletal disorder risk? Scand. J. Work. Environ. Health 113–126.

Sluiter, J.K., Rest, K.M., Frings-Dresen, M.H., 2001. Criteria document for evaluating the work-relatedness of upper-extremity musculoskeletal disorders. Scand. J. Work. Environ. Health 27, 1–30 & 43–45. https://doi.org/10.5271/sjweh.637

Smith, E., Hoy, D.G., Cross, M., Vos, T., Naghavi, M., Buchbinder, R., Woolf, A.D., March, L., 2014. The global burden of other musculoskeletal disorders: estimates from the Global Burden of Disease 2010 study. Ann. Rheum. Dis. 73, 1462–1469. https://doi.org/10.1136/annrheumdis-2013-204680

Smith, H., Havinga, I.C., Vereinte Nationen (Eds.), 2015. Estimation procedures and accuracy, in: Handbook on Economic Tendency Surveys, Statistical Papers Series M. United Nations, New York, pp. 45–64.

Soares, C.O., Pereira, B.F., Pereira Gomes, M.V., Marcondes, L.P., de Campos Gomes, F., de Melo-Neto, J.S., 2020. Preventive factors against work-related musculoskeletal disorders: narrative review. Rev. Bras. Med. Trab. 17, 415–430. https://doi.org/10.5327/Z1679443520190360

Sobeih, T.M., Salem, O., Daraiseh, N., Genaidy, A., Shell, R., 2006. Psychosocial factors and musculoskeletal disorders in the construction industry: a systematic review. Theor. Issues Ergon. Sci. 7, 329–344. https://doi.org/10.1080/14639220500090760

Soerjomataram, I., Shield, K., Marant-Micallef, C., Vignat, J., Hill, C., Rogel, A., Menvielle, G., Dossus, L., Ormsby, J.-N., Rehm, J., Rushton, L., Vineis, P., Parkin, M., Bray, F., 2018. Cancers related to lifestyle and environmental factors in France in 2015. Eur. J. Cancer 105, 103–113. https://doi.org/10.1016/j.ejca.2018.09.009

Spahn, G., Wollny, J., Hartmann, B., Schiele, R., Hofmann, G.O., 2012. Metaanalysis for the evaluation of risk factors for carpal tunnel syndrome (CTS) Part II. Occupational risk factors. Z. Orthopadie Unfallchirurgie 150, 516–524. https://doi.org/10.1055/s-0032-1315346

Spiegelman, D., Hertzmark, E., Wand, H.C., 2007. Point and interval estimates of partial population attributable risks in cohort studies: examples and software. Cancer Causes Control 18, 571–579. https://doi.org/10.1007/s10552-006-0090-y

Steenland, K., Armstrong, B., 2006. An Overview of Methods for Calculating the Burden of Disease Due to Specific Risk Factors: Epidemiology 17, 512–519. https://doi.org/10.1097/01.ede.0000229155.05644.43

Stephan, F.F., 1942. An iterative method of adjusting sample frequency tables when expected marginal totals are known. Ann. Math. Stat. 13, 166–178.

Stock, S., Nicolakakis, N., Messing, K., Turcot, A., Raiq, H., 2013. Quelle est la relation entre les troubles musculo-squelettiques (TMS) liés au travail et les facteurs psychosociaux ?: Survol de diverses conceptions des facteurs psychosociaux du travail et proposition d’un nouveau modèle de la genèse des TMS. Perspect. Interdiscip. Sur Trav. Santé. https://doi.org/10.4000/pistes.3407

Stock, S.R., Nicolakakis, N., Vezina, N., Vezina, M., Gilbert, L., Turcot, A., Sultan-TaÃ¯eb, H., Sinden, K., Denis, M.-A., Delga, C., Beaucage, C., 2018. Are work organization interventions effective in preventing or reducing work-related musculoskeletal disorders? A systematic review of the literature. Scand. J. Work. Environ. Health. https://doi.org/10.5271/sjweh.3696

Storheim, K., Zwart, J.-A., 2014. Musculoskeletal disorders and the Global Burden of Disease study. Ann. Rheum. Dis. 73, 949–950. https://doi.org/10.1136/annrheumdis-2014-205327

Summers, K., Jinnett, K., Bevan, S., 2015. Musculoskeletal Disorders, Workforce Health and Productivity in the United States. Musculoskelet. Disord. 41.

Szymkowiak, M., 2014. Weighting and Estimation - Calibration, in: The Memobust Handbook on Methodology for Modern Business Statistics.

Tamimi, R.M., Spiegelman, D., Smith-Warner, S.A., Wang, M., Pazaris, M., Willett, W.C., Eliassen, A.H., Hunter, D.J., 2016. Population Attributable Risk of Modifiable and Nonmodifiable Breast Cancer Risk Factors in Postmenopausal Breast Cancer. Am. J. Epidemiol. 184, 884–893. https://doi.org/10.1093/aje/kww145

Thygesen, L.C., Mikkelsen, S., Pedersen, E.B., Møller, K.L., Alkjær, T., Koblauch, H., Simonsen, E.B., Møller, S.P., Brauer, C., 2016. Subacromial shoulder disorders among baggage handlers: an observational cohort study. Int. Arch. Occup. Environ. Health 89, 867–876. https://doi.org/10.1007/s00420-016-1127-5

Titchener, A.G., Fakis, A., Tambe, A.A., Smith, C., Hubbard, R.B., Clark, D.I., 2013. Risk factors in lateral epicondylitis (tennis elbow): a case-control study. J. Hand Surg. Eur. Vol. 38, 159–164. https://doi.org/10.1177/1753193412442464

Treaster, D., Burr, D., 2004. Gender differences in prevalence of upper extremity musculoskeletal disorders. Ergonomics 47, 495–526. https://doi.org/10.1080/00140130310001638171

Tseng, M., Weinberg, C.R., Umbach, D.M., Longnecker, M.P., 1999. Calculation of population attributable risk for alcohol and breast cancer (United States). Cancer Causes Control 10, 119–123. https://doi.org/10.1023/A:1008853115901

Tunaiji, H.A., Davis, J.C., Mansournia, M.A., Khan, K.M., 2019. Population attributable fraction of leading non-communicable cardiovascular diseases due to leisure-time physical inactivity: a systematic review. BMJ Open Sport Exerc. Med. 5, e000512. https://doi.org/10.1136/bmjsem-2019-000512

United States Bone and Joint Initiative, 2018. The Hidden Impact of Musculoskeletal Disorders on Americans, 4th Edition. ed.

United States Bone and Joint Initiative, 2015. The Burden of Musculoskeletal Diseases in the United States: Prevalence, Societal and Economic Costs (BMUS), Third Edition, Third Edition. ed. Rosemont, IL.

van der Molen, H.F., de Vries, S.C., Stocks, S.J., Warning, J., Frings-Dresen, M.H.W., 2016. Incidence rates of occupational diseases in the Dutch construction sector, 2010–2014. Occup. Environ. Med. 73, 350–352. https://doi.org/10.1136/oemed-2015-103429

van der Molen, H.F., Foresti, C., Daams, J.G., Frings-Dresen, M.H.W., Kuijer, P.P.F.M., 2017. Work-related risk factors for specific shoulder disorders: a systematic review and meta-analysis. Occup. Environ. Med. 74, 745–755. https://doi.org/10.1136/oemed-2017-104339

van der Molen, H.F., Hulshof, C.T., Kuijer, P.P.F., 2019. How to improve the assessment of the impact of occupational diseases at a national level? The Netherlands as an example. Occup. Environ. Med. 76, 30–32. https://doi.org/10.1136/oemed-2018-105387

van der Molen, H.F., Sluiter, J.K., Hulshof, C.T., Vink, P., Frings-Dresen, M.H., 2005. Effectiveness of measures and implementation strategies in reducing physical work demands due to manual handling at work. Scand. J. Work. Environ. Health 31, 191–87.

van der Windt, D.A., Thomas, E., Pope, D.P., Winter, A.F. de, Macfarlane, G.J., Bouter, L.M., Silman, A.J., 2000. Occupational risk factors for shoulder pain: a systematic review. Occup. Environ. Med. 57, 433–442. https://doi.org/10.1136/oem.57.7.433

Van Eerd, D., Munhall, C., Irvin, E., Rempel, D., Brewer, S., van der Beek, A.J., Dennerlein, J.T., Tullar, J., Skivington, K., Pinion, C., Amick, B., 2016. Effectiveness of workplace interventions in the prevention of upper extremity musculoskeletal disorders and symptoms: an update of the evidence. Occup. Environ. Med. 73, 62–70. https://doi.org/10.1136/oemed-2015-102992

van Niekerk, S.-M., Louw, Q.A., Hillier, S., 2012. The effectiveness of a chair intervention in the workplace to reduce musculoskeletal symptoms. A systematic review. BMC Musculoskelet. Disord. 13, 145. https://doi.org/10.1186/1471-2474-13-145

van Oostrom, S.H., Driessen, M.T., de Vet, H.C.W., Franche, R.-L., Schonstein, E., Loisel, P., van Mechelen, W., Anema, J.R., 2009. Workplace interventions for preventing work disability. Cochrane Database Syst. Rev. CD006955. https://doi.org/10.1002/14651858.CD006955.pub2

van Rijn, R.M., Huisstede, B.M., Koes, B.W., Burdorf, A., 2010. Associations between work-related factors and specific disorders of the shoulder — a systematic review of the literature. Scand. J. Work. Environ. Health 36, 189–201.

van Rijn, R.M., Huisstede, B.M., Koes, B.W., Burdorf, A., 2009a. Associations between work-related factors and specific disorders at the elbow: a systematic literature review. Rheumatology 48, 528–536. https://doi.org/10.1093/rheumatology/kep013

van Rijn, R.M., Huisstede, B.M., Koes, B.W., Burdorf, A., 2009b. Associations between work-related factors and the carpal tunnel syndrome—a systematic review. Scand. J. Work. Environ. Health 35, 19–36.

Vanderhoeft, C., 2001. Generalised calibration at Statistics Belgium : SPSS module g-CALIB-S and current practices, Statistics Belgium working paper. Bruxelles : Inst. National de Statistique.

Varatharajan, S., Côté, P., Shearer, H.M., Loisel, P., Wong, J.J., Southerst, D., Yu, H., Randhawa, K., Sutton, D., van der Velde, G., Mior, S., Carroll, L.J., Jacobs, C., Taylor-Vaisey, A., 2014. Are Work Disability Prevention Interventions Effective for the Management of Neck Pain or Upper Extremity Disorders? A

Systematic Review by the Ontario Protocol for Traffic Injury Management (OPTIMa) Collaboration. J. Occup. Rehabil. 24, 692–708. https://doi.org/10.1007/s10926-014-9501-1
Vargas-Prada, S., Coggon, D., 2015. Psychological and psychosocial determinants of musculoskeletal pain and associated disability. Best Pract. Res. Clin. Rheumatol., Occupation and Musculoskeletal Disorders 29, 374–390. https://doi.org/10.1016/j.berh.2015.03.003
Viikari-Juntura, E., Shiri, R., Solovieva, S., Karppinen, J., Leino-Arjas, P., Varonen, H., Kalso, E., Ukkola, O., 2008. Risk factors of atherosclerosis and shoulder pain – Is there an association? A systematic review. Eur. J. Pain 12, 412–426. https://doi.org/10.1016/j.ejpain.2007.08.006
Violante, F.S., Farioli, A., Graziosi, F., Marinelli, F., Curti, S., Armstrong, T.J., Mattioli, S., Bonfiglioli, R., 2016. Carpal tunnel syndrome and manual work: the OCTOPUS cohort, results of a ten-year longitudinal study. Scand. J. Work. Environ. Health 42, 280–290. https://doi.org/10.5271/sjweh.3566
Wacholder, S., Benichou, J., Heineman, E.F., Hartge, P., Hoover, R.N., 1994. Attributable Risk: Advantages of a Broad Definition of Exposure. Am. J. Epidemiol. 140, 303–309. https://doi.org/10.1093/oxfordjournals.aje.a117252
Walker-Bone, K., Palmer, K.T., Reading, I., Coggon, D., Cooper, C., 2004. Prevalence and impact of musculoskeletal disorders of the upper limb in the general population. Arthritis Rheum. 51, 642–651. https://doi.org/10.1002/art.20535
Walter, S.D., 1983. Effects of interaction, confounding and observational error on attributable risk estimation. Am. J. Epidemiol. 117, 598–604. https://doi.org/10.1093/oxfordjournals.aje.a113582
Walter, S.D., 1980. Prevention for multifactorial diseases. Am. J. Epidemiol. 112, 409–416. https://doi.org/10.1093/oxfordjournals.aje.a113007
Walter, S.D., 1976. The Estimation and Interpretation of Attributable Risk in Health Research. Biometrics 32, 829. https://doi.org/10.2307/2529268
Weinstein, S.L., 2016. The Burden of Musculoskeletal Conditions. J. Bone Jt. Surg. 98, 1331. https://doi.org/10.2106/JBJS.16.00595
WHO (Ed.), 2008. The International Statistical Classification of Diseases and Health Related Problems ICD-10, Second Edition, Tenth Revision. ed. Geneva, Switzerland.
WHO, 2000. Obesity: preventing and managing the global epidemic: report of a WHO consultation, WHO technical report series. World Health Organization, Geneva.
WHO Expert Committee on Identification and Control of Work-Related Diseases & World Health Organization, 1985. Identification and control of work-related diseases : report of a WHO expert committee. [meeting held in Geneva from 28 November to 2 December 1983], Geneva : World Health Organization.
Widanarko, B., Legg, S., Devereux, J., Stevenson, M., 2014. The combined effect of physical, psychosocial/organisational and/or environmental risk factors on the presence of work-related musculoskeletal symptoms and its consequences. Appl. Ergon. 45, 1610–1621. https://doi.org/10.1016/j.apergo.2014.05.018
Zhang, L.-C., 2002. A method of weighting adjustment for survey data subject to nonignorable nonresponse.
Zhao, K., 2013. Proper estimation of relative risk using PROC GENMOD in population studies, in: Proceedings of the Western Users of SAS Software Conference. pp. 13–15.
Zins, M., Bonenfant, S., Carton, M., Coeuret-Pellicer, M., Guéguen, A., Gourmelen, J., Nachtigal, M., Ozguler, A., Quesnot, A., Ribet, C., Rodrigues, G., Serrano, A., Sitta, R., Brigand, A., Henny, J., Goldberg, M., 2010. The CONSTANCES cohort: an open epidemiological laboratory. BMC Public Health 10, 479. https://doi.org/10.1186/1471-2458-10-479
Zins, M., Goldberg, M., CONSTANCES team, 2015. The French CONSTANCES population-based cohort: design, inclusion and follow-up. Eur. J. Epidemiol. 30, 1317–1328. https://doi.org/10.1007/s10654-015-0096-4
Zou, G., 2004. A Modified Poisson Regression Approach to Prospective Studies with Binary Data. Am. J. Epidemiol. 159, 702–706. https://doi.org/10.1093/aje/kwh090

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Appendices

Appendix 1. Self-administered inclusion questionnaire of the COSALI study

ETUDE SUR LES TROUBLES MUSCULO-SQUELETTIQUES EN PAYS DE LA LOIRE – ANNEE 2004

Conformément aux dispositions de la loi sur l'Informatique et les libertés, nous vous informons que votre participation à cette étude n'a aucun caractère obligatoire, c'est pourquoi nous vous demandons de bien vouloir nous donner par écrit votre *consentement pour participer à cette étude*

Je, soussigné(e) NOM ____ PRENOM _________________________, déclare accepter de participer à l'étude sur les troubles musculo-squelettiques menée par le Département Santé –Travail - Ergonomie de la Faculté de Médecine d'Angers sous la responsabilité du Docteur Yves ROQUELAURE et du Docteur _______________________________.

Fait à _____________, le /___ / ___ / 200___ / **Signature**

Si vous souhaitez des informations complémentaires, vous pouvez en parler avec votre médecin du travail ou nous joindre à l'adresse ci-dessous. De plus, vous pouvez à tout moment demander l'accès aux informations vous concernant auprès du Docteur Yves ROQUELAURE, Centre de coordination régionale du réseau de surveillance des TMS, Département Santé – Travail - Ergonomie, CHU, 49033 ANGERS CEDEX, Téléphone : 02 41 35 34 85 – Télécopie : 02 41 35 34 48

Numéro d'anonymat |_3_|_4_| |__|__|__|__| |__|__|__|__| (ne pas remplir)

COMMENT REMPLIR CE QUESTIONNAIRE ?

Lorsque le questionnaire se présente sous la forme de petites cases, cochez celle (ou celles) qui correspond (ent) le mieux à votre réponse.

Exemple : **3 – Etes-vous ?** Un homme … ☒ Une femme …❑

Lorsque le questionnaire se présente sous la forme de cases à remplir, veuillez les compléter de la manière la plus précise possible.

Exemple : **6-Quelle est votre taille ? |_1_|_7_|_0_| cm**

21 - Votre durée de travail hebdomadaire est-elle variable ? Oui … ☒ Non …❑

Emploi exercé : évitez de noter des informations trop vagues, comme « fonctionnaire », précisez votre emploi particulier et décrivez les tâches ou activités de la manière la plus précise possible.

17 - Quelle emploi occupez-vous actuellement ? *(Précisez en clair l'intitulé) :* *Exemple* : *….*SECRETARIAT DANS UNE ENTREPRISE COMMERCIALE*..............*

19 – Pouvez-vous décrire les principales tâches ou activités que vous devez accomplir dans votre emploi actuel ? ACCUEIL DES CLIENTS ; FRAPPE DES COURRIERS, ACCUEIL TELEPHONIQUE, RENSEIGNEMENTS DIVERS

Pour certaines questions, nous vous demandons de bien vouloir vous placer sur une échelle. Vous devez mettre une croix sur la case qui mesure le mieux votre niveau d'effort (de nul à maximum).

48 - Comment estimez-vous la force habituellement requise par votre travail ? (mettez une croix dans la case correspondant -au niveau d'effort auquel vous vous situez)

Par exemple, si vous jugez votre effort plutôt fort, vous cocherez :

Effort nul |_____|_____|_____|_____|_____|_____|_____|__X__|_____|_____| Effort maximal

Nous vous remercions de bien vouloir répondre avec précision au questionnaire suivant et de le remettre à votre médecin du travail. ***Pour assurer la qualité des résultats, nous avons besoin que vous répondiez à toutes les questions.***

|_3_|_4_| |__|__|__|__| |__|__|__|__|

(ne pas remplir)

PARTIE DU QUESTIONNAIRE A REMPLIR

1 – A quelle date remplissez-vous ce questionnaire ? |__|__| |__|__| 20|_0_|__|
jour mois année

2 – Quelle est votre année de naissance ? |_1_|_9_|__|__|

3 – Etes-vous ? Un homme … ❑ Une femme … ❑

4 – Etes-vous ? Droitier(ère) … ❑ Gaucher(ère) …❑ Ambidextre … ❑

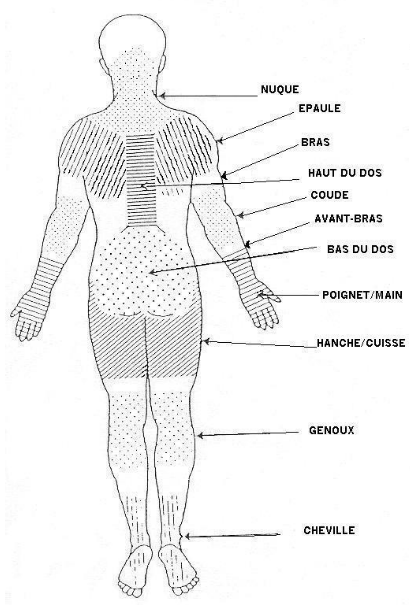
5 – Quel est votre poids ? |__|__|__| kg

6 – Quelle est votre taille ? |__|__|__| cm

CONCERNANT VOTRE SANTE

7 – Avez-vous eu, au cours *des 12 derniers mois,* des problèmes (courbatures, douleurs, gêne, engourdissement) au niveau des zones du corps suivantes ? *Pour chacune des zones du corps, cochez la case correspondante*

1. Nuque / cou	Oui….❑	Non…❑				
2. Epaule / bras	Oui….❑	Non…❑	**Si oui,**	du côté droit…❑	du côté gauche…❑	des deux côtés…❑
3. Coude/ avant-bras	Oui….❑	Non…❑	**Si oui,**	du côté droit…❑	du côté gauche…❑	des deux côtés…❑
4. Main / poignet	Oui….❑	Non…❑	**Si oui,**	du côté droit…❑	du côté gauche…❑	des deux côtés…❑
5. Doigts	Oui….❑	Non…❑	**Si oui,**	du côté droit…❑	du côté gauche…❑	des deux côtés…❑
6. Haut du dos	Oui….❑	Non…❑				
7. Bas du dos	Oui….❑	Non…❑				
8. Hanche / cuisse	Oui….❑	Non…❑	**Si oui,**	du côté droit…❑	du côté gauche…❑	des deux côtés…❑
9. Genou / jambe	Oui….❑	Non…❑	**Si oui,**	du côté droit…❑	du côté gauche…❑	des deux côtés…❑
10. Cheville / pied	Oui….❑	Non…❑	**Si oui,**	du côté droit…❑	du côté gauche…❑	des deux côtés…❑



Si vous avez répondu *Non* à toutes ces questions, passez directement à la *question 12.*

8- Durant *<u>ces 12 derniers mois,</u>* combien de temps, au total, avez-vous souffert ?

Pour chacune des zones du corps, cochez la case qui correspond le mieux à votre réponse

	Moins de 24 heures	De 1 à 7 jours	De 8 à 30 jours	Plus de 30 jours	En permanence
1. Nuque / cou	❑	❑	❑	❑	❑
2. Epaule / bras	❑	❑	❑	❑	❑
3. Coude/ avant-bras	❑	❑	❑	❑	❑
4. Main / poignet	❑	❑	❑	❑	❑
5. Doigts	❑	❑	❑	❑	❑
6. Haut du dos	❑	❑	❑	❑	❑
7. Bas du dos	❑	❑	❑	❑	❑
8. Hanche / cuisse	❑	❑	❑	❑	❑
9. Genou / jambe	❑	❑	❑	❑	❑
10. Cheville / pied	❑	❑	❑	❑	❑

9 – Si vous avez souffert de douleurs du bas du dos (lombalgies) *<u>au moins un jour au cours des 12 derniers mois</u>*, s'agissait-il de ?

