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The regulation of manual aiming movements using the example of baton passing in the 4 x 100 metres relay

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Baton passing is a manual aiming movement which necessitates the co-ordination of precise visual and motor performances in a high-pressure situation. The authors examine the various passing techniques which can be used, detailing the structural and kinematic characteristics of the targeting and receiving movements. They discuss positive and negative influences on performance and various training methods aimed at perfecting the pass. They conclude with the observation that research on this problem, particularly in the field of dynamic characteristics, is still far from being comprehensive.

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1 Introduction

Precise manual aiming movements play an important role in sport. Marksmen, golfers and athletes must be able to make contact with stationary or moving objects using movements of great precision, such as the planting of the pole in the box for the Pole Vault take-off. Table 1 on the following page classifies these aiming movements, and defines the requirements for their performance.

The passing of the baton during the relay is a particularly complex example of such a movement. Ideally, the pass must be carried out within a few milliseconds, although the target area consists of only a few square centimetres and the athlete is attempting the exchange in a situation of high pressure and great strain. This paper will examine the various passing techniques which can be used, detailing the structural and kinematic characteristics of both the targeting and receiving movements, positive and negative influences on performance and various training methods aimed at perfecting the pass.

2 Structural characteristics of the aiming movement during the passing of the relay baton

In the 4 x 100 metres relay the incoming runner, who is running as fast as possible and is already under great strain after

Table 1: Classification of aiming movements (Following Poulton 1957)

Category	Task	Demand	Examples
1	Hitting a stationary object with/ without (a/b) locomotion	Prediction of the muscle activity specific to the task (a)	1a: golf, billiards 1b: free kick/corner kick in soccer
2	Hitting a moving object the path of which, a priori, is determined by known constants or statistical probability - with/without(a/b) locomotion	(a) and prediction of the duration of the aiming movement(b)	2a: tennis service 2b: receiving/passing in sports games
3	Hitting a moving object the path of which, a priori, is not known - without/with (a/b) locomotion	(a) and (b) and prediction of the target position at the moment of hitting and of the most favourable distance at which to begin the aiming movement (c)	3a: behaviour of the goalkeeper 3b: ball games; baton passing in relay running

having sprinted 100-120m, must make a rapid movement of the hand-arm-baton system in order to reach the outgoing runner's hand. This target is not fixed, and is moving in all three dimensions.

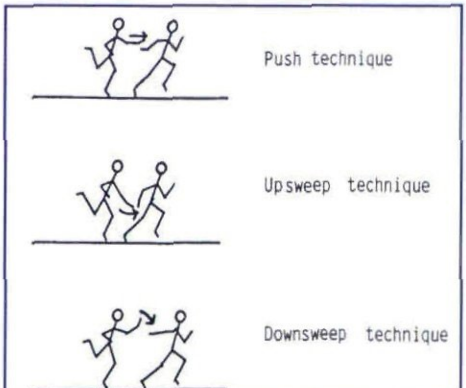

Figure 1 - Illustration of the three different baton-passing techniques

2.1 Baton-passing techniques

There are three distinct techniques for passing the baton: the 'push' technique, the 'upsweep' technique and the 'downsweep' technique. These are illustrated in Figure 1.

The techniques vary, especially with regard to the target position of the baton-receiving hand and the aiming movement of the baton-passing arm.

In the push technique, the arm of the baton-carrying hand is held almost straight, in line with the horizontal target position. The two sweep techniques differ from one another in the direction the sweeping movement takes, and in the position of the baton-receiving hand (in the downsweep technique it is held in a horizontal position; in the upsweep technique it is held vertically).

2.2 Kinematic and dynamic characteristics of baton passing

In the case of a high-performance, homogeneous relay team, it is assumed that the speed curves of the two passing runners (A and B) cross in the second half of the exchange zone. This means that, given optimal conditions, the speeds of A and B are exactly the same when the horizontal distance between the partners is reduced to between 1 and 1.5m and an exchange becomes possible.

Figure 2 illustrates the various phases in the process of baton passing (push technique).

A is continually reducing the distance to B (ta = approach phase) because of the differing speeds. As soon as the distance is reduced enough for the pass to begin, A gives a pre-arranged oral signal (te = decisive phase), the timing of which is determined by anticipation, i.e. he anticipates the change in the distance which will occur in the period between te and tx. With the least possible loss of velocity, the aiming movement of the arm-hand-baton system (tr and tz) begins. While covering the distance in the minimal possible time has priority in the transport phase (tr), accuracy is more important in the subsequent targeting phase (tz).

The actions of the muscles and joints involved in the arm-hand movement are different for each of the three passing techniques. In the case of the upsweep technique, the elbow joint and the wrist are almost extended during the transport and targeting phases, and the arm-hand-baton system forms a straight line. A change of angle is at first only discernible in the shoulder joint. Shortly before tx a radial adduction can be detected (Wiemeyer and Oberste, 1990).

During the push and downsweep techniques, however, there is activity in the shoulder joint, the elbow joint and the wrist. Thus, whereas in all techniques the shoulder joint and the wrist are involved in steering the baton towards the target, in the upsweep technique the elbow joint does not participate in the action.

3 Important influencing factors in baton passing - an attempt at systematics

The aiming movement is influenced by numerous factors, both internal and external (Oberste, 1981). The most important of these are illustrated in Table 2 (see the following page).

3.1 Neurophysiological and psychological state of the system

3.1.1 The ability to perceive movement visually

In the approach phase (see Figure 2), runner A anticipates the time-to-contact with the target. To ascertain the necessary information he must be aware of the path of movement of the baton-receiving hand; only in this way can he anticipate its position at the moment of contact. For this he