Sciatique, avec des douleurs s'étendant plus bas que le genou	Oui.......❑	Non.......❑
Sciatique, avec des douleurs ne dépassant pas le genou	Oui.......❑	Non.......❑
Lumbago (douleur lombaire aiguë localisée)	Oui.......❑	Non.......❑
Autre type de lombalgie	Oui.......❑	Non.......❑

10 – Avez-vous eu, au cours *__des 7 derniers jours,__* des problèmes (courbatures, douleurs, gêne, engourdissement) au niveau des zones du corps suivantes ?
Pour chacune des zones du corps, cochez la case correspondante

1. Nuque / cou	Oui....❑	Non...❑				
2. Epaule / bras	Oui....❑	Non...❑	**Si oui,**	du côté droit...❑	du côté gauche...❑	des deux côtés...❑
3. Coude/ avant-bras	Oui....❑	Non...❑	**Si oui,**	du côté droit...❑	du côté gauche...❑	des deux côtés...❑
4. Main / poignet	Oui....❑	Non...❑	**Si oui,**	du côté droit...❑	du côté gauche...❑	des deux côtés...❑
5. Doigts	Oui....❑	Non...❑	**Si oui,**	du côté droit...❑	du côté gauche...❑	des deux côtés...❑
6. Haut du dos	Oui....❑	Non...❑				
7. Bas du dos	Oui....❑	Non...❑				
8. Hanche / cuisse	Oui....❑	Non...❑	**Si oui,**	du côté droit...❑	du côté gauche...❑	des deux côtés...❑
9. Genou / jambe	Oui....❑	Non...❑	**Si oui,**	du côté droit...❑	du côté gauche...❑	des deux côtés...❑
10. Cheville / pied	Oui....❑	Non...❑	**Si oui,**	du côté droit...❑	du côté gauche...❑	des deux côtés...❑

Si vous avez répondu *Non* à toutes ces questions, passez directement à la *question 12.*

11 - Comment évaluez-vous l'intensité de ce problème *__au moment où vous remplissez le questionnaire__*, sur l'échelle ci-dessous ?
Pour chacune des zones du corps, entourez la case correspondante

1. Nuque / cou	Ni gêne ni douleur	→	**|_0_|_1_|_ 2_|_3_|_4_|_5_|_6_|_7_|_8_|_9_|_10_|**	←	gêne ou douleur intolérable
2. Epaule / bras	Ni gêne ni douleur	→	**|_0_|_1_|_ 2_|_3_|_4_|_5_|_6_|_7_|_8_|_9_|_10_|**	←	gêne ou douleur intolérable
3. Coude/ avant-bras	Ni gêne ni douleur	→	**|_0_|_1_|_ 2_|_3_|_4_|_5_|_6_|_7_|_8_|_9_|_10_|**	←	gêne ou douleur intolérable
4. Main / poignet	Ni gêne ni douleur	→	**|_0_|_1_|_ 2_|_3_|_4_|_5_|_6_|_7_|_8_|_9_|_10_|**	←	gêne ou douleur intolérable
5. Doigts	Ni gêne ni douleur	→	**|_0_|_1_|_ 2_|_3_|_4_|_5_|_6_|_7_|_8_|_9_|_10_|**	←	gêne ou douleur intolérable
6. Haut du dos	Ni gêne ni douleur	→	**|_0_|_1_|_ 2_|_3_|_4_|_5_|_6_|_7_|_8_|_9_|_10_|**	←	gêne ou douleur intolérable
7. Bas du dos	Ni gêne ni douleur	→	**|_0_|_1_|_ 2_|_3_|_4_|_5_|_6_|_7_|_8_|_9_|_10_|**	←	gêne ou douleur intolérable
8. Hanche / cuisse	Ni gêne ni douleur	→	**|_0_|_1_|_ 2_|_3_|_4_|_5_|_6_|_7_|_8_|_9_|_10_|**	←	gêne ou douleur intolérable
9. Genou / jambe	Ni gêne ni douleur	→	**|_0_|_1_|_ 2_|_3_|_4_|_5_|_6_|_7_|_8_|_9_|_10_|**	←	gêne ou douleur intolérable
10. Cheville / pied	Ni gêne ni douleur	→	**|_0_|_1_|_ 2_|_3_|_4_|_5_|_6_|_7_|_8_|_9_|_10_|**	←	gêne ou douleur intolérable

CONCERNANT VOTRE TRAVAIL

12 – En quelle année avez-vous commencé votre vie professionnelle ? …………………………………………………………………………. |__|__|__|__|

13 – Dans quel département travaillez-vous actuellement ? (*notez le numéro du département 44, 49, 53, 72 ou 85)*……………………… |__|__|

14 – Dans quel secteur d'activité travaillez-vous actuellement ? *Cochez une seule case*

1. Agriculture ………………………………………………………………………………………………… ❑ 1
2. Secteur privé non agricole ………………………………………………………………………………… ❑ 2
3. Secteur public ……………………………………………………………………………………………… ❑ 3

15 – Etes-vous ? *Cochez une seule case*

1. Manœuvre ou ouvrier(ère) spécialisé(e) (OS1, OS2, OS3, etc.) ……………………………………………. ❑ 1
2. Ouvrier(ère) qualifié(e) ou hautement qualifié(e) (P1, P2, P3, TA, OQ) …………………………………. ❑ 2
3. Agent de maîtrise dirigeant les ouvriers, maîtrise administrative ou commerciale ……………………….. ❑ 3
4. Agent de maîtrise dirigeant des techniciens ou d'autres agents de maîtrise ………………………………. ❑ 4
5. Technicien(en), dessinateur(rice), VRP (non cadre) ………………………………………………………. ❑ 5
6. Instituteur(rice), assistant(e) social(e), infirmier(ère) et autre personnel de catégories B de la fonction publique ………………. ❑ 6
7. Ingénieur ou cadre ………………………………………………………………………….. ❑ 7
8. Professeur et personnel de catégories A de la fonction publique ……………………………………………. ❑ 8
9. Employé(e) de bureau ou employé(e) de commerce ……………………………………………………… ❑ 9
10. Agent de service, aide soignant(e) ou gardien(ne) d'enfant………………………………………… ❑ 10
11. Autre cas (précisez en clair) : ______________________________________ ❑ 11

16 – Quel est votre contrat de travail actuel ? *Cochez une seule case*

1. Emploi sans limite de durée (CDI) ……………………………………………………… ❑ 1
2. Sous contrat à durée déterminée (CDD) ou autre emploi à durée limitée (contrat saisonnier, etc.) ……………………… ❑ 2
3. Intérimaire (placé par une agence d'intérim)……………………………………………… ❑ 3
4. Fonctionnaire …………………………………………………………………………. ❑ 4
5. Apprenti(e) ou contrat de formation à l'emploi en alternance……………………………… ❑ 5
6. Stagiaire ou contrat de mesure pour l'emploi ……………………………………………….. ❑ 6

17 - Quel emploi occupez-vous actuellement ? *(Précisez en clair l'intitulé) :* ______________________________

ne pas remplir PCS|__|__|__|__|

18 - Quelle est votre ancienneté dans l'emploi actuel ?

Moins de 1 an ...❑ 1   1 - 2 ans...❑ 2   3 - 10 ans...❑ 3   Plus de 10 ans...❑ 4

19 – Pouvez-vous décrire les principales tâches ou activités que vous devez accomplir dans votre emploi actuel ? ______________________________

____

____

20 - Quel nombre d'heures de travail avez-vous effectué lors de la dernière semaine travaillée ? .... |__|__| heures

21 - Votre durée de travail hebdomadaire est-elle variable ? Oui ...❑ Non ...❑

22 - Vous arrive-t-il de travailler, certains jours ou certaines semaines, plus longtemps que l'horaire officiellement prévu ? Oui ...❑ Non ...❑

23 – Quel type d'horaires de travail avez-vous ? (une seule réponse)

Horaire normal ou régulier...................................... ❑ 1
Horaires variables ou décalés...................................... ❑ 2

24 – Travaillez vous en équipe postée? (une seule réponse)

Non .... ❑ 1
Oui, en équipe fixe .... ❑ 2
Oui, en équipe alternante (en 2 x 8, en 3 x 8 ou plus) .... ❑ 3

25 - Quand vous embauchez le matin ou en début de poste, savez-vous quelles sont les tâches que vous aurez à effectuer au cours de votre journée de travail ?

Jamais ...❑ 1   Rarement ...❑ 2   Souvent ...❑ 3   Toujours...❑ 4

26- Travaillez-vous souvent avec des collègues qui se trouvent en situation précaire (CDD, intérimaires) ?

Jamais ...❑ 1   Rarement ...❑ 2   Souvent ...❑ 3   Toujours...❑ 4

27 - Occupez-vous différents postes ou fonctions (polyvalence) au cours de votre travail ?

Presque jamais / jamais .... ❑ 1
1 à 3 jours par mois .... ❑ 2
1 jour par semaine .... ❑ 3
2 à 4 jours par semaine .... ❑ 4
Tous les jours .... ❑ 5

28 - Y a-t-il dans votre travail des changements de fabrication ou de produits ?

Au cours de la journée	Oui ... ❑	Non ... ❑	Sans objet ... ❑
Au cours d'une heure de travail	Oui ... ❑	Non ... ❑	Sans objet ... ❑

29 - Certains éléments de votre salaire dépendent-ils de la quantité ou de la qualité de votre travail ? Oui ... ❑ Non ... ❑

Les questions suivantes se rapportent à une journée typique de travail AU COURS DES 12 DERNIERS MOIS

30 - Comment évaluez-vous l'intensité des efforts physiques de votre travail au cours d'une journée typique de travail ?
*Entourez **le chiffre** correspondant à votre choix sur l'échelle graduée de 6 à 20 ci-dessous, qui va de "pas d'effort du tout" à "épuisant" :*

6 ….. pas d'effort du tout
7 ….. extrêmement léger
8
9 ….. très léger
10
11 ….. léger
12
13 ….. un peu dur
14
15 ….. dur
16
17 ….. très dur
18
19 ….. extrêmement dur
20 ….. épuisant

31 - Au cours d'une journée de travail typique, votre rythme de travail vous est-il imposé par ?

1. Le déplacement automatique d'un produit ou d'une pièce ………………..	Oui….❑	Non...❑
2. La cadence automatique d'une machine ………………..	Oui….❑	Non...❑
3. D'autres contraintes techniques ………………..	Oui….❑	Non...❑
4. La dépendance immédiate vis-à-vis du travail d'un ou plusieurs collègues ………………..	Oui….❑	Non...❑
5. Des normes de production, ou des délais, à respecter ………………..	Oui….❑	Non...❑
6. Une demande extérieure (public, client) ………………..	Oui….❑	Non...❑
~~7.~~ Les contrôles ou une surveillance permanents………………..	Oui….❑	Non...❑

32 - Votre travail nécessite-t-il habituellement de répéter les mêmes actions plus de 2 à 4 fois environ <u>par minute ?</u>

Jamais ...❑ 1 Moins de 2 heures par jour ...❑ 2 De 2 à 4 heures par jour....❑ 3 Plus de 4 heures par jour ....❑ 4

33 – Si votre rythme de travail est imposé par la cadence d'une machine ou le déplacement d'un produit ou d'une pièce, devez vous ?

1. suivre un temps de cycle de travail de 30 secondes ou moins ? oui...❑ 1 non ...❑ 2 sans objet....❑ 2
2. répéter les mêmes gestes la moitié du cycle de travail ? oui...❑ 1 non ...❑ 2 sans objet....❑ 2

34 - Comment évaluez-vous la répétitivité de vos gestes au cours de votre travail sur l'échelle ci-dessous ? (mettez une croix dans la case correspondant à votre choix)

Répétitivité nulle |______|______|______|______|______|______|______|______|______|______| Répétitivité maximale

35 - Pouvez-vous interrompre votre travail ou changer de tâche ou d'activité pendant 10 minutes ou plus chaque heure ?

Jamais ...❑ 1 Rarement ...❑ 2 Souvent ...❑ 3 Toujours...❑ 4

36 - Au cours d'une journée typique de travail, pouvez-vous quitter votre travail des yeux pendant quelques secondes ?

Jamais ...❑ 1 Rarement ...❑ 2 Souvent ...❑ 3 Toujours...❑ 4

37- Au cours d'une journée typique de travail, devez-vous faire des gestes précis ?

Non ou presque jamais ...❑ 1 Rarement (< 2 heures par jour) ...❑ 2 Souvent (2 à 4 heures par jour)....❑ 3 Toujours ou presque toujours...❑ 4

38- Au cours d'une journée typique de travail, êtes-vous assis ?

Non ou presque jamais ...❑ 1 Rarement (< 2 heures par jour) ...❑ 2 Souvent (2 à 4 heures par jour)....❑ 3 Toujours ou presque toujours...❑ 4

39 - Au cours d'une journée typique de travail, devez-vous vous agenouiller ou vous accroupir ?

Non ou presque jamais ...❑ 1 Rarement (< 2 heures par jour) ...❑ 2 Souvent (2 à 4 heures par jour)....❑ 3 Toujours ou presque toujours...❑ 4

40 - Au cours d'une journée typique de travail, devez-vous vous pencher en avant régulièrement ou de manière prolongée ?

Non ou presque jamais ...❑ 1 Rarement (< 2 heures par jour) ...❑ 2 Souvent (2 à 4 heures par jour)....❑ 3 Toujours ou presque toujours...❑ 4

41 - Au cours d'une journée typique de travail, devez-vous vous pencher sur le côté régulièrement ou de manière prolongée ?

Non ou presque jamais ...❑ 1 Rarement (< 2 heures par jour) ...❑ 2 Souvent (2 à 4 heures par jour)....❑ 3 Toujours ou presque toujours...❑ 4

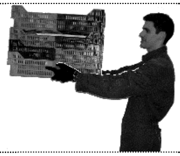
42 - Au cours d'une journée typique de travail, devez-vous travailler sur des surfaces glissantes ou irrégulières ?

Non ou presque jamais …❑ 1 Rarement (< 2 heures par jour) …❑ 2 Souvent (2 à 4 heures par jour)….❑ 3 Toujours ou presque toujours...❑ 4

43 – Au cours d'une journée typique de travail, combien de temps passez-vous à porter une charge qui pèse ? *Cocher la case correspondant ci-dessous*

Moins de 10 kg	Jamais ou presque jamais. ❑ 1	Rarement (moins de 2 heures/ jour).❑ 2	Souvent (2 à 4 heures/ jour).❑ 3	Toujours ou la plupart du temps (plus de 4 heures/jour).❑ 4
10 à 25 kg	Jamais ou presque jamais. ❑ 1	Rarement (moins de 2 heures/ jour).❑ 2	Souvent (2 à 4 heures/ jour).❑ 3	Toujours ou la plupart du temps (plus de 4 heures/jour).❑ 4
Plus de 25 kg	Jamais ou presque jamais. ❑ 1	Rarement (moins de 2 heures/ jour).❑ 2	Souvent (2 à 4 heures/ jour).❑ 3	Toujours ou la plupart du temps (plus de 4 heures/jour).❑ 4

44 - Au cours d'une journée typique de travail, combien de temps passez-vous à faire les tâches ou activités suivantes ?
Entourez la case correspondant à la bonne durée pour chaque tâche ou activité décrite ci-dessous

Porter des objets encombrants et volumineux les bras tendus		Jamais ou presque jamais ………………….. Rarement (moins de 2 heures / jour)… Souvent (2 à 4 heures / jour)…………… La plupart du temps (plus de 4 heures/jour)	❑ 1 ❑ 2 ❑ 3 ❑ 4
Porter des objets difficiles à attraper, instables ou sans poignée		Jamais ou presque jamais ….……………… Rarement (moins de 2 heures / jour)… Souvent (2 à 4 heures / jour)…………… La plupart du temps (plus de 4 heures/jour)	❑ 1 ❑ 2 ❑ 3 ❑ 4
Pousser ou tirer des charges (cartons, tiroirs, etc.)		Jamais ou presque jamais …………………….. Rarement (moins de 2 heures / jour)…… Souvent (2 à 4 heures / jour)……………….. La plupart du temps (plus de 4 heures/jour)	❑ 1 ❑ 2 ❑ 3 ❑ 4

45 - Au cours d'une journée typique de travail, conduisez-vous un engin de chantier, un tracteur ou un chariot automoteur ?

Non ou presque jamais …❑ 1 Moins de 4 heures par jour …❑ 2 Plus de 4 heures par jour…❑ 3

46 - Au cours d'une journée typique de travail, conduisez-vous un véhicule (automobile, camion, autocar, autobus) sur la voie publique (trajet domicile –travail inclus)?

Non ou presque jamais …❑ 1 Moins de 4 heures par jour …❑ 2 Plus de 4 heures par jour…❑ 3

47 – Au cours d'une journée typique de travail, combien de temps passez-vous à manipuler régulièrement une charge ou un objet qui pèse ?

1 à 4 kg Jamais ou presque jamais. ❑ 1 Rarement (moins de 2 heures/ jour).❑ 2 Souvent (2 à 4 heures/ jour).❑ 3 Toujours ou la plupart du temps (plus de 4 heures/jour)..❑ 4

Plus de 4 kg Jamais ou presque jamais. ❑ 1 Rarement (moins de 2 heures/ jour).❑ 2 Souvent (2 à 4 heures/ jour).❑ 3 Toujours ou la plupart du temps (plus de 4 heures/jour)..❑ 4

48 - Comment estimez-vous la force habituellement requise par votre travail ? (mettez une croix dans la case correspondant au niveau d'effort auquel vous vous situez)

Effort nul |______|______|______|______|______|______|______|______|______|______| Effort maximal

49 - Au cours d'une journée typique de travail, utilisez-vous des outils tenus en main ?

Jamais ou presque jamais …❑ Rarement …❑ Souvent …❑ Toujours ou la plupart du temps …❑

50 - Au cours d'une journée typique de travail, utilisez-vous des outils vibrants ou devez-vous poser la (es) main(s) sur des machines vibrantes ?

Jamais ou presque jamais …❑ Rarement …❑ Souvent …❑ Toujours ou la plupart du temps …❑

51 - Au cours d'une journée typique de travail, devez-vous porter des gants ?

Jamais ou presque jamais …❑ Rarement …❑ Souvent …❑ Toujours ou la plupart du temps …❑

52 - Au cours d'une journée typique de travail, manipulez-vous des objets froids (moins de 15° C) ou travaillez-vous au froid (moins de 15° C) ?

Jamais ou presque jamais …❑ Rarement …❑ Souvent …❑ Toujours ou la plupart du temps …❑

53 - Au cours de votre travail habituel, utilisez-vous ?

- **Un écran d'ordinateur ou de contrôle**

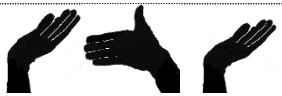
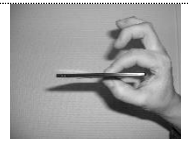
Non ou presque jamais …❑ 1 Rarement (moins de 2 heures par jour) …❑ 2 Souvent (2 à 4 heures par jour)….❑ 3 Toujours ou presque toujours...❑ 4

- **Un clavier pour saisir des données ou une souris ou un dispositif analogue d'entrée de données (crayon optique, scanner, douchette, etc.)**

Non ou presque jamais …❑ 1 Rarement (moins de 2 heures par jour) …❑ 2 Souvent (2 à 4 heures par jour)….❑ 3 Toujours ou presque toujours...❑ 4

54 - Combien de temps devez-vous adopter les positions suivantes au cours d'une journée typique de travail ? *Cochez la case correspondant à la bonne durée pour chaque tâche ou activité décrite ci-dessous*

Pencher la tête *en avant* régulièrement ou de manière prolongée		Jamais ou presque jamais .... Rarement (moins de 2 heures / jour)...... Souvent (2 à 4 heures / jour)............... La plupart du temps (plus de 4 heures/jour)	❑ 1 ❑ 2 ❑ 3 ❑ 4
Pencher la tête *en arrière* régulièrement ou de manière prolongée		Jamais ou presque jamais .... Rarement (moins de 2 heures / jour)...... Souvent (2 à 4 heures / jour)............... La plupart du temps (plus de 4 heures/jour)	❑ 1 ❑ 2 ❑ 3 ❑ 4
Travailler avec un ou deux bras en l'air (au-dessus des épaules) régulièrement ou de manière prolongée		Jamais ou presque jamais .... Rarement (moins de 2 heures / jour)...... Souvent (2 à 4 heures / jour)............... La plupart du temps (plus de 4 heures/jour)	❑ 1 ❑ 2 ❑ 3 ❑ 4
Attraper régulièrement des objets derrière le dos		Jamais ou presque jamais .... Rarement (moins de 2 heures / jour)...... Souvent (2 à 4 heures / jour)............... La plupart du temps (plus de 4 heures/jour)	❑ 1 ❑ 2 ❑ 3 ❑ 4
Travailler avec un ou deux bras écartés du corps régulièrement ou de manière prolongée		Jamais ou presque jamais .... Rarement (moins de 2 heures / jour)...... Souvent (2 à 4 heures / jour)............... La plupart du temps (plus de 4 heures/jour)	❑ 1 ❑ 2 ❑ 3 ❑ 4
Reposer vos avant-bras sur un accoudoir ou un plan de travail		Jamais ou presque jamais .... Rarement (moins de 2 heures / jour)...... Souvent (2 à 4 heures / jour)............... La plupart du temps (plus de 4 heures/jour)	❑ 1 ❑ 2 ❑ 3 ❑ 4

Fléchir le(s) coude(s) régulièrement ou de manière prolongée		Jamais ou presque jamais .... ❑ 1 Rarement (moins de 2 heures / jour)...... ❑ 2 Souvent (2 à 4 heures / jour)............... ❑ 3 La plupart du temps (plus de 4 heures/jour) ❑ 4
Tourner la main comme pour visser		Jamais ou presque jamais .... ❑ 1 Rarement (moins de 2 heures / jour)...... ❑ 2 Souvent (2 à 4 heures / jour)............... ❑ 3 La plupart du temps (plus de 4 heures/jour) ❑ 4
Tordre le poignet		Jamais ou presque jamais .... ❑ 1 Rarement (moins de 2 heures / jour)...... ❑ 2 Souvent (2 à 4 heures / jour)............... ❑ 3 La plupart du temps (plus de 4 heures/jour) ❑ 4
Appuyer ou taper avec la base de la main sur un plan dur ou sur un outil		Jamais ou presque jamais .... ❑ 1 Rarement (moins de 2 heures / jour)...... ❑ 2 Souvent (2 à 4 heures / jour)............... ❑ 3 La plupart du temps (plus de 4 heures/jour) ❑ 4
Presser ou prendre fermement des objets ou des pièces entre le pouce et l'index		Jamais ou presque jamais .... ❑ 1 Rarement (moins de 2 heures / jour)...... ❑ 2 Souvent (2 à 4 heures / jour)............... ❑ 3 La plupart du temps (plus de 4 heures/jour) ❑ 4

Les questions suivantes se rapportent à votre <u>travail habituel</u> <u>au cours des 12 derniers mois</u>

*Veuillez cocher la case qui correspond le mieux à ce que vous ressentez. Cochez <u>une seule case</u> par question et **n'oubliez pas de répondre à toutes les questions.***

55 - Dans mon travail, je dois apprendre des choses nouvelles

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

56 - Dans mon travail, j'effectue des tâches répétitives

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

57 - Mon travail me demande d'être créatif

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

58 - Mon travail me permet souvent de prendre des décisions moi-même

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

59 - Mon travail demande un haut niveau de compétence

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

60 - Dans ma tâche, j'ai très peu de liberté pour décider comment je fais mon travail

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

61 - Dans mon travail, j'ai des activités variées

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

62 - J'ai la possibilité d'influencer le déroulement de mon travail

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

63 - J'ai l'occasion de développer mes compétences professionnelles

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

64 - Mon travail demande de travailler très vite

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

65 - Mon travail demande de travailler intensément

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

66 – On ne me demande pas d'effectuer une quantité de travail excessive

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

67 - Je dispose du temps nécessaire pour exécuter mon travail

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

68 - Je reçois des ordres contradictoires de la part d'autres personnes

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

69 - Mon travail nécessite de longues périodes de concentration intense

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

70 - Mes tâches sont souvent interrompues avant d'être achevées, nécessitant de les reprendre plus tard

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

71- Mon travail est très « bousculé »

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

72 - Attendre le travail de collègues ou d'autres départements ralentit souvent mon propre travail

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

73 - Mon supérieur se sent concerné par le bien-être de ses subordonnés

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

74 - Mon supérieur prête attention à ce que je dis

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

75 - Mon supérieur m'aide à mener ma tâche à bien

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

76 - Mon supérieur réussit facilement à faire collaborer ses subordonnés

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

77 - Les collègues avec qui je travaille sont des gens professionnellement compétents

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

78 - Les collègues avec qui je travaille me manifestent de l'intérêt

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

79 - Les collègues avec qui je travaille sont amicaux

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

80 - Les collègues avec qui je travaille m'aident à mener les tâches à bien

Pas du tout d'accord ...❑ 1 Pas d'accord ...❑ 2 D'accord ...❑ 3 Tout à fait d'accord...❑ 4

REMARQUES EVENTUELLES CONCERNANT VOTRE SANTE OU VOTRE TRAVAIL (à écrire au verso)

Nous vous remercions de votre participation, n'oubliez pas de remettre ce questionnaire à votre médecin du travail et d'en parler avec lui (elle) si nécessaire

Appendix 2. The clinical examination protocol for the diagnosis of work-related upper extremity musculoskeletal disorders and the clinical manipulations performed during the examination (SALTSA consensus)

III. SYMPTOMES DES MEMBRES SUPERIEURS AU COURS DES 12 DERNIERS MOIS ET DES 7 DERNIERS JOURS

1. Le salarié a-t-il eu, **au cours des 12 derniers mois**, des problèmes (courbatures, douleurs, gêne, engourdissement) au niveau des zones du corps suivantes ? *Pour chacune des zones du corps, cochez la case correspondante*

	Oui	Non		Du côté gauche	Du côté droit	Des deux côtés
Nuque / cou	❑	❑				
Epaule / bras	❑	❑	Si oui :	❑	❑	❑
Coude/ avant-bras	❑	❑	Si oui :	❑	❑	❑
Main / poignet	❑	❑	Si oui :	❑	❑	❑
Doigts	❑	❑	Si oui :	❑	❑	❑
Bas du dos	❑	❑				

Si vous avez répondu NON à toutes ces questions, **L'EXAMEN CLINIQUE STANDARDISE EST TERMINE.**

2. SI OUI, VEUILLEZ ENTOURER LA (ES) CASE(S) GRISEE(S) CORRESPONDANT A LA SITUATION CLINIQUE :

Régions concernées	**Cou** ❑	**Epaule et haut du bras** G ❑ D ❑	**Coude*** G ❑ D ❑	**Avant-bras*** G ❑ D ❑	**Poignet et main*** G ❑ D ❑
TMS spécifiques					
Syndrome de la coiffe des rotateurs		X Pages 8-11			
Epicondylite latérale			X Pages 12-13		
Syndrome du tunnel cubital			X (ulnaire) Pages 14-15	X (ulnaire) Pages 14-15	X (ulnaire) Pages 14-15
Syndrome du canal carpien					X (palmaire) Pages 16-19
Tendinite des fléchisseurs / extenseurs de l'avant-bras				X Pages 20-21	X Pages 20-21
Ténosynovite de De Quervain				X (radial) Pages 22-23	X (radial) Pages 22-23
TMS non spécifiques	X Page 24	X Page 24	X Page 24	X Page 24	X Page 24

* La zone anatomique précise figure entre parenthèses.

REMARQUES : ……

……

IV. ARBRES DIAGNOSTIQUES

Pour chaque TMS, il est nécessaire de préciser si l'arbre diagnostique s'y rapportant est à compléter ou non.

- En l'absence de symptômes au cours des 12 DERNIERS MOIS[1] **dans une région considérée,** aucun diagnostic n'est à évoquer **et** aucun arbre de la région considérée n'est à compléter.
- Dans le cas contraire, vous devez adopter la démarche suivante pour chaque région pour laquelle des symptômes ont été déclarés (cases grises entourées du tableau de la page précédente) :
  - ✓ 1er arbre : Est-ce une forme ***latente*** ou ***symptomatique*** du TMS ?
  - ✓ 2ème arbre : Est-ce une forme ***avérée*** du TMS (résultats positifs aux tests et manœuvres cliniques) ?

***La démarche diagnostique doit être effectuée séparément pour le côté gauche et le côté droit*.** Si le salarié présente une symptomatologie bilatérale, remplir les deux arbres, droit et gauche.
Ces arbres diagnostiques reprennent les critères qui figurent dans les tableaux du guide des manœuvres cliniques. Ce dernier précise les modalités de réalisation de chaque manœuvre dans des tableaux et sur des photos numérotées.

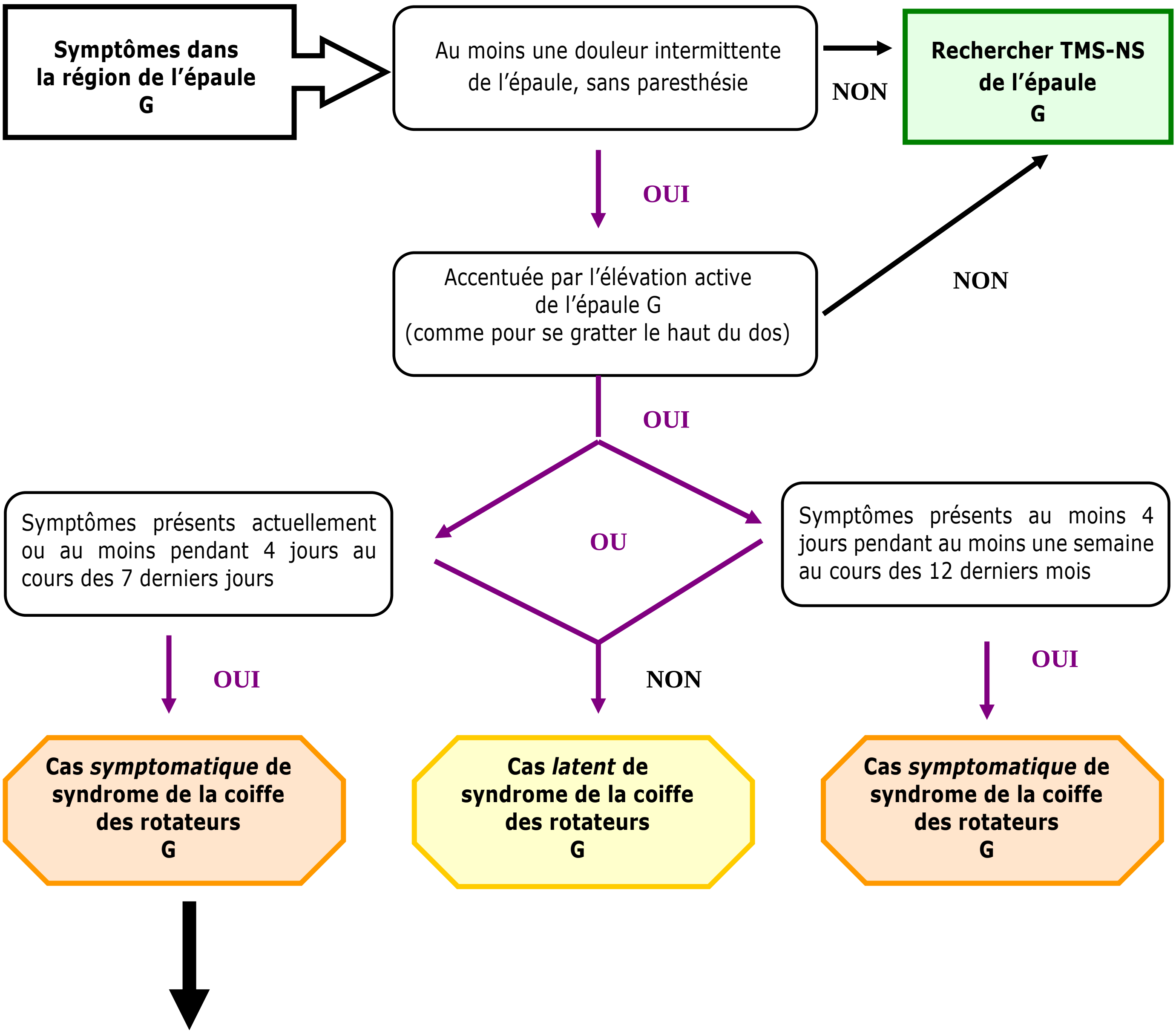
Lorsque plusieurs tests sont proposés et qu'un seul test positif est nécessaire au diagnostic du TMS considéré, il est possible d'arrêter la démarche diagnostique dès que l'un des tests est positif. Pour cela, il faut effectuer les manœuvres en respectant l'ordre proposé ***de haut en bas*** *et/ou* ***de gauche à droite****.*

- *A chaque étape de l'arbre diagnostique, il faut* ***entourer*** *:*
  - *L'une des bulles « cas symptomatique », « cas latent » ou « recherche autre TMS »*
  - *Ensuite, si une forme avérée doit être recherchée,* ***entourer le(s) test(s) positifs et barrer le(s) test(s) non réalisé(s).***

[1] Ainsi, si les derniers symptômes remontent à 18 mois, il n'est pas nécessaire de procéder à l'examen dans la région considérée.

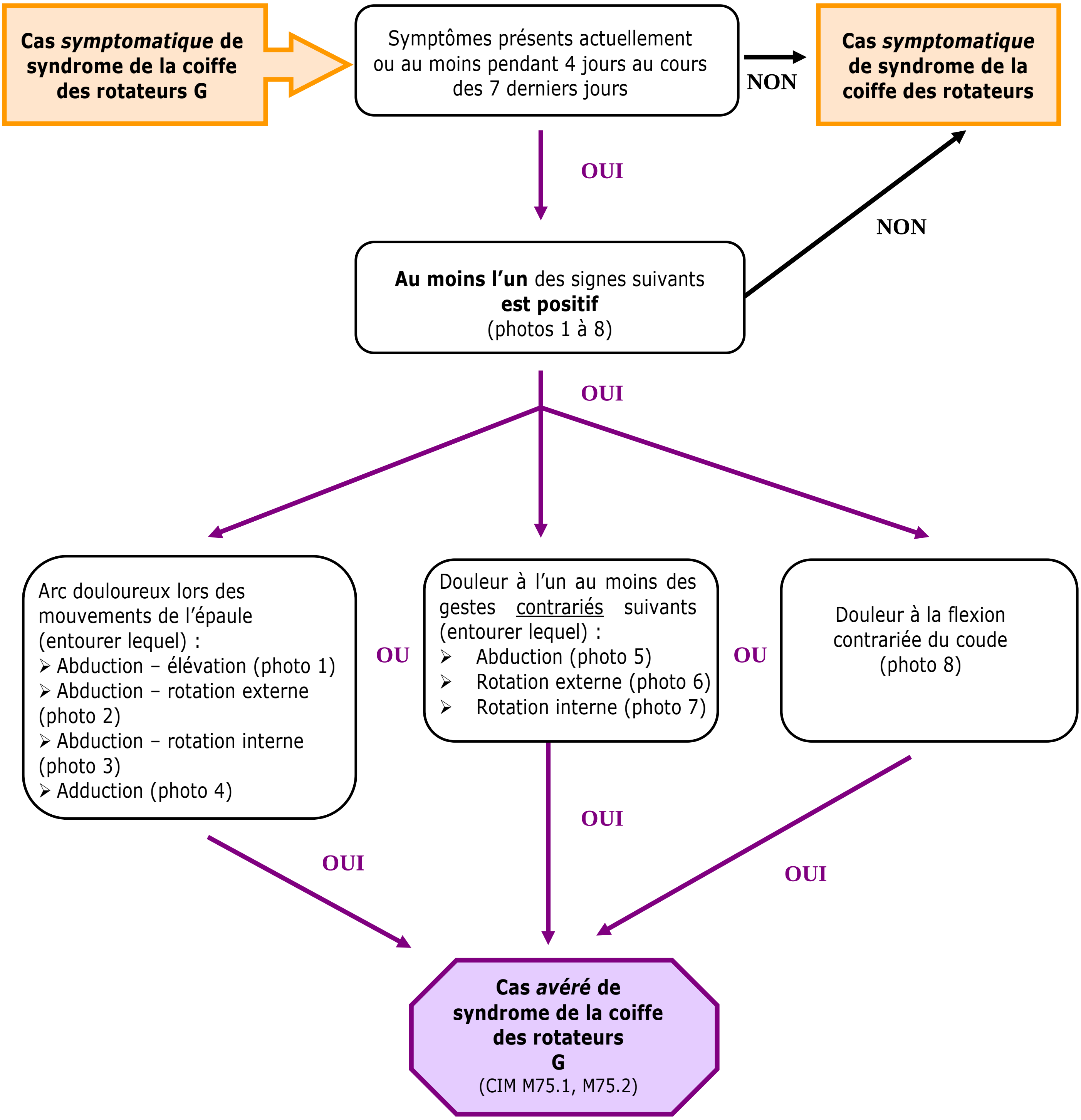
RECHERCHE (*entourer*) : OUI / NON

1) Recherche d'une forme *latente* ou *symptomatique*



Recherchez une forme *avérée*

2) Recherche d'une forme *avérée*

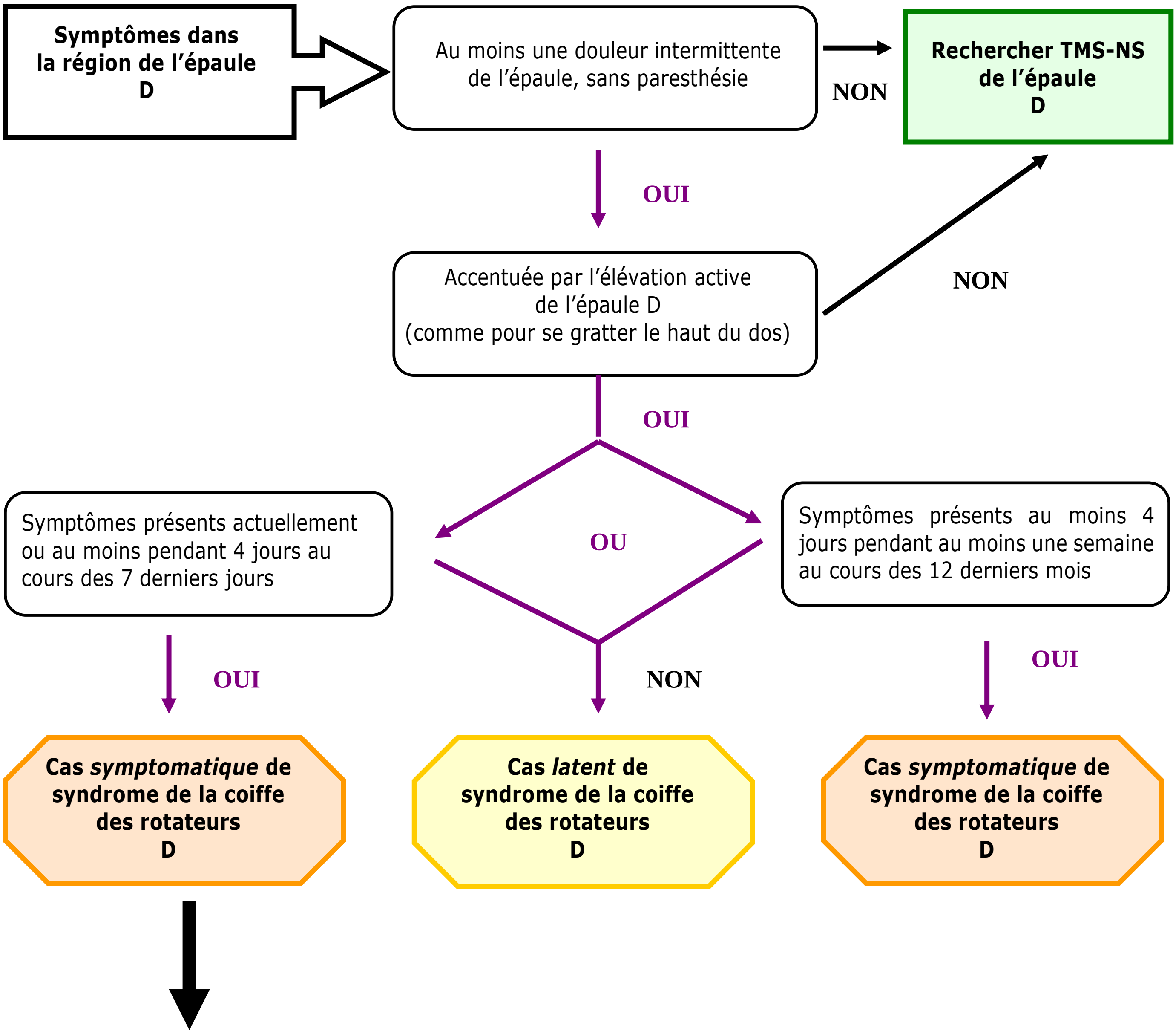


REMARQUES : ....

..

SYNDROME DE LA COIFFE DES ROTATEURS DROITE (p 1/2)

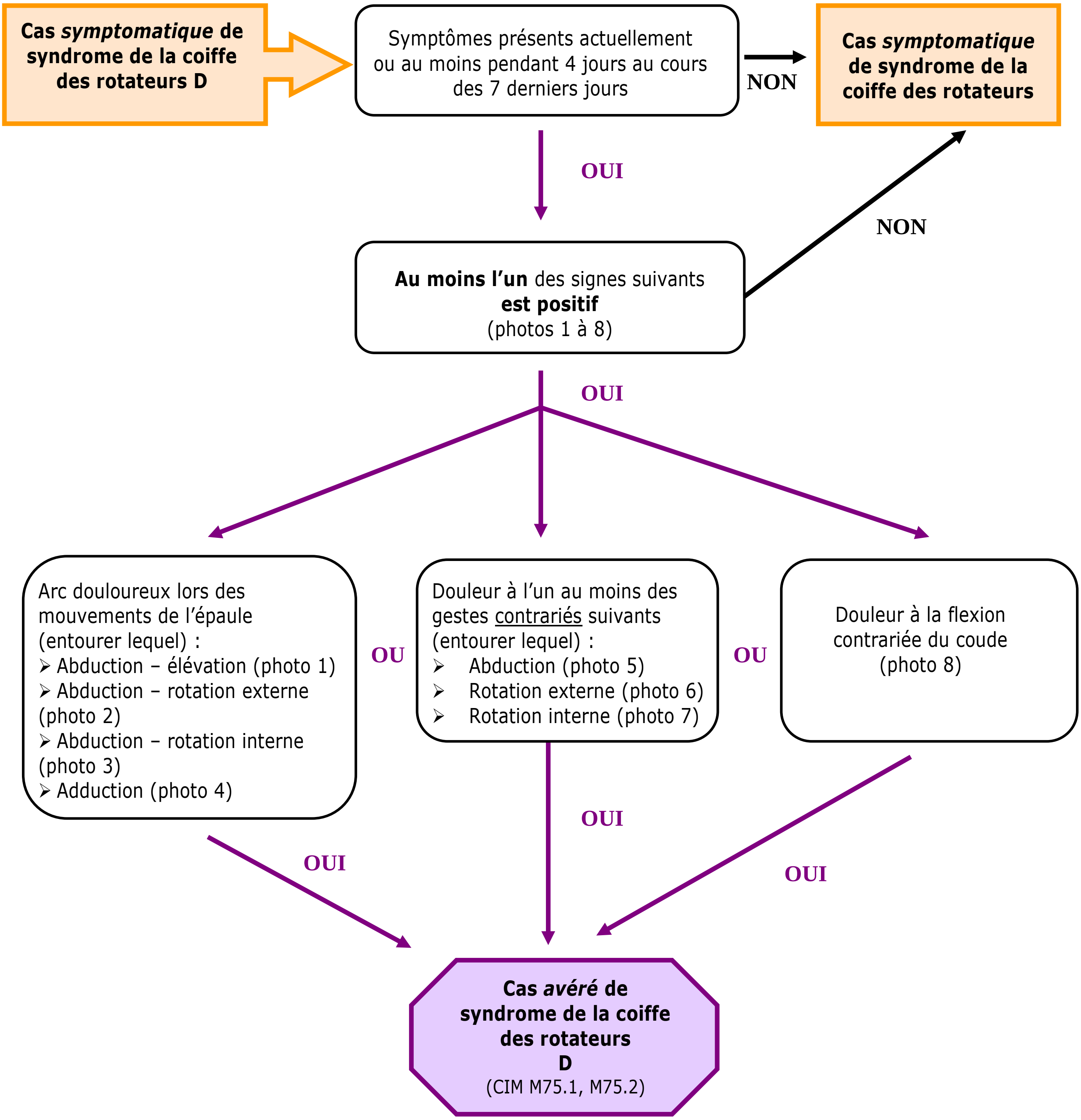
1) Recherche d'une forme *latente* ou *symptomatique*



Recherchez une forme *avérée* de tendinite de la coiffe des rotateurs D

SYNDROME DE LA COIFFE DES ROTATEURS DROITE (p 2/2)

2) Recherche d'une forme *avérée*

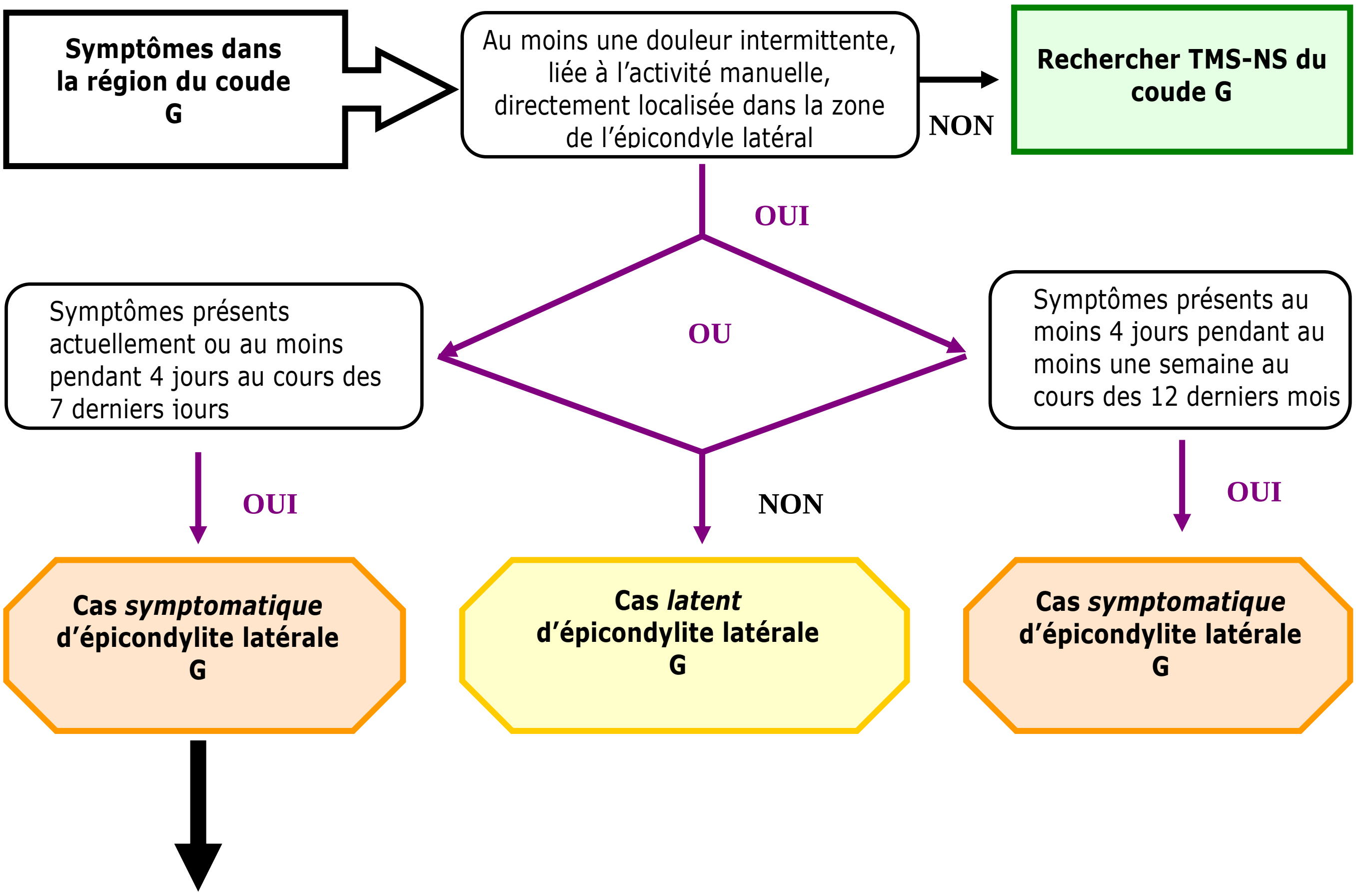


REMARQUES : ....

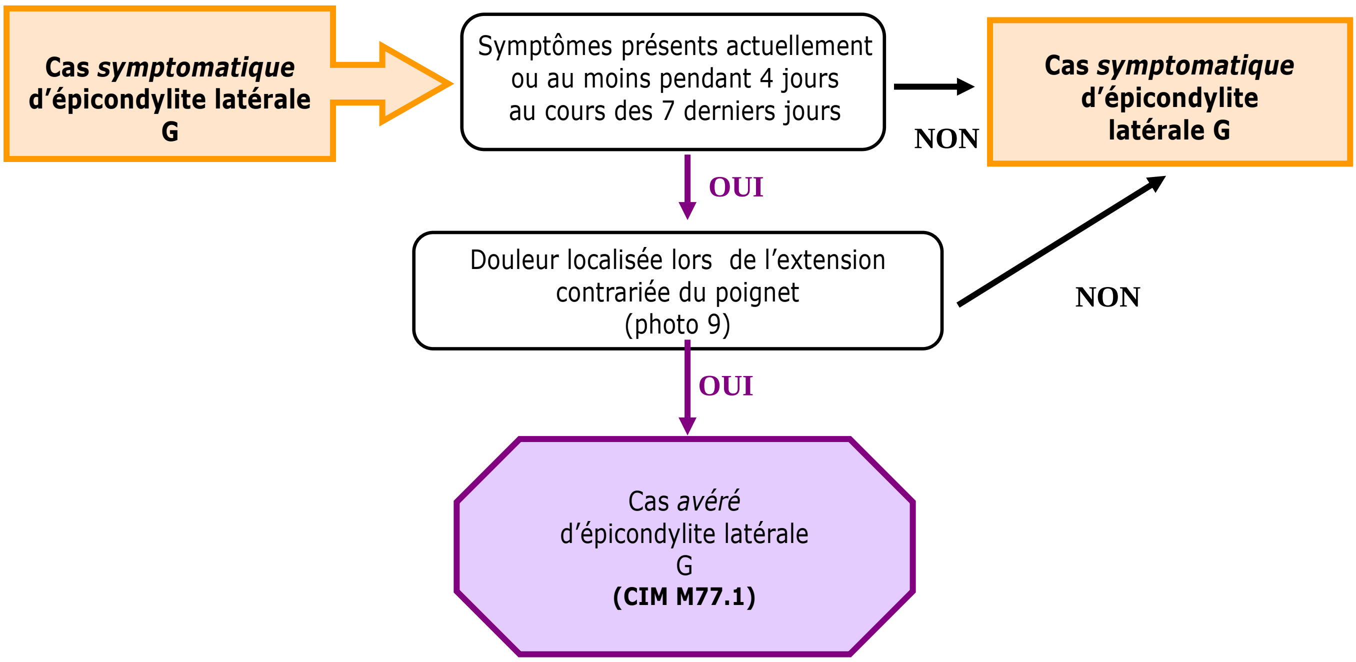
....

ÉPICONDYLITE LATÉRALE GAUCHE

1) Recherche d'une forme *latente* ou *symptomatique*

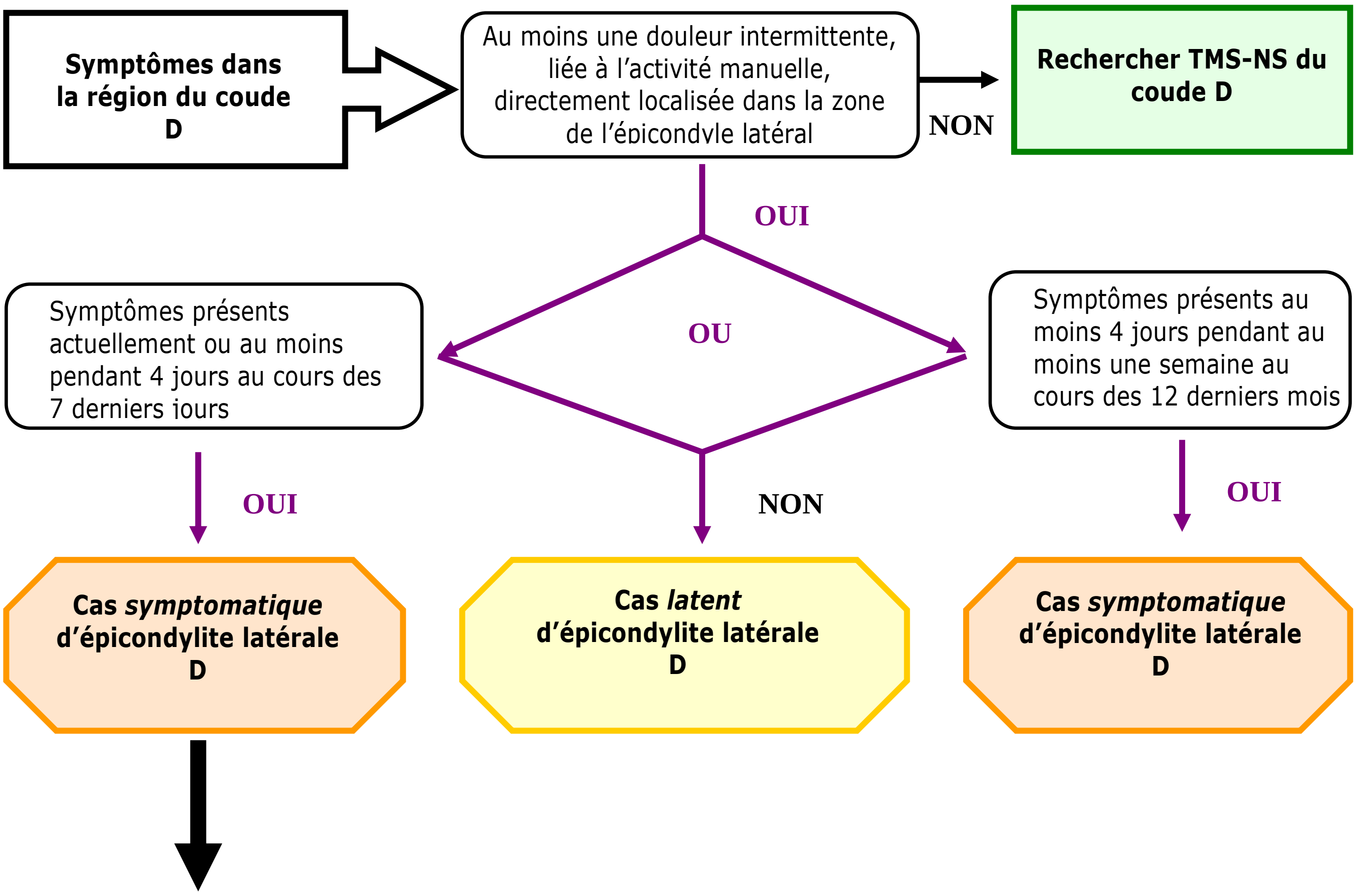


2) Recherche d'une forme *avérée*

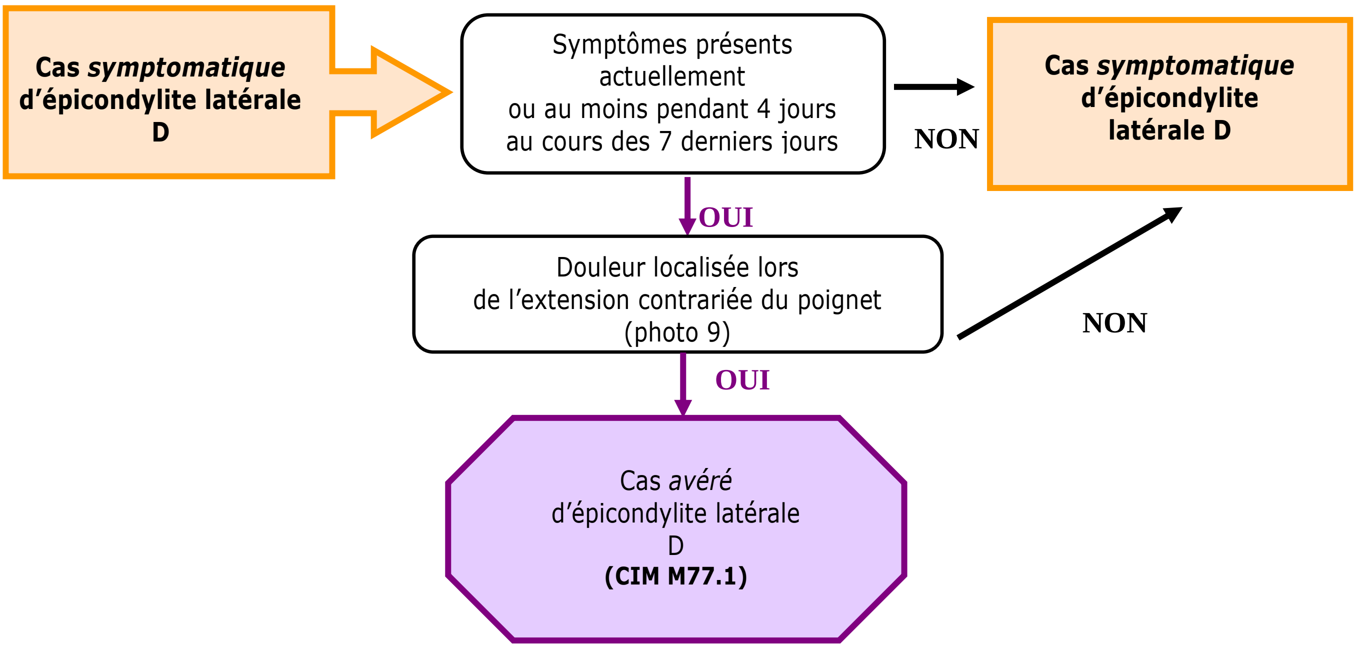


REMARQUES : ……………………………………………………………………………………

1) Recherche d'une forme *latente* ou *symptomatique*



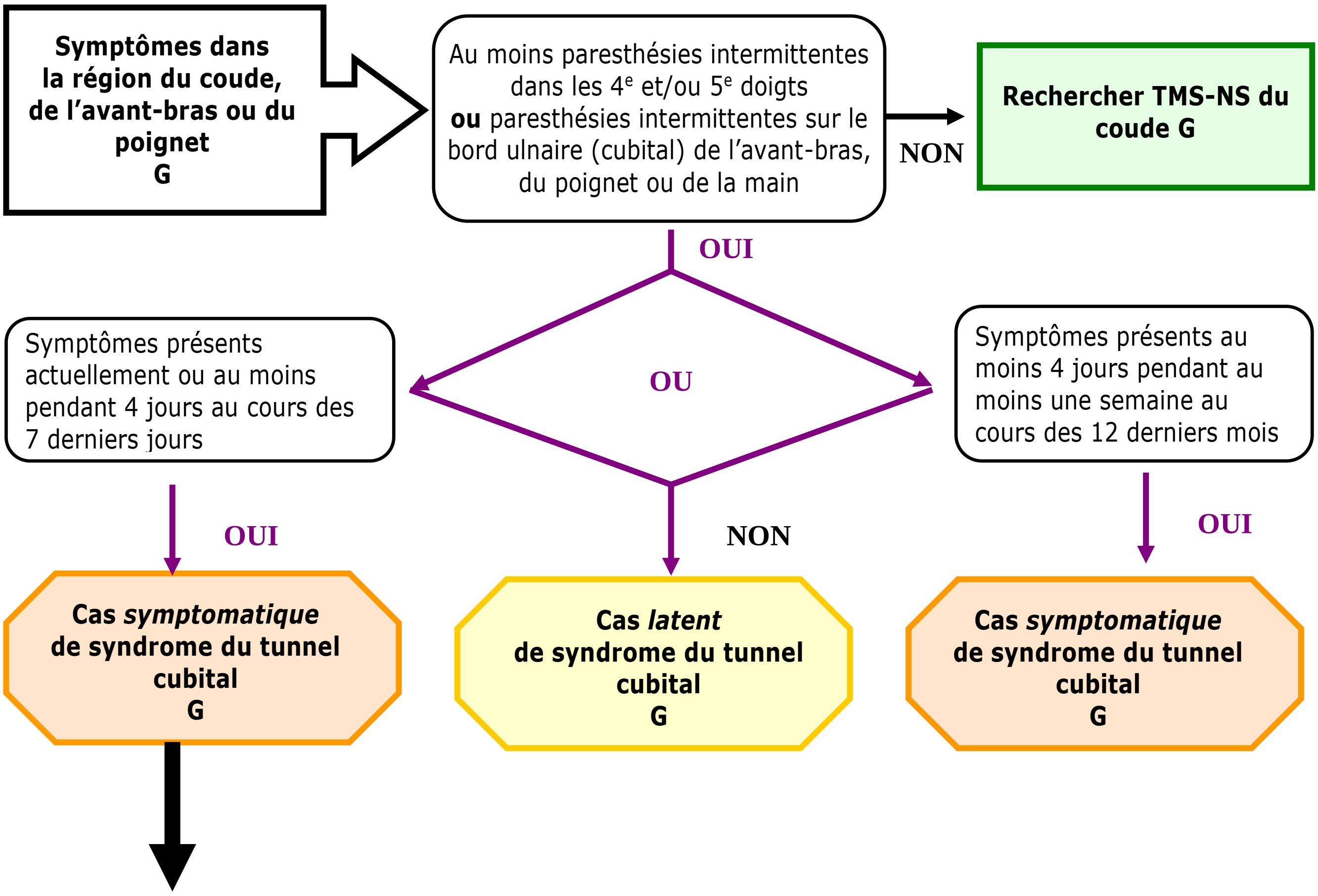
2) Recherche d'une forme *avérée*



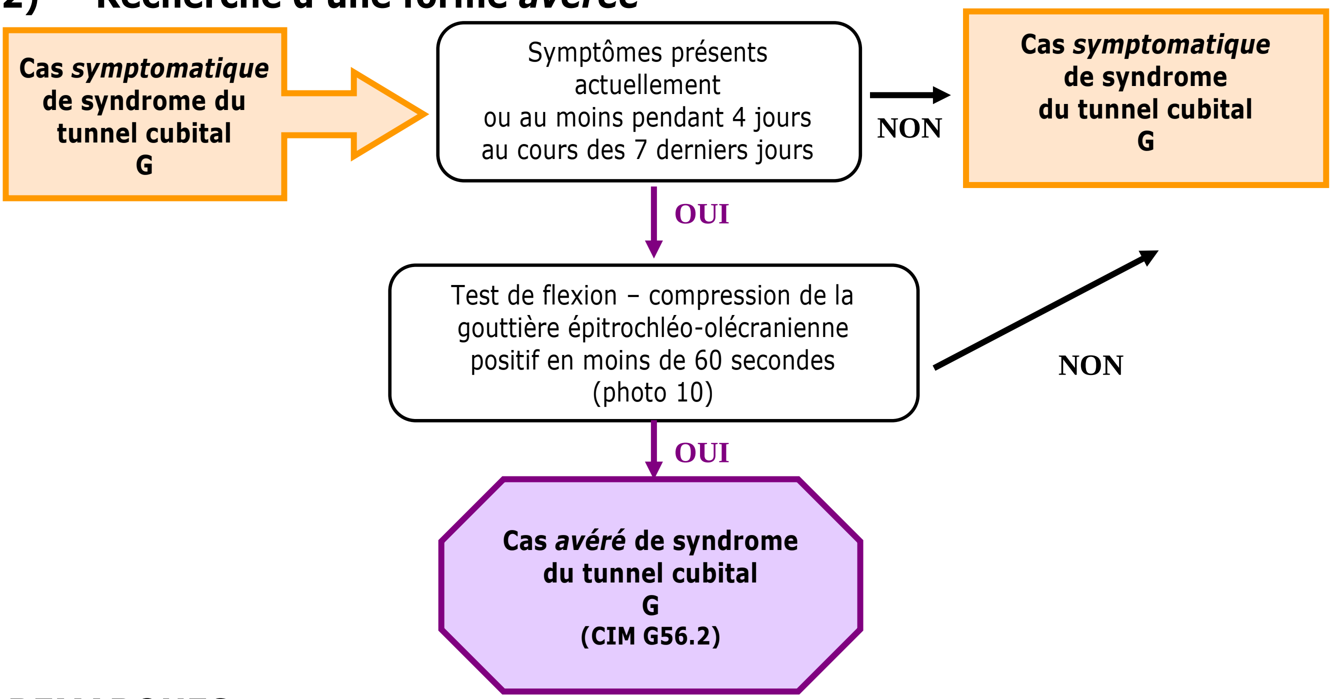
REMARQUES : ……………………………………………………………………………………

SYNDROME DU TUNNEL CUBITAL GAUCHE
Compression du nerf cubital dans la gouttière épitrochléo-olécranienne

1) Recherche d'une forme *latente* ou *symptomatique*



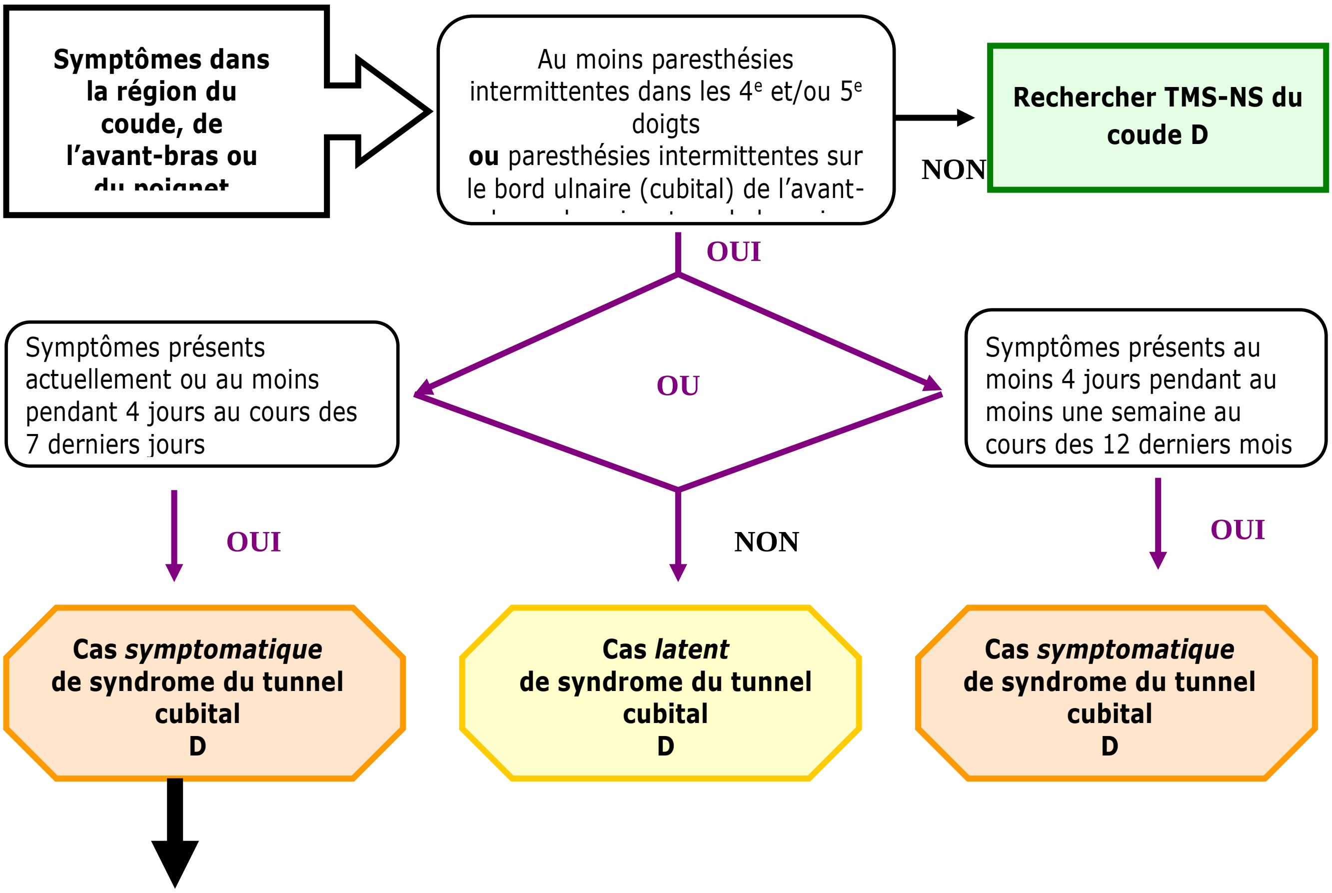
2) Recherche d'une forme *avérée*



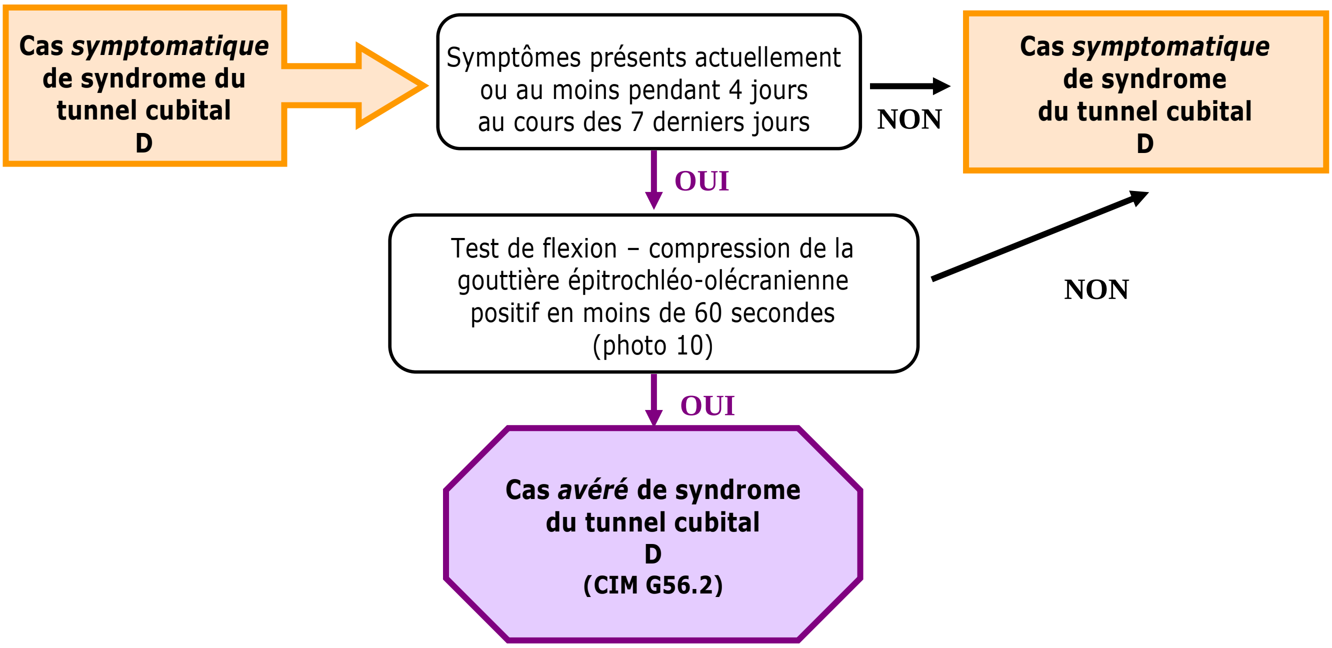
REMARQUES : ……………………………………………………………………………………

SYNDROME DU TUNNEL CUBITAL DROIT
Compression du nerf cubital dans la gouttière épitrochléo-olécranienne

1) Recherche d'une forme *latente* ou *symptomatique*

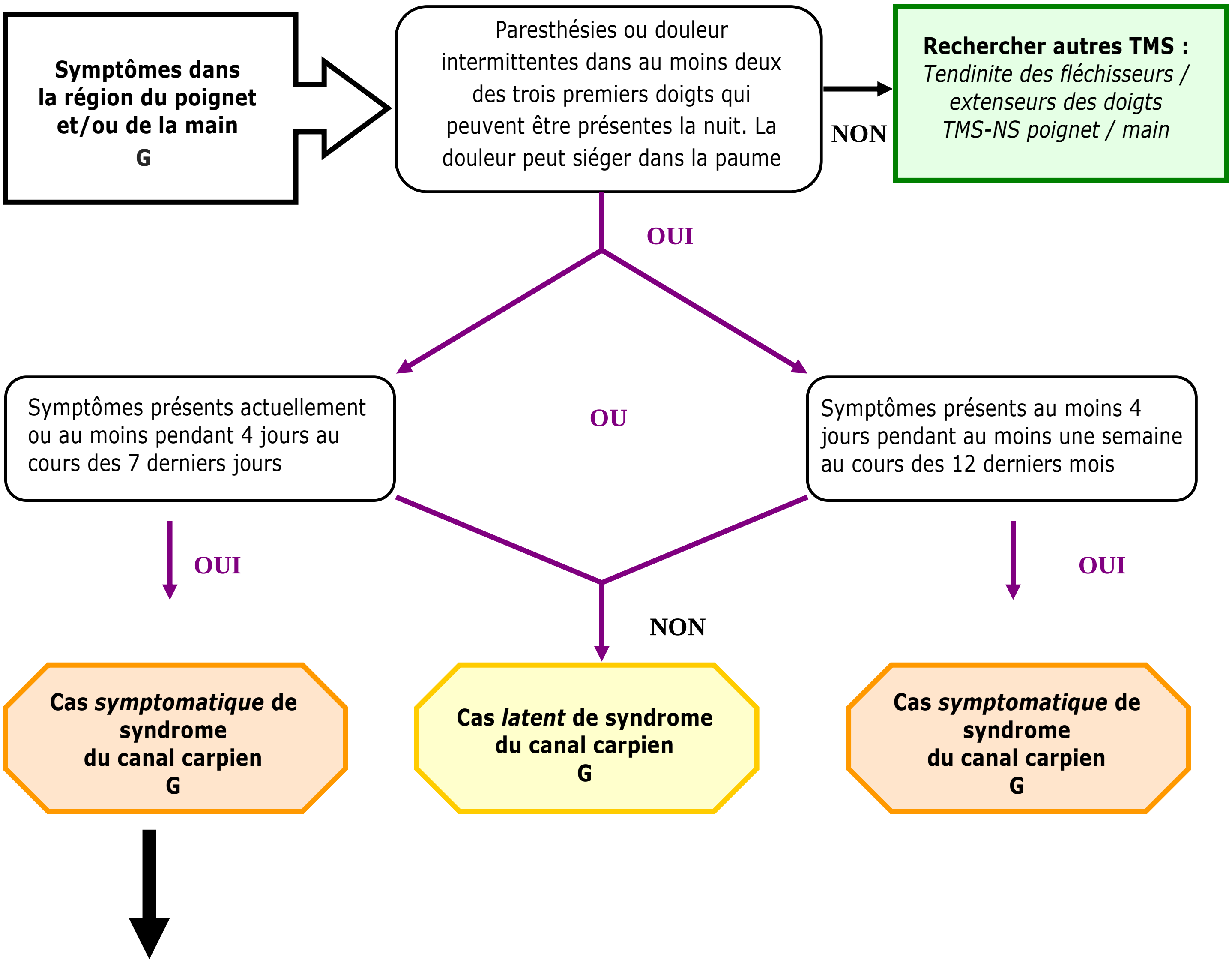


2) Recherche d'une forme *avérée*



REMARQUES : ....

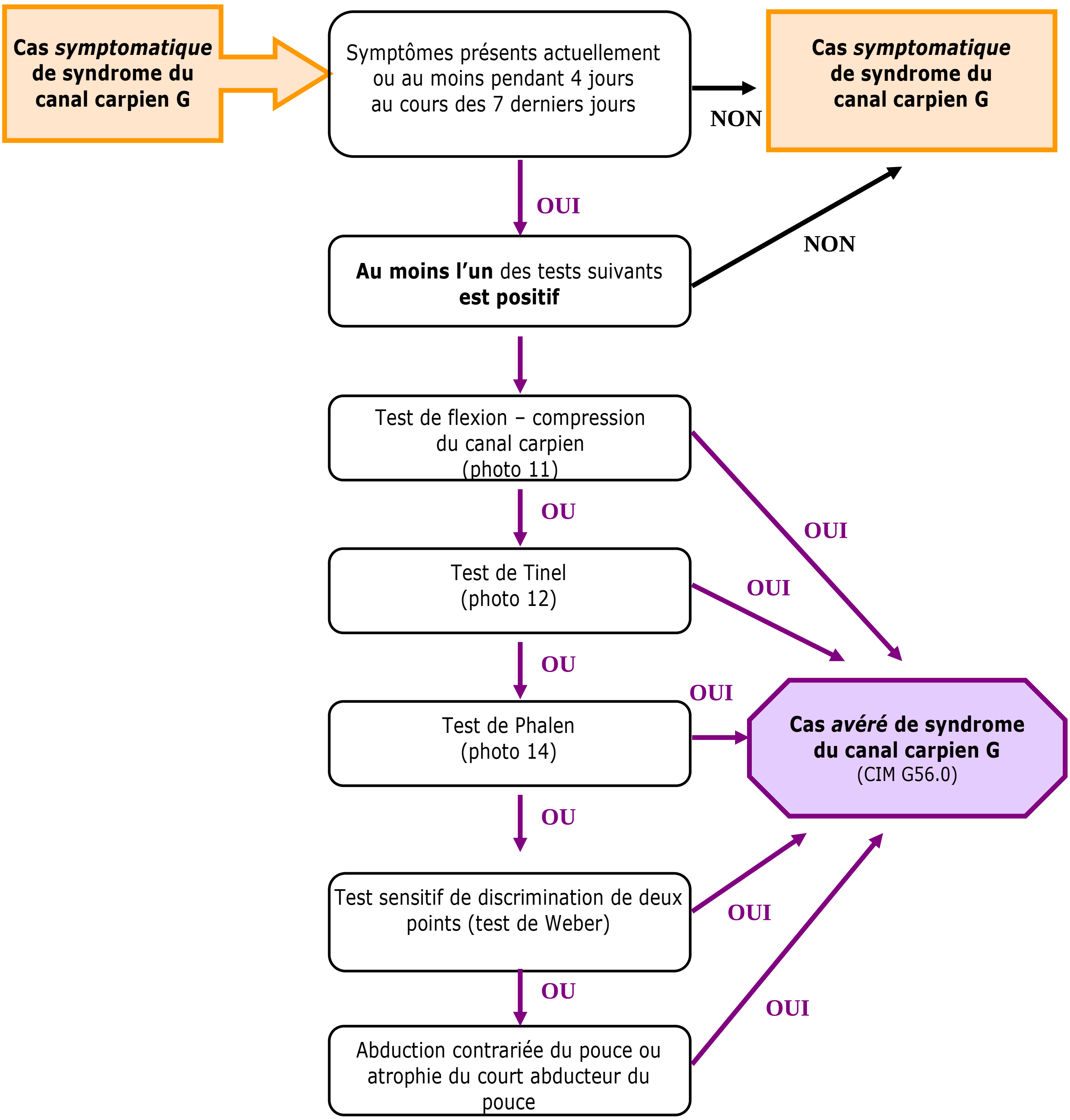
1) Recherche d'une forme *latente* ou *symptomatique*



Recherchez une forme *avérée de syndrome du canal carpien*

SYNDROME DU CANAL CARPIEN GAUCHE (p 2/2)

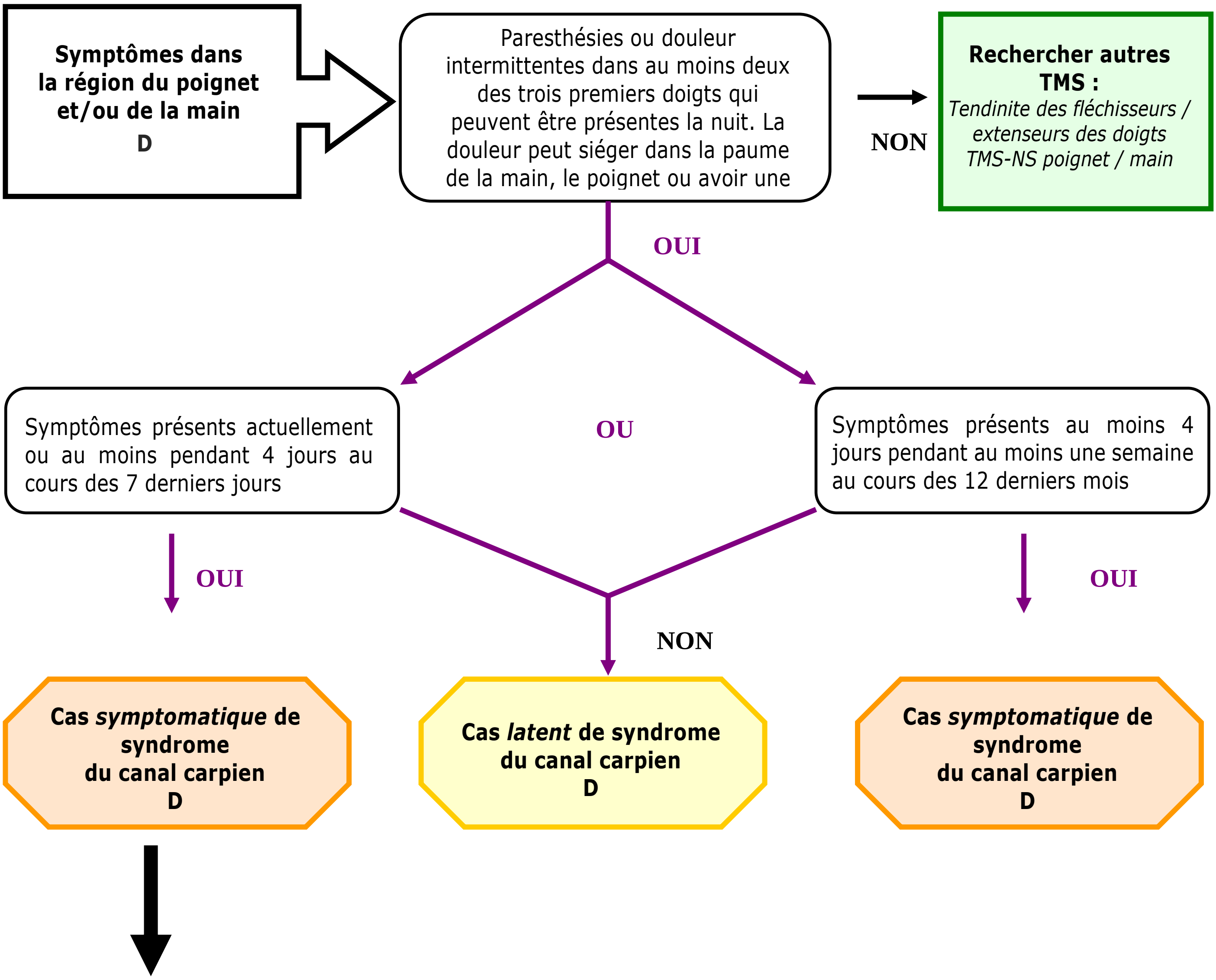
2) Recherche d'une forme *avérée*



REMARQUES : ....

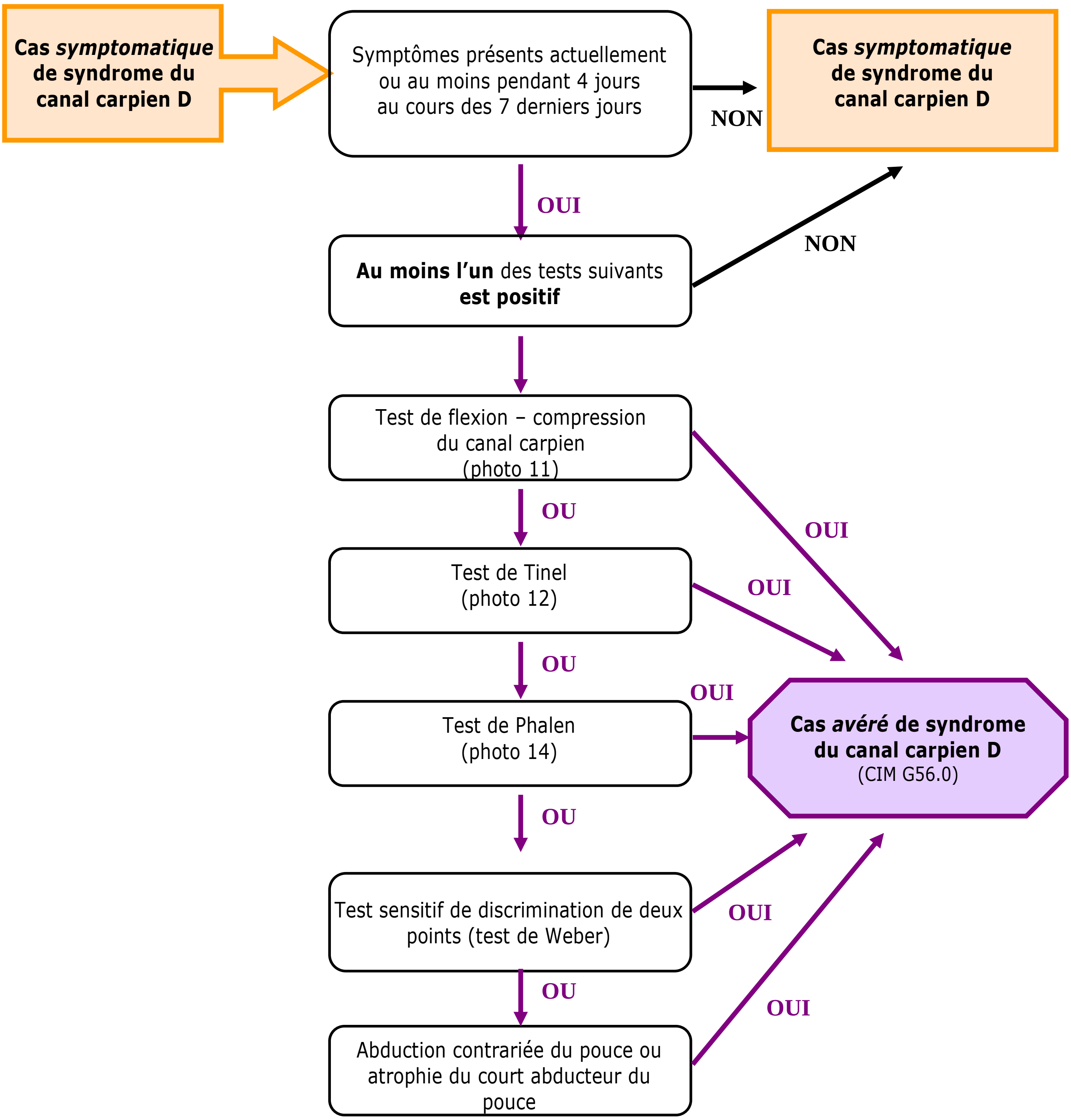
SYNDROME DU CANAL CARPIEN DROIT (p 1/2)

1) Recherche d'une forme *latente* ou *symptomatique*



Recherchez une forme *avérée de syndrome du canal carpien*

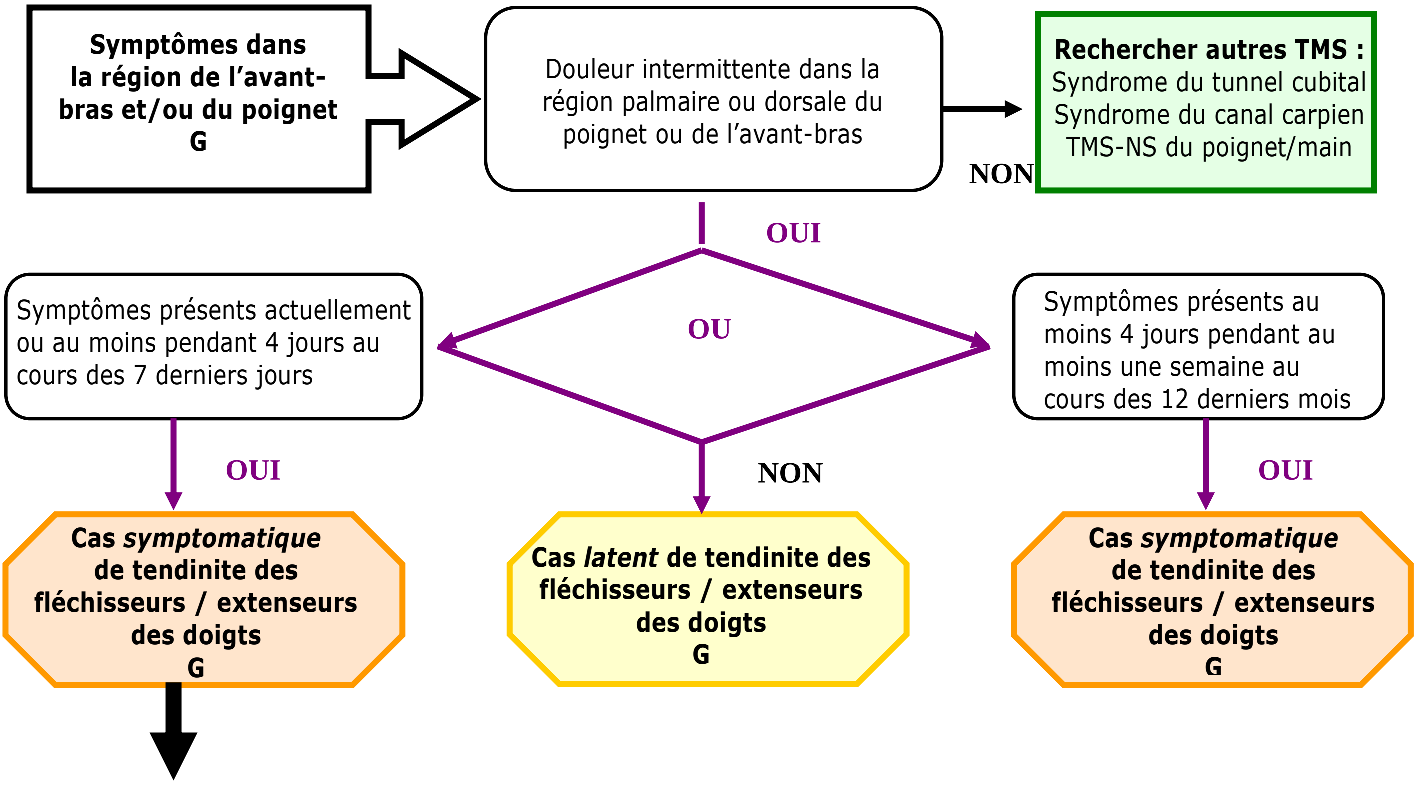
2) Recherche d'une forme *avérée*



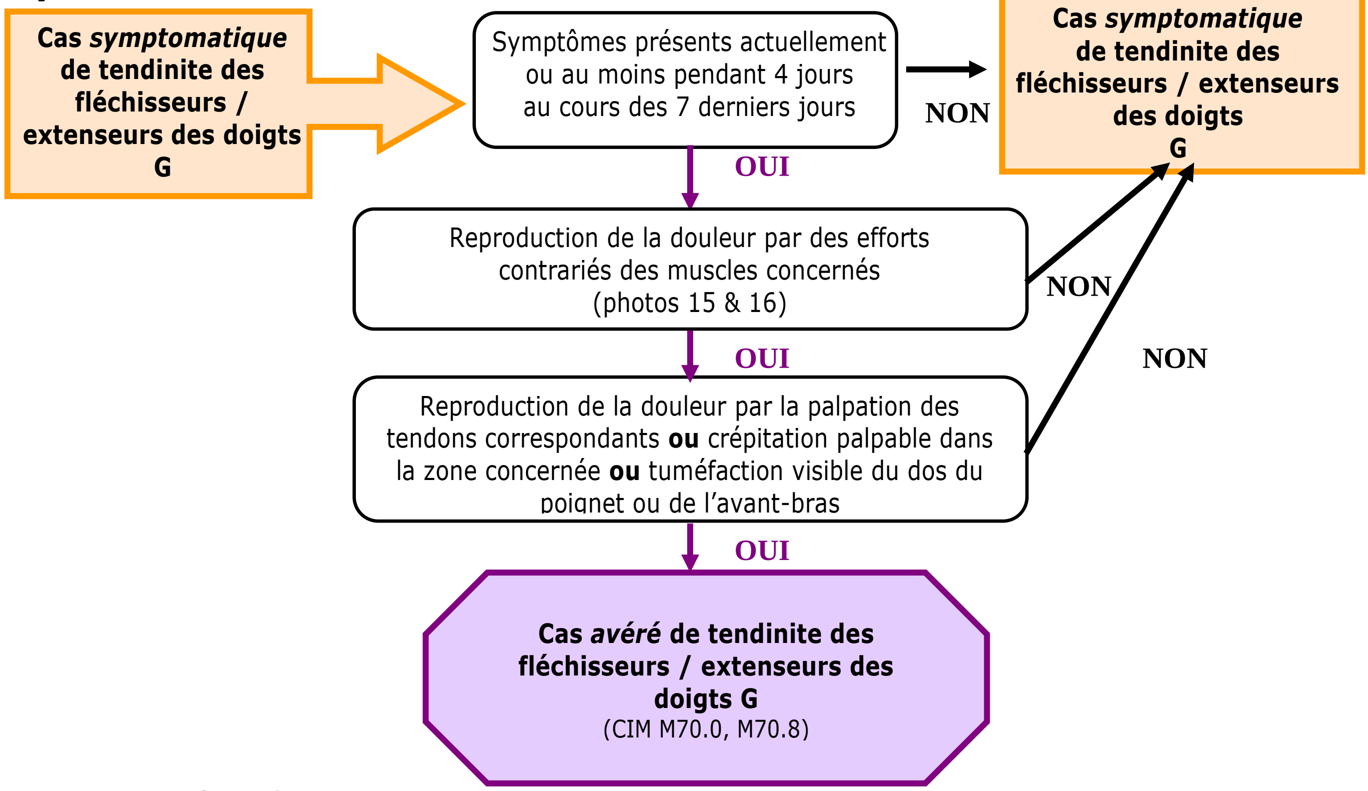
REMARQUES : ....

TENDINITE OU TENOSYNOVITE DES FLÉCHISSEURS ET DES EXTENSEURS DE LA MAIN ET DES DOIGTS GAUCHES

1) Recherche d'une forme *latente* ou *symptomatique*



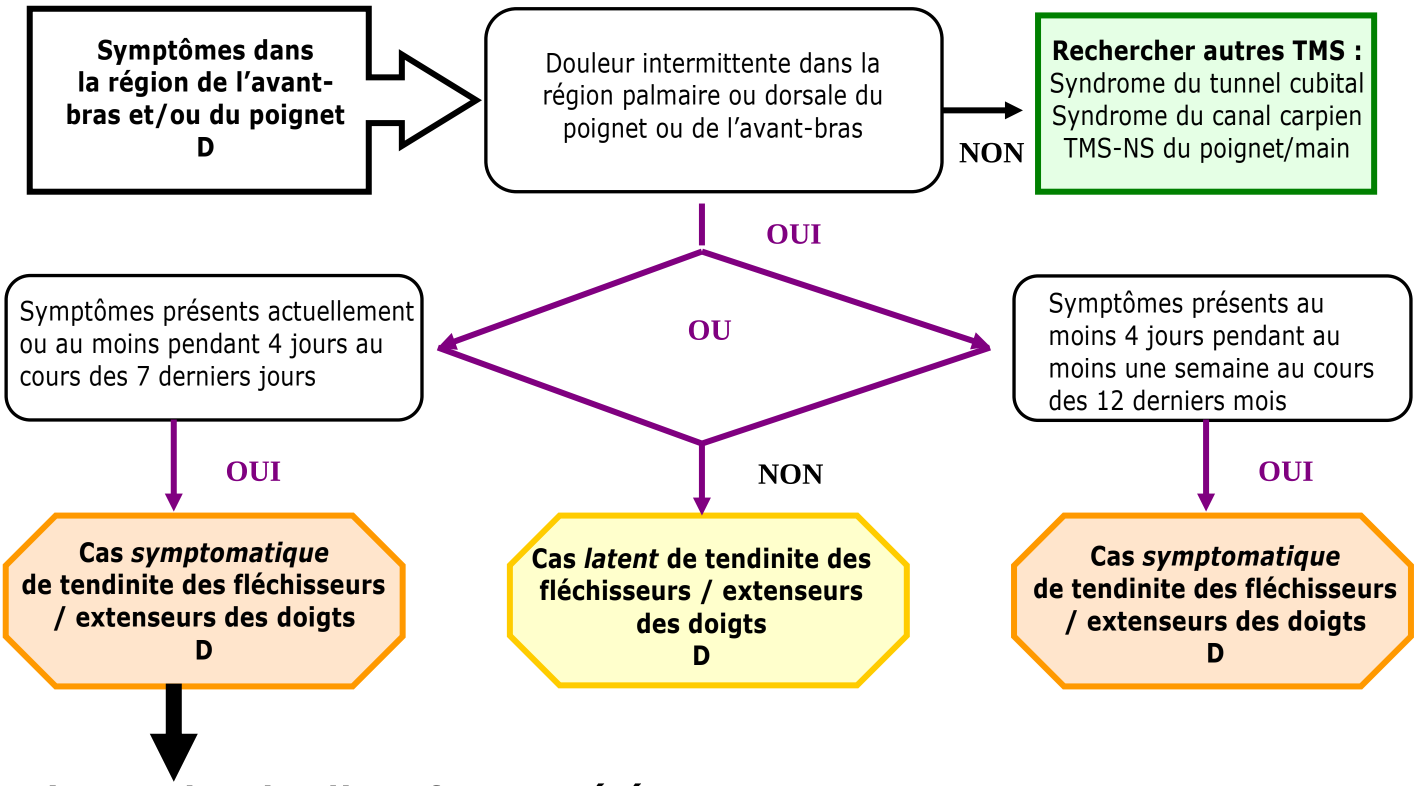
2) Recherche d'une forme *avérée*



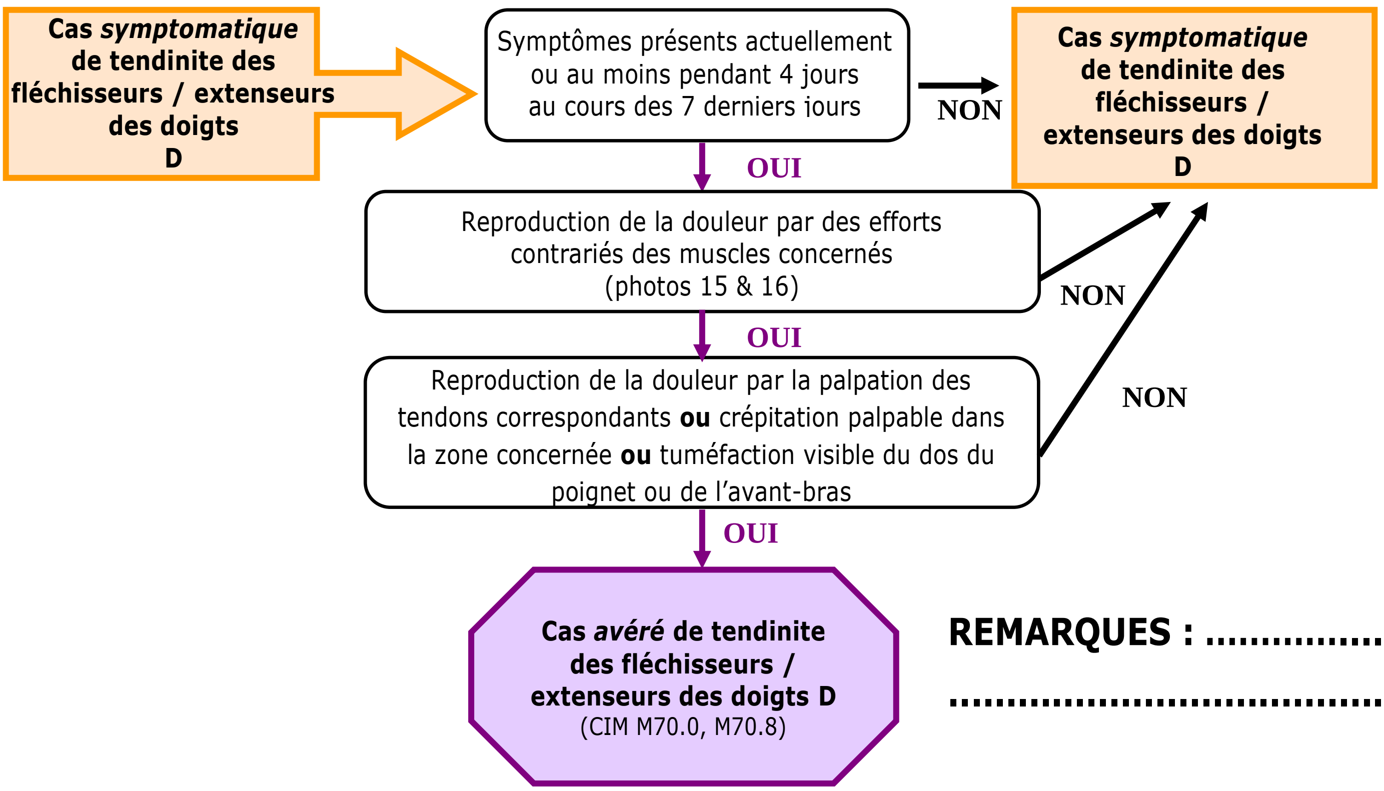
REMARQUES : ....

TENDINITE OU TENOSYNOVITE DES FLÉCHISSEURS ET DES EXTENSEURS DE LA MAIN ET DES DOIGTS DROITS

1) Recherche d'une forme *latente* ou *symptomatique*



2) Recherche d'une forme *avérée*



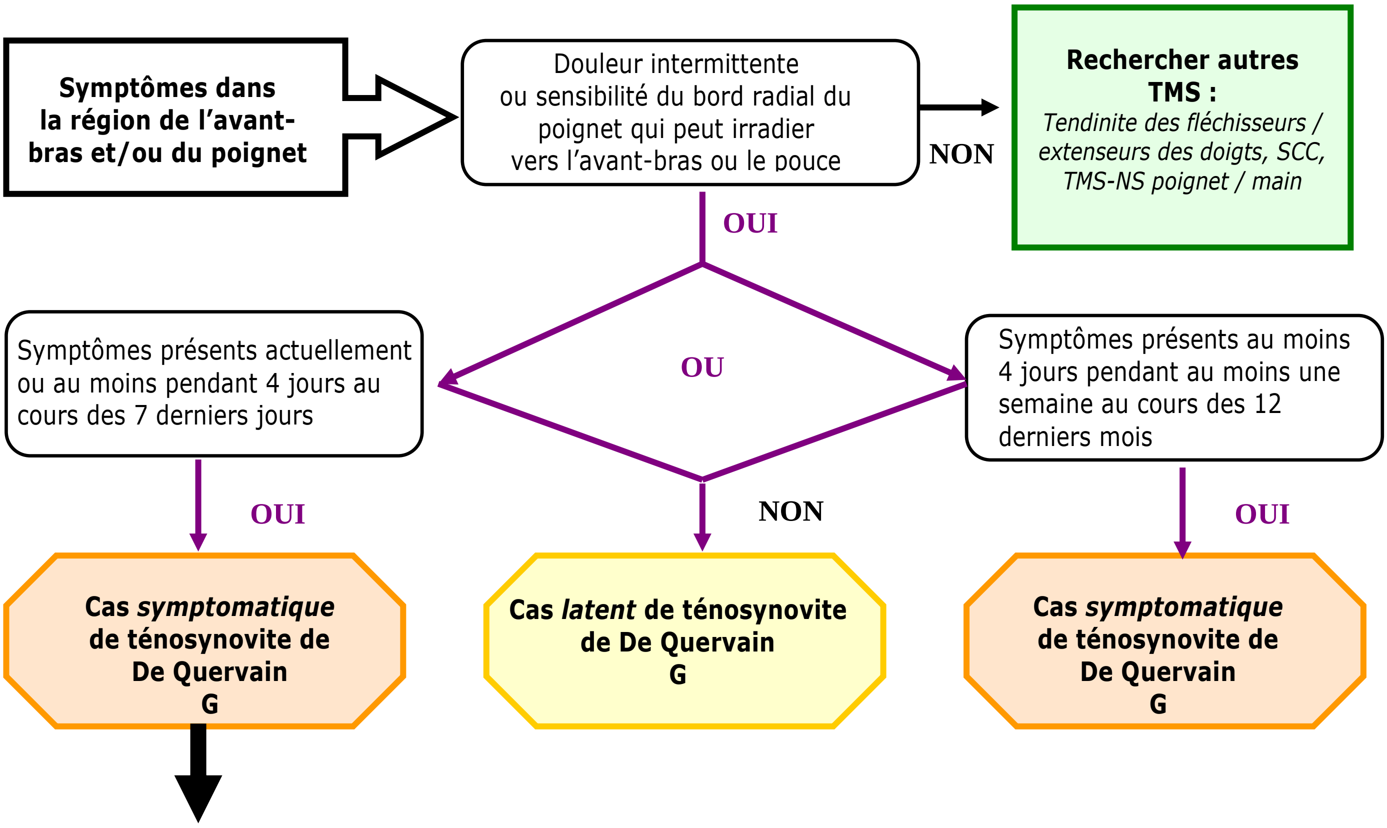
REMARQUES : ....

..

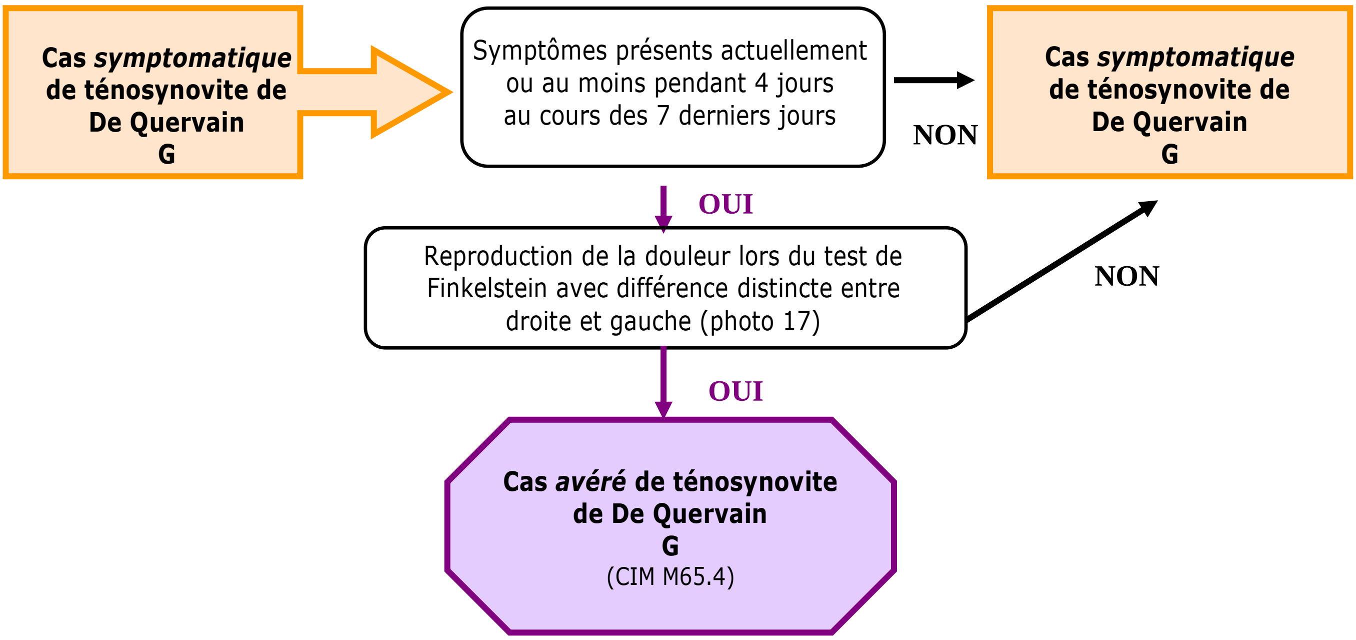
TÉNOSYNOVITE De DE QUERVAIN GAUCHE

(Ténosynovite chronique sténosante du pouce)

1) Recherche d'une forme *latente* ou *symptomatique*



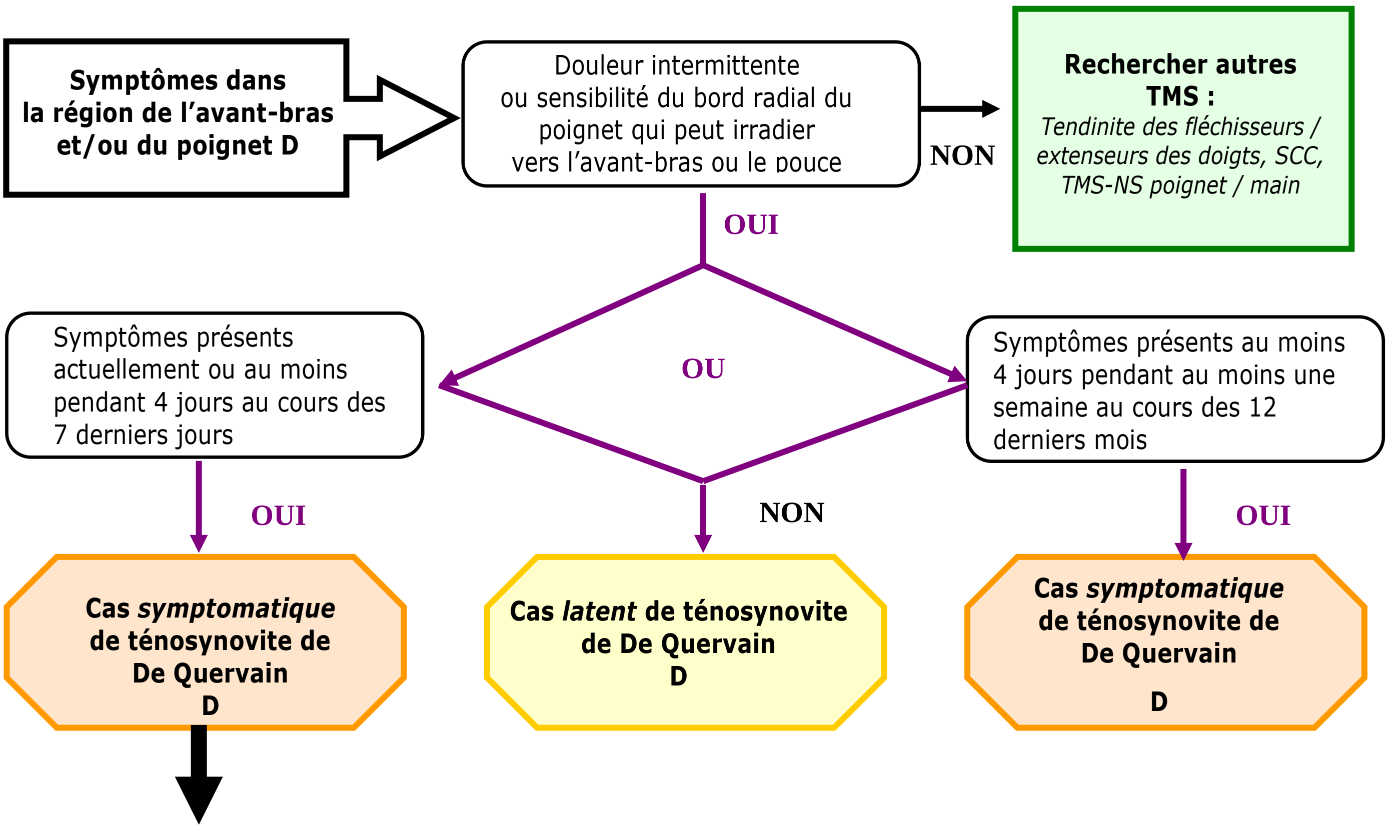
2) Recherche d'une forme *avérée*



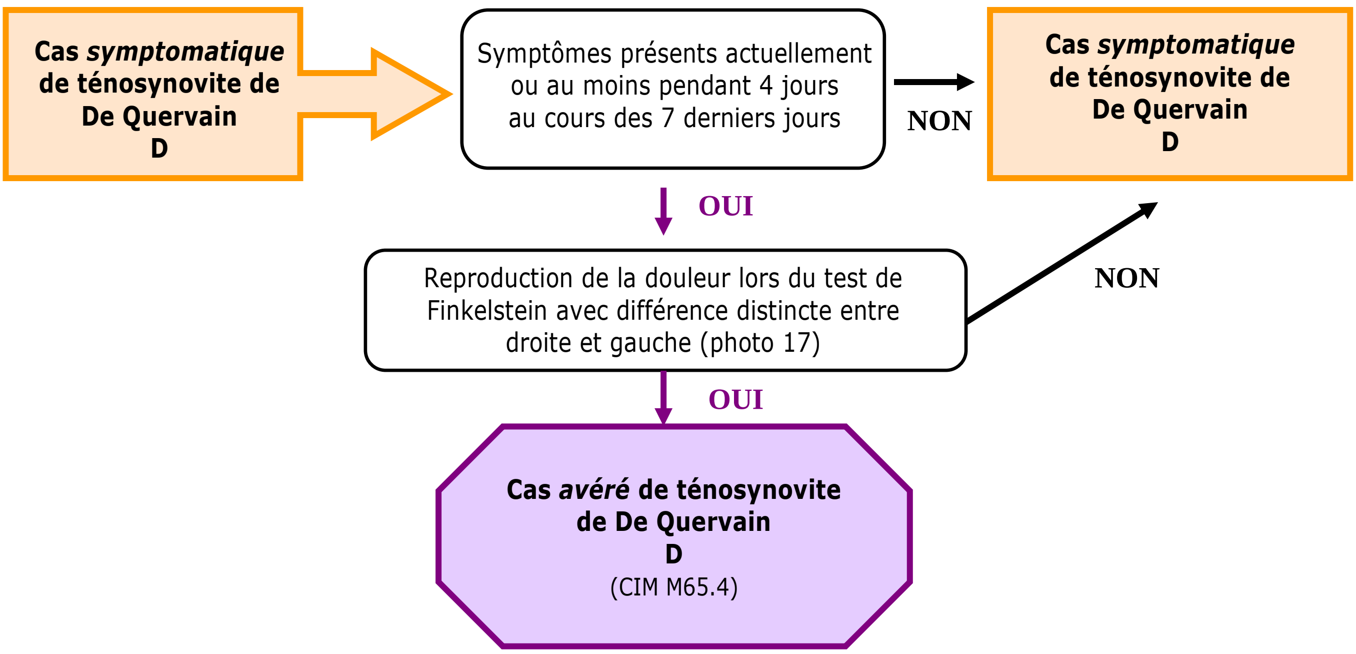
REMARQUES : ....

TÉNOSYNOVITE De DE QUERVAIN DROITE
(Ténosynovite chronique sténosante du pouce)

1) Recherche d'une forme *latente* ou *symptomatique*



2) Recherche d'une forme *avérée*



REMARQUES : ....

ANNEXE 1

CLASSIFICATION PHARMACOLOGIQUE DES ANTALGIQUES: RESEAU TMS

RAPPEL: LES PALIERS DE LA DOULEUR

L'organisation mondiale de la santé (OMS) a établi une échelle pour l'utilisation des antalgiques Elle classe la douleur selon 3 paliers

1. **Douleur légère (palier I):** Utilisation d'antalgiques périphériques pouvant être associés ou non à des thérapeutiques adjuvantes.
2. **Douleur légère à modérée (palier Il) :** Utilisation d'opiacés faibles associés ou non à des antalgiques périphériques et/ou des adjuvants.
3. **Douleur modérée à sévère (palier III)** : Utilisation d'antalgiques centraux (morphiniques) associés ou non à des antalgiques non opiacés et/ou adjuvants. Chaque palier ne sera atteint que lorsque les médicaments du palier précédent, utilisés à dose optimale, se révèlent insuffisants ou inefficaces.

CLASSIFICATION PHARMACOLOGIQUE DES ANTALGIQUES

A. Les antalgiques périphériques (non dérivés de l'opium) : Ils exercent essentiellement leur action en périphérie au niveau des tissus lésés. Ils sont très souvent utilisés pour traiter des douleurs légères de palier I. Ils se répartissent de la façon suivante

1) Antalgiques anti-inflammatoires anti-pyrétiques ce sont les anti-inflammatoires non stéroïdiens ou A.l.N.S. Leur chef de file est l'aspirine. Parmi les autres membres de cette classe, on peut citer le nalgésic*, le nurofen*.

2) Antalgiques antipyrétiques : chef de file, le paracétamol (efferalgan*, doliprane*). Son pouvoir antalgique est comparable à celui de l'aspirine. On y trouve également la noramidopyrine mais celle-ci est réservée au traitement des douleurs de palier Il. Elle est surtout commercialisée sous forme d'associations de principes actifs dont les plus connues sont : baralgine*, viscéralgine forte*, optalidon* ou salgydal*.

3) Antalgiques "purs" : une spécialité est encore commercialisée à ce jour. Il s'agit de l'idarac dont le pouvoir antalgique est légèrement supérieur à celui de l'aspirine ou du paracétamol.

B. Les antalgiques centraux : Ce sont des opiacés puissants ayant pour chef de file la morphine. Ils servent à traiter les douleurs de palier III. On divise les morphiniques en :
. Produits naturels : morphine, codéine
. Produits semi-synthétiques : héroïne, buprénorphine (temgésic), nalbuphine (topalgic)

. Produits synthétiques : méthadone, dextromoramide (palfium), dextropropoxyphène (antalvic), pentazocine (fortal), péthidine (dolosal), tramadol (topalgic)

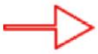
C. Les antalgiques mixtes : Ce sont des associations d'un antalgique central et d'un antalgique périphérique. On associe très fréquemment la codéine au paracétamol (efferalgan codéine*, dafalgan codéine*, codoliprane*, klipal*, lindilane*) ou à l'aspirine (compralgyl*). Ces produits traitent généralement des douleurs de palier Il

Principaux antalgiques
Palier III Morphine chlorhydrate inj. skenan*, palfium*, nubain*, dolosal*, temgésic* , durogésic (percutané)
Palier Il avafortan*, codoliprane*, efferalgan codéiné*, dafalgan codéiné*; di-antalvic*, propofan*, acupan* , topalgic (tramadol)
Palier I Doliprane*, dafalgan*, efferalgan*, aspirine upsa*, solupsan*, aspégic*, pro-dafalgan*

MANŒUVRES CLINIQUES STANDARDISEES

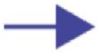
Aide à la réalisation des tests cliniques

- Signification des symboles utilisés sur les photos :

 = force appliquée par le sujet

 = mouvements actifs réalisés par le sujet

 = direction du mouvement induit par l'examinateur

 = force appliquée par l'examinateur

 = percussion réalisée par l'examinateur

N.B : A côté de la nouvelle dénomination française des muscles, nous avons indiqué en italique l'appellation classique.

- <u>Comparaison droite (D) – gauche (G) (D/G) :</u>

  Pour décider si le test est positif, la comparaison D/G est importante pour la plupart des tests. De plus, il est classique dans la pratique clinique de débuter un test par le côté non symptomatique. Les descriptions littérales des différents tests présentés ont volontairement été réalisées pour le c ôté droit du sujet.

- <u>Force appliquée par l'examinateur durant les tests contre résistance:</u>

  Durant les tests réalisés contre résistance, l'examinateur applique sa force dans le sens opposé à celui imprimé par les muscles concernés.

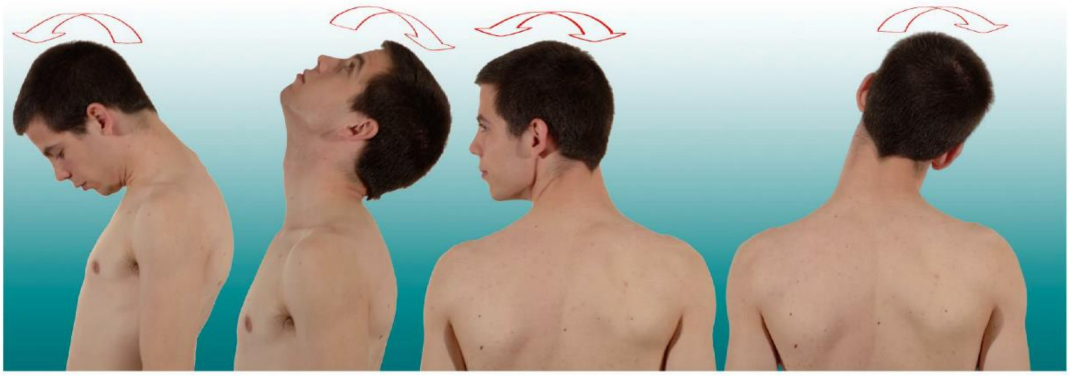
  Par exemple : durant le test de flexion du coude contre résistance, l'examinateur applique sa force pour étendre le coude alors que le sujet essaie de le fléchir, de façon a contracter le biceps, muscle fléchisseur du coude.

- <u>Tests complémentaires:</u>

  Un test est dit complémentaire quand il n'est habituellement pas réalisé comme test de base lors de l'examen clinique en cabinet médical.

Nom du test	Mouvements actifs du rachis cervical D & G
Photo	1
Type de test	Test de mouvements actifs à réaliser avant le test de rotation passive du rachis cervical (2).
Position de départ du sujet	Assis.
Position de départ de l'examinateur	Debout ou assis, face au sujet
Réalisation du test	On demande au sujet de bouger la tête doucement jusqu'à atteindre les amplitudes maximales en flexion antérieure, extension, rotation (D/G) et flexion latérale (D/G)
Positif si	Symptômes provoqués par les mouvements ou limitation des mouvements (comparaison D/G)

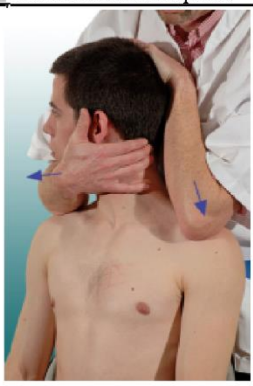
Flexion/Extension **Rotation** **Flexion latérale**

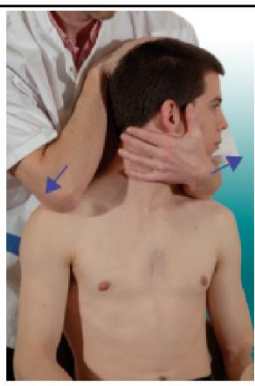


1

Nom du test	Rotation passive du rachis cervical D & G
Photo	2
Type de test	Passif, pour les douleurs du cou avec irradiation
Position de départ du sujet	Assis (ou allongé si sensations de vertiges lors du test de mouvements actifs (1)) Rachis cervical moyen : tête en position neutre Rachis cervical bas : tête en légère extension
Position de départ de l'examinateur	Debout derrière le sujet
Réalisation du test	La main D est placée sur la partie G de la tête, de façon à ce que les doigts puissent palper le rachis cervical, La main G est placée derrière la tête, le coude G stabilisant la face antérieure de l'épaule G. On effectue une rotation lente de la tête vers la D.
Positif si	Douleur avec irradiation provoquée en cours ou à la fin de la manœuvre ou immédiatement après.

2D





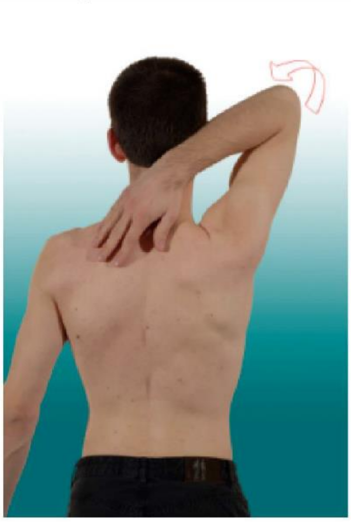
2G

Nom du test	Test de l'arc douloureux lors de l'abduction/élévation de l'épaule D&G
Photo	3
Type de test	Mouvement actif de circumduction de l'épaule pour le syndrome de la coiffe des rotateurs dans le plan de l'omoplate
Position de départ du sujet	Debout avec les bras pendants, les pouces dirigés vers l'avant
Position de départ de l'examinateur	Debout, face au sujet, il positionne les membres supérieurs du sujet à 30° vers l'avant
Consigne donnée au sujet	« Levez les bras jusqu'à hauteur des épaules, tournez les paumes vers le haut et levez les bras jusqu'à ce que vos mains se touchent au-dessus de la tête »
Positif si	Douleur au cours du mouvement (entre 60 et 120° d'abduction)

3

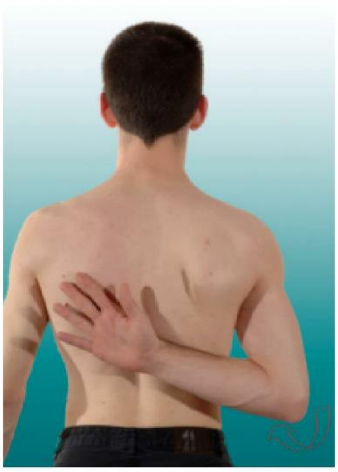
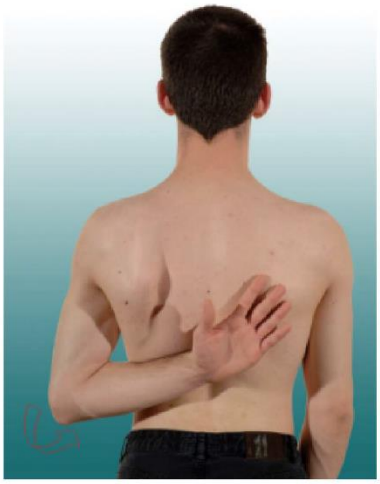
Nom du test	Test d'élévation active de l'épaule 1. abduction / rotation externe Comparaison D / G
Photo	4
Type de test	Mouvement actif de l'épaule, pour le syndrome de la coiffe des rotateurs
Position de départ du sujet	Debout
Position de départ de l'examinateur	Debout, derrière le sujet
Consigne donnée au sujet	« Placez votre main D derrière la tête et essayez de toucher le haut de l'omoplate G du bout des doigts »
Positif si	Douleur locale de l'épaule D au cours ou à la fin du mouvement

4D



4G

Nom du test	Test d'élévation active de l'épaule 2. abduction / rotation interne Comparaison D / G
Photo	5
Type de test	Mouvement actif de l'épaule pour le syndrome de la coiffe des rotateurs
Position de départ du sujet	Debout
Position de départ de l' examinateur	Debout, derrière le sujet
Consigne donnée au sujet	« Placez votre main D derrière le dos et essayez de toucher le bas de votre omoplate G du bout des doigts »
Positif si	Douleur locale de l'épaule D au cours ou à la fin du mouvement

5D


5G

Nom du test	Test d'élévation active de l'épaule 3. adduction Comparaison D / G
Photo	6
Type de test	Mouvement actif de l'épaule pour le syndrome de la coiffe des rotateurs
Position de départ du sujet	Debout
Position de départ de l'examinateur	Debout, f ace au sujet
Consigne donnée au sujet	"Empaumez le sommet de votre épaule G avec la main D
Positif si	Douleur locale de l'épaule D au cours ou à la fin du mouvement

6D


6G

Nom du test	Abduction contrariée de l'articulation gléno -humérale
Photo	7
Type de test	Résistance isométrique pour le syndrome de la coiffe des rotateurs
Position de départ du sujet	Assis, avec le bras D en abduction de 10-20°
Position de départ de l'examinateur	Debout à D du sujet. La main G stabilise le sommet de l'épaule D, la main D appuie pour s'opposer à l'abduction du bras D.
Consigne donnée au sujet	<< Maintenez le bras dans cette position et résistez contre ma force>>
Positif si	Douleur locale de l'épaule D et/ou déficit (muscle supra-épineux / *sus-épineux*)

7D

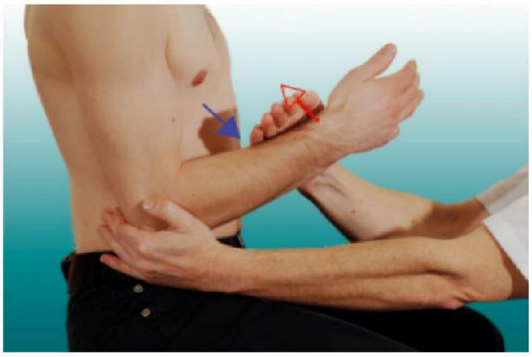

7G

Nom du test	Rotation externe contrariée de l'articulation gléno -humérale
Photo	8
Type de test	Résistance isométrique pour le syndrome de la coiffe des rotateurs
Position de départ du sujet	Assis, bras D contre le corps, coude D fléchi à 90°, poignet D en position neutre
Position de départ de l'examinateur et réalisation du test	Debout à D du sujet. La main G contrôle la position du coude, la main D empaume la face dorsale de l'avant-bras D et appuie pour entraîner l'épaule en rotation interne
Consigne donnée au sujet	<< Maintenez le coude D contre votre corps et résistez contre ma force>>
Positif si	Douleur locale de l'épaule D et/ou déficit (muscle infra-épineux / *sous-épineux*)

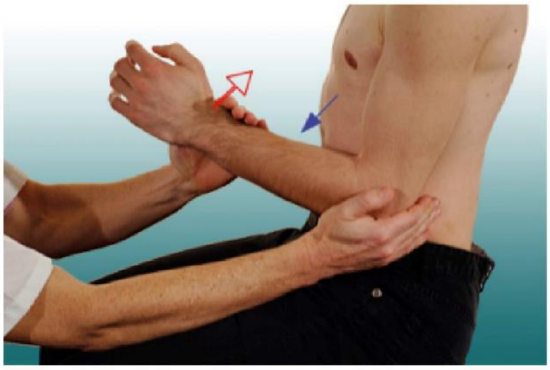
8D


8G

Nom du test	Rotation interne contrariée de l'articulation gléno -humérale
Photo	9
Type de test	Résistance isométrique pour le syndrome de la coiffe des rotateurs
Position de départ du sujet	Assis, bras D contre le corps, coude D fléchi à 90°, poigne t D en position neutre
Position de départ de l'examinateur	Debout, face au sujet. La main G contrôle la position du coude du sujet, la main D empaume la face ventrale de l'avant -bras et appuie pour empêcher la rotation interne de l'épaule.
Consigne do nnée au sujet	<< Maintenez le coude contre votre corps et résistez contre ma force>>
Positif si	Douleur locale de l'épaule D et/ou déficit (muscle sub -scapulaire / *sous-scapulaire*)

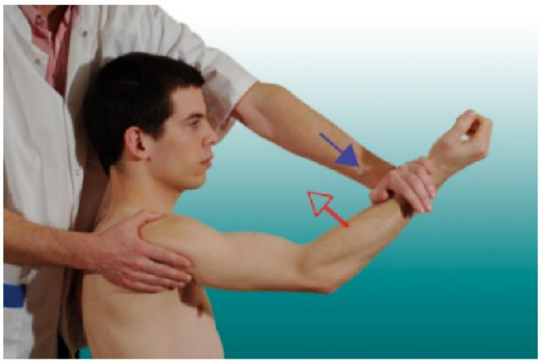


9D



9G

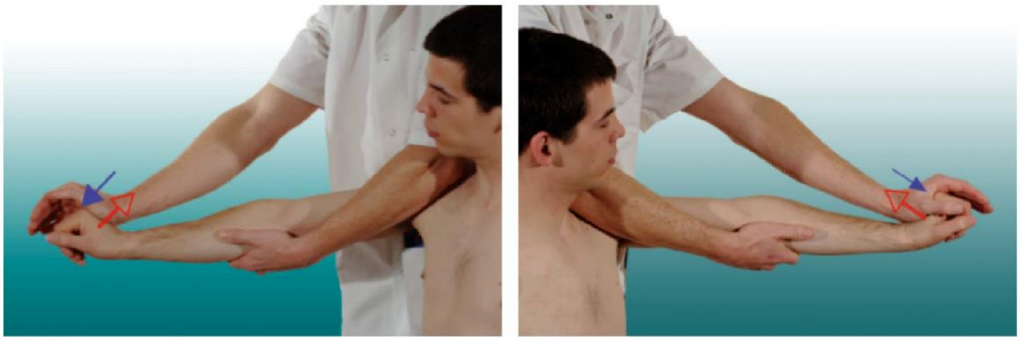
Nom du test	Flexion contrariée du coude
Photo	10
Type de test	Résistance isométrique pour le syndrome de la coiffe des rotateurs
Position de départ du sujet	Assis, bras D à 90° d'antéflexion, avant -bras D en supination (paume vers le haut), coude D légèrement fléchi
Position de départ de l'examinateur et réalisation du test	Debout à G du sujet. La main D stabilise l'articulation gléno -humérale D, la main G empaume la face ventrale de l'avant -bras D et appuie pour étendre le coude.
Consigne donnée au sujet	<< Maintenez le bras D dans cette position et résistez contre ma force>>
Positif si	Douleur locale au -dessus de l'insertion du tendon du biceps brachial et/ou déficit



10D

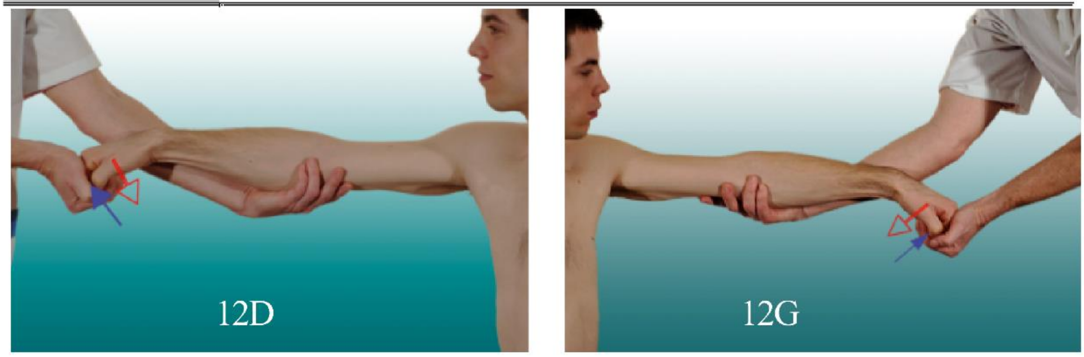
10G

Nom du test	Extension contrariée du poignet
Photo	11
Type de test	Résistance isométrique des extenseurs du poignet pour l'épicondylite latérale *(épicondylite)*
Position de départ du sujet	Assis ou debout, bras D à 90° d'antéflexion, avant -bras D en pronation (paume vers le bas), coude D en extension complète
Position de départ de l'examinateur et réalisation du test	Debout. La main G stabilise l'avant -bras D et le coude D du sujet. La main D empaume la face dorsale de la main D (poing fermé) du sujet et exerce une f orce dans le sens de la flexion palmaire
Consigne donnée au sujet	<< Maintenez la main dans cette position et résistez contre ma force>>
Positif si	Douleur locale au niveau de l'épicondyle latéral (*épicondyle)*



11D 11G

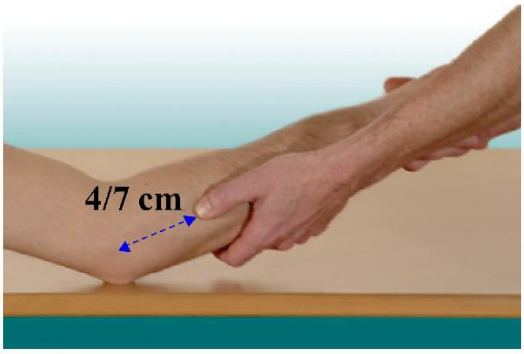
Nom du test	Test de flexion contrariée du poignet
Photo	12
Type de test	Résistance isométrique des fléchisseurs du poignet, pour l'épicondylite médiale (*épitrochléite*)
Position de départ du sujet	Assis ou debout; le bras D est en élévation antérieure à 90°, le coude est en extension complète, l'avant-bras est en pronation (paume vers le bas), le poignet est en flexion palmaire.
Position de départ de l'examinateur	Debout
Réalisation du test	La main G stabilise le coude D du sujet; la main D est placée sur la face palmaire de la main D du patient et imprime une force pour étendre le poignet
Consigne donnée au sujet	« Maintenez votre main dans cette position et résistez contre ma force»
Positif si	Apparition d'une douleur localisée auniveau de l'épicondyle médial (*épitrochlée)*



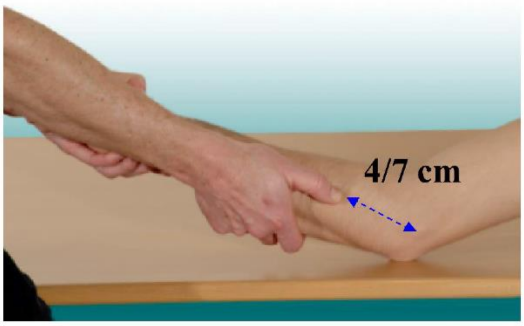
12D 12G

Nom du test	Test combiné de compression/flexion du coude
Photo	13
Type de test	Test passif combiné : étirement et compression du nerf ulnaire (*cubital*), pour le syndrome du tunnel cubital
Position de départ du sujet	Assis ou debout
Position de départ de l'examinateur	Debout, à D du sujet
Réalisation du test	La main D positionne le coude D du patient en flexion maximale ; la compression est provoquée par les 2° et 3° doigts de la main G sur le nerf ulnaire, en regard du tunnel cubital et maintenue pendant 30 à 60 secondes
Positif si	Paresthésies dans le territoire innervé par le nerf ulnaire, au niveau de l'avant -bras D et de la main

Nom du test	Palpation des extenseurs
Photo	14
Type de test	Palpation pour rechercher le point de sensibilité maximale, pour le syndrome de compression du nerf radial.
Position de départ du sujet	Assis, l'avant-bras D repose sur la table en pronation (paume vers le bas)
Position de départ de l'examinateur	Assis ou debout, la main D stabilise le poignet D du sujet, le pouce G palpe la face externe de l'avant-bras D.
Réalisation du test	Palpation douce avec le pouce de la masse musculaire des extenseurs de l'avant-bras (4-7 cm en dessous de l'épicondyle latéral (*épicondyle*))
Positif si	Point de sensibilité maximale ressenti lors de la palpation



14D



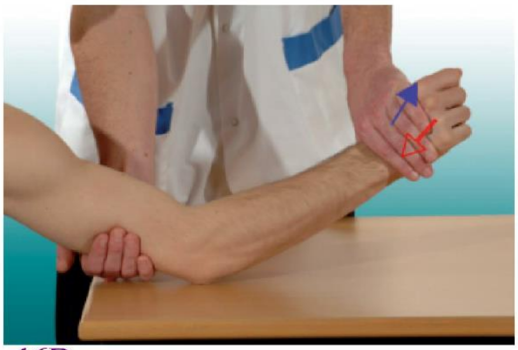
14G

Nom du test	Test de supination contrariée de l'avant -bras
Photo	15
Type de test	Résistance isométrique des supinateurs de l'avant-bras, pour le syndrome de compression du nerf radial
Position de départ du sujet	Assis ou debout ; le coude D est en extension presque complète, l'avant -bras D en position neutre, poing fermé .
Position de départ de l'examinateur	Debout, la cuisse G stabilise le membre supérieur D du patient
Réalisation du test	Les mains empaument le poignet D du patient, pouces au dessus et amènent l'avant - bras D en pronation
Consigne donnée au sujet	« Maintenez votre avant-bras dans cette position et résistez contre ma force »
Positif si	Point douloureux sur la face dorsale de l'avant -bras D


15D


15G

Nom du test	Test d'extension contrariée du poignet
Photo	16
Type de test	Test de résistance isométrique des extenseurs du poignet, pour la tendinite des extenseurs du poignet
Position de départ du sujet	Assis, le coude D fléchi à 30°, l'avant-bras D reposant sur la table en pronation (paume vers le bas), le poignet D maintenu en extension
Position de départ de l'examinateur et réalisation du test	Debout ou assis face au sujet, la main D stabilise le bras D, la main G tient la face dorsale de la main D du sujet et imprime une force vers la flexion palmaire
Consigne donnée au sujet	<< Maintenez le poignet dans cette position et résistez contre ma force>>
Positif si	Apparition de douleur sur la face dorsale du poignet et de l'avant -bras D


16D


16G

Nom du test	Test de flexion contrariée du poignet
Photo	17
Type de test	Test de résistance isométrique des fléchisseurs du poignet, pour la tendinite des fléchisseurs du poignet
Position de départ du sujet	Assis, le coude D fléchi à 30°, l'avant-bras D reposant sur la table en supination (paume vers le haut), le poignet D maintenu en flexion
Position de départ de l'examinateur et réalisation du test	Debout ou assis, la main D stabilise le bras D du sujet, la main G tient la face palmaire de la main D du sujet et imprime une force vers l'extension du poignet
Consigne donnée au sujet	<< Maintenez le poignet dans cette position et résistez contre ma force>>
Positif si	Apparition de douleur sur la face ventrale du poignet et de l'avant-bras D


17D

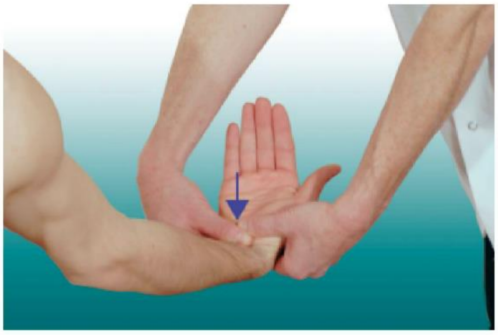

17G

Nom du test	Test de Finkelstein Comparaison D/G
Photo	18
Type de test	Test de provocation pour la ténosynovite de De Quervain
Position de départ du sujet	Assis, l'avant-bras D reposant sur la table en pronation (paume vers le bas), le poignet D en position neutre. La main forme une poigne, le pouce étant recouvert par les doigts longs fermés sur lui
Position de départ de l'examinateur et réalisation du test	Debout ou assis. La main G stabilise la face ulnaire (*cubitale*) de l'extrémité de l'avant-bras D du sujet, la main D empaume la face radiale de la main du sujet et appuie modérément pour imprimer un mouvement de déviation ulnaire (sans résistance)
	Apparition de douleur au niveau des extenseurs du premier rayon (long abducteur du pouce et court extenseur du pouce)


18D


18G

Nom du test	Test de flexion - compression du canal carpien
Photo	19
Type de test	Test de compression active du nerf médian pour le syndrome du canal carpien
Position de départ du sujet	Assis, le coude D en extension presque complète, l'avant-bras D en supination (paume vers le haut)
Position de départ de l'examinateur	Assis en face du sujet, du côté du test. Les deux mains entourent le poignet du sujet
Réalisation du test	Le poignet D est fléchi à 60° tout en exerçant une pression constante avec au moins un pouce transversalement sur le canal carpien pendant 30 secondes
Positif si	Apparition de paresthésies ou d'engourdissement dans le territoire du nerf médian en moins de 30 secondes



19D

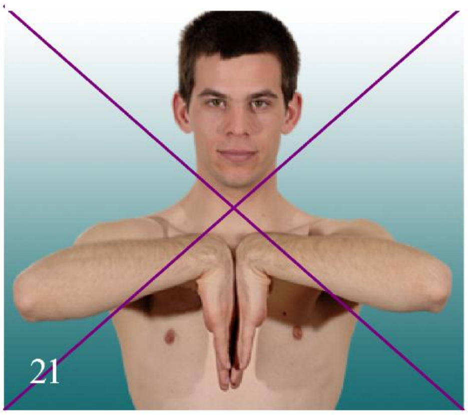
19G

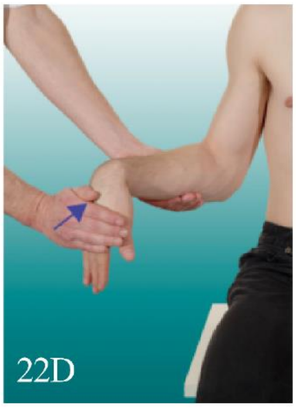
Nom du test	Test de Tinel (nerf médian)
Photo	20
Type de test	Test de provocation pour le syndrome du canal carpien
Position de départ du sujet	Assis, l'avant-bras D en supination (paume vers le haut), le poignet D en position neutre
Position de départ de l'examinateur	Debout ou assis face au sujet, la main G stabilise l'avant-bras D du sujet, la main D réalise le test
Réalisation du test	4 à 6 percussions modérées au niveau du ligament annulaire du carpe du bout de l'index et du majeur (ou avec un marteau à réflexe qu'on laisse tomber de 10cm environ)
Positif si	Apparition de paresthésies ou hyperesthésies dans la main et les doigts

20D

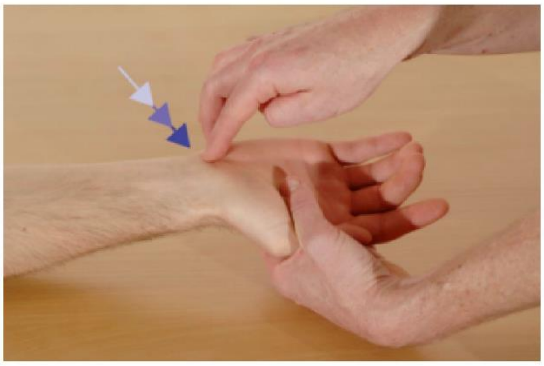
20G

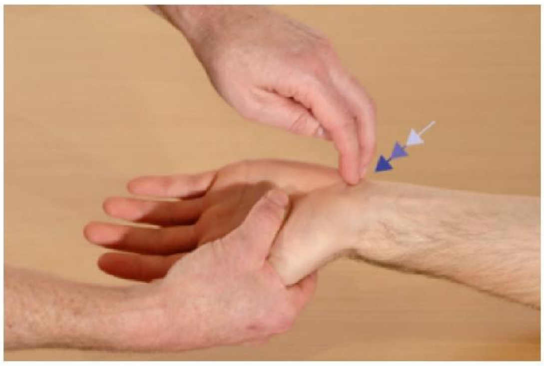
Nom du test	Test de Phalen
Photo	21-22
Type de test	Test de compression passive du nerf médian pour le syndrome du canal carpien
Position de départ du sujet	Assis, le coude D fléchi à 90°, l'avant -bras D en pronation (paume vers le bas), le poignet D et les doigts relâchés en flexion
Position de départ de l'examinateur	Debout ou assis, la main G stabilise l'avant -bras D du sujet, la main D réalise le test
Réalisation du test	La main D place le poignet D en flexion palmaire maximale, position mainte nue pendant 60 secondes. Contrairement au test traditionnel (photo 2 1), la manœuvre n'est pas faite par le sujet lui -même (mains jointes, coudes en l'air) pour permettre la distinction avec le syndrome du défilé thoraco -brachial
Positif si	Apparition de d ouleur ou paresthésies dans au moins un des 3 premiers doigts de la main D





Nom du test	Signe de Tinel (nerf ulnaire)
Photo	23
Type de test	Excitation du nerf ulnaire (*cubital*), pour le syndrome de la loge de Guyon
Position de départ du sujet	Assis, l'avant bras D est en supination, le poignet D en position neutre
Position de départ de l'examinateur	Assis ou debout. La main G stabilise la main D du sujet.
Réalisation du test	Avec le bout des 2° et 3° doigts D (ou avec un marteau à réflexe), on tape doucement 4 à 6 fois sous l'os pisiforme
Positif si	Des paresth ésies ou une hyperesthésie surviennent en aval de la zone percutée.





23D

23G

Nom du test	Test de Phalen inversé
Photo	24
Type de test	Test combiné de compression / étirement passif du nerf ulnaire (*cubital*), pour le syndrome de la loge de Guyon
Position de départ du sujet	Assis, le coude D fléchi à 90°, l'avant -bras en pronation (paume vers le bas)
Position de départ de l'examinateur	Assis ou debout
Réalisation du test	La main G stabilise l'avant -bras D du sujet, la main D est placée sur la face palmaire des doigts et maintient le poignet/main D en extension maxi male durant 60 secondes
Positif si	Des paresthésies surviennent au niveau de la main et des doigts dans le territoire de distribution du nerf ulnaire

24D

24G

Nom du test	Test de provocation à l'eau froide
N° test	25
Type de test	Test additionnel de provocation, pour le phénomène de Raynaud associé aux vibrations main - bras
Position de départ du sujet	Assis, bras pendant en position neutre
Position de départ de l'examinateur	Assis ou debout de façon à pouvoir observer la main
Réalisation du test	La main du sujet est immergée dans l'eau froide ($\approx$ 10° C) pendant 4 minutes au maximum
Positif si	Décoloration de la pulpe d'au moins un doigt

Appendix 3A. Comparison of baseline characteristics of workers with follow-up (who undergo the second clinical examination) and workers without follow-up

	Overall cohort (N=3710)				
	With follow-up (N=1611)		Without follow-up (N=2099)		p
	n	%	n	%	
Sex					0.243
Men	921	57.2	1240	59.1	
Women	690	42.8	859	40.9	
Age (years)					<0.001
<35	533	33.1	892	42.5	
35-44	568	35.3	492	23.5	
≥45	510	31.7	714	34.0	
Overweight/obesity	579	36.5	799	38.6	0.199
Diabetes mellitus	17	1.1	44	2.1	0.013
Rheumatoid arthritis	29	1.8	49	2.3	0.259
Seniority in current job (years)					<0.001
<1	130	8.1	325	15.7	
1-2	235	14.7	356	17.2	
3-10	573	35.9	665	32.0	
>10	660	41.3	729	35.1	
Occupational class					0.055
Craftsmen, salesmen and managers	6	0.4	10	0.5	
Professionals	114	7.1	174	8.3	
Technicians, associate professionals	378	23.5	451	21.5	
Low-grade white-collar workers	455	28.3	531	25.3	
Blue-collar workers	656	40.8	930	44.4	
Temporary employment	93	5.8	333	15.9	<0.001
Economic sector					<0.001
Agriculture	13	0.8	58	2.8	
Industry	599	37.2	623	29.7	
Construction	80	5.0	134	6.4	
Trade and services	918	57.0	1282	61.1	
High perceived physical exertion (RPE Borg scale ≥ 12)	877	54.7	1201	57.6	0.082
High perceived physical exertion (RPE Borg scale ≥ 13)	778	48.5	1078	51.7	0.058
High repetitiveness of tasks (>4 hours/day)	396	24.8	562	27.0	0.138
Use of vibrating tools (≥2 hours/day)	204	12.7	265	12.7	0.982
Repeated/sustained posture with arms above shoulder level (≥2 hours/day)	190	11.8	297	14.2	0.035
Repeated/sustained posture with shoulder abduction	525	32.7	731	35.0	0.139
Repeated/sustained elbow movements (flexion/extension) (≥2 hours/day)	495	30.9	719	34.5	0.020
Pronation and supination movements (≥2 hours/day)	217	13.5	317	15.2	0.161
Wrist twisting movements (≥2 hours/day)	523	32.8	713	34.4	0.311
Use of the pinch grip (≥4 hours/day)	127	7.9	170	8.1	0.804
Low social support	577	36.8	831	40.9	0.011
Low decision latitude	768	48.3	978	47.3	0.566
High psychosocial demand	785	49.1	1030	49.8	0.668

P: p-value of independent Khi-2 test

Appendix 3B. Comparison of baseline characteristics, outcome and working conditions between respondents with complete and missing data

	With complete data (n = 1275)		With missing data (n = 110)		P
	n	%	n	%	
Baseline characteristics					
Gender					0.003
Men	754	59.1	49	44.5	
Women	521	40.9	61	55.5	
Age (years)					0.001
<35	470	36.9	25	22.7	
35-44	456	35.8	39	35.5	
≥45	349	27.4	46	41.8	
Overweight/obesity	447	35.3	33	31.7	0.469
Diabetes mellitus	13	1.0	2	1.8	0.335*
Rheumatoid arthritis	20	1.6	2	1.8	0.691*
Seniority in current job (years)					0.091
<1	114	9.0	7	6.5	
1-2	198	15.7	15	14.0	
3-10	470	37.2	31	29.0	
>10	483	38.2	54	50.5	
Occupational class					0.008
Craftsmen, salesmen and managers	3	0.2	0	0.0	
Professionals	96	7.5	5	4.6	
Technicians, associate professionals	310	24.3	24	22.2	
Low-grade white-collar workers	348	27.3	47	43.5	
Blue-collar workers	518	40.6	32	29.6	
Temporary employment	77	6.4	9	8.3	0.349
Economic sector					0.013
Agriculture	12	0.9	1	0.9	
Industry	483	37.9	24	22.0	
Construction	66	5.2	6	5.5	
Trade and services	714	56.0	78	71.6	
Working conditions					
At least one of the six UEMSD#	143	11.2	9	9.5	0.602
High perceived physical exertion (RPE Borg scale ≥ 12)	668	52.4	58	56.3	0.444
High perceived physical exertion (RPE Borg scale ≥ 13)	591	46.4	52	50.5	0.419
High repetitiveness of tasks (>4 hours/day)	276	21.6	27	28.1	0.14
Use of vibrating tools (≥2 hours/day)	160	12.5	8	7.6	0.138
Repeated/sustained posture with arms above shoulder level (≥2 hours/day)	132	10.4	12	11.5	0.704
Repeated/sustained posture with shoulder abduction	386	30.3	36	33.6	0.467
Repeated/sustained elbow movements (flexion/extension) (≥2 hours/day)	364	28.5	28	26.7	0.681
Pronation and supination movements (≥2 hours/day)	163	12.8	13	12.6	0.962
Wrist twisting movements (≥2 hours/day)	397	31.1	29	29.9	0.799
Use of the pinch grip (≥4 hours/day)	89	7.0	5	4.8	0.398
Low social support	456	35.8	28	34.6	0.827
Low decision latitude	638	50.0	51	54.8	0.372
High psychosocial demand	625	49.0	42	42.4	0.206

P: p-value of Chi-square test; *Fisher's exact test; #UEMSD = upper extremity musculoskeletal disorders

Appendix 3C: Characteristics and working conditions of the study population at baseline according to gender

	Men (N = 754)		Women (N = 521)		p
	n	%	n	%	
Baseline characteristics					
Age (years)					0.295
<35	288	38.2	182	34.9	
35-44	271	35.9	185	35.5	
≥45	195	25.9	154	29.6	
Overweight/obesity	318	42.6	129	24.8	<0.001
Diabetes mellitus	8	1.1	5	1.0	0.861
Rheumatoid arthritis	10	1.3	10	1.9	0.401
Seniority in current job (years)					0.899
<1	67	9.0	47	9.1	
1-2	112	15.0	86	16.6	
3-10	279	37.4	191	36.8	
>10	288	38.6	195	37.6	
Occupational class					<0.001
Craftsmen, salesmen and managers	3	0.4	0	0.0	
Professionals	67	8.9	29	5.6	
Technicians, associate professionals	204	27.1	106	20.3	
Low-grade white-collar workers	65	8.6	283	54.3	
Blue-collar workers	415	55.0	103	19.8	
Temporary employment	49	6.5	28	5.4	0.407
Economic sector					<0.001
Agriculture	8	1.1	4	0.8	
Industry	354	46.9	129	24.8	
Construction	59	7.8	7	1.3	
Trade and services	333	44.2	381	73.1	
Working conditions					
High perceived physical exertion (RPE Borg scale ≥ 12)	432	57.3	236	45.3	<0.001
High perceived physical exertion (RPE Borg scale ≥ 13)	380	50.4	211	40.5	0.001
High repetitiveness of tasks (>4 hours/day)	145	19.2	131	25.1	0.012
Use of vibrating tools (≥2 hours/day)	142	18.8	18	3.5	<0.001
Repeated/sustained posture with arms above shoulder level (≥2 hours/day)	81	10.7	51	9.8	0.583
Repeated/sustained posture with shoulder abduction	258	34.2	128	24.6	0.0002
Repeated/sustained elbow movements (flexion/extension) (≥2 hours/day)	219	29.0	145	27.8	0.637
Pronation and supination movements (≥2 hours/day)	135	17.9	28	5.4	<0.001
Wrist twisting movements (≥2 hours/day)	247	32.8	150	28.8	0.133
Use of the pinch grip (≥4 hours/day)	46	6.1	43	8.3	0.138
Low social support	286	37.9	170	32.6	0.052
Low decision latitude	338	44.8	300	57.6	<0.001
High psychosocial demand	358	47.5	267	51.2	0.186
P: p-value of Chi-square test					

RÉSUMÉ

Les troubles musculo-squelettiques du membre supérieur (TMS-MS) constituent aujourd'hui l'une des questions les plus préoccupantes en santé au travail et santé publique du fait d'un coût humain et socioprofessionnel considérable. La prévention efficace et durable des TMS-MS reste un défi pour les praticiens et les décideurs en matière de santé publique. L'impact modéré des plans de prévention mis en œuvre au cours des dernières décennies nécessite d'approfondir la réflexion sur les stratégies de prévention à l'échelle de la population active. L'objectif de ce travail de thèse était d'estimer et de comparer les effets potentiels de la réduction des expositions professionnelles aux principaux facteurs de risque (FdR) biomécaniques et psychosociaux sur l'incidence des TMS-MS dans la cohorte COSALI. Cette thèse a révélé qu'une proportion importante et un grand nombre de TMS-MS pourraient être évités si l'exposition aux FdR modifiables tels que les efforts physiques élevés, les postures contraignantes de l'épaule et le faible soutien social, était réduite. De plus, elle a montré qu'une intervention multidimensionnelle qui combinerait à la fois une réduction de l'exposition aux efforts physiques élevés et une amélioration du soutien social, permettrait de prévenir un plus grand nombre de cas.

En conclusion, cette thèse a permis d'estimer l'impact potentiel des interventions sur le nombre de cas de TMS-MS dans une population active salariée. Elle apporte aussi la preuve que pour être efficace, la prévention des TMS-MS ne peut se limiter à la réduction de l'exposition aux FdR biomécaniques mais nécessite une approche multidimensionnelle qui prend également en compte les FdR psychosociaux.

mots-clés : TMS du membre supérieur ; facteur de risque professionnel ; effet combiné ; fraction attribuable en population ; cas évitable ; prévention.

ABSTRACT

Upper-extremity musculoskeletal disorders (UEMSD) constitute one of the most worrying issues in occupational and public health due to their considerable human, social and occupational costs. Effective and sustainable prevention of UEMSD continues to be a challenge for public health practitioners and policy-makers. The moderate impact of the prevention plans implemented over the last few decades requires further reflection on prevention strategies at the working population level. The objective of this thesis work was to estimate and compare the potential effects of reducing work-related exposures to the main biomechanical and psychosocial risk factors on the incidence of UEMSD in the COSALI cohort. This thesis revealed that an important proportion and a large number of UEMSD could be avoided if exposure to the modifiable risk factors, such as high physical exertion, uncomfortable shoulder postures and social support, were reduced in the working population. Moreover, this study showed that a multidimensional combining both a reduction of exposure to high physical exertion and improved social support would reduce a larger number of cases.

In conclusion, this thesis made it possible to estimate the potential impact of interventions on the number of UEMSD cases in a working population. It also provides evidence that to be effective, UEMSD prevention cannot be limited to reducing exposure to biomechanical risk factors but requires a multidimensional approach that also takes into account psychosocial risk factors.

keywords: Upper-extremity MSD; occupational risk factor; combined effect; population attributable fraction; preventable case; prevention.

Présidence de l'université
40 rue de rennes – BP 73532
49035 Angers cedex
Tél. 02 41 96 23 23 | Fax 02 41 96 23 00

université angers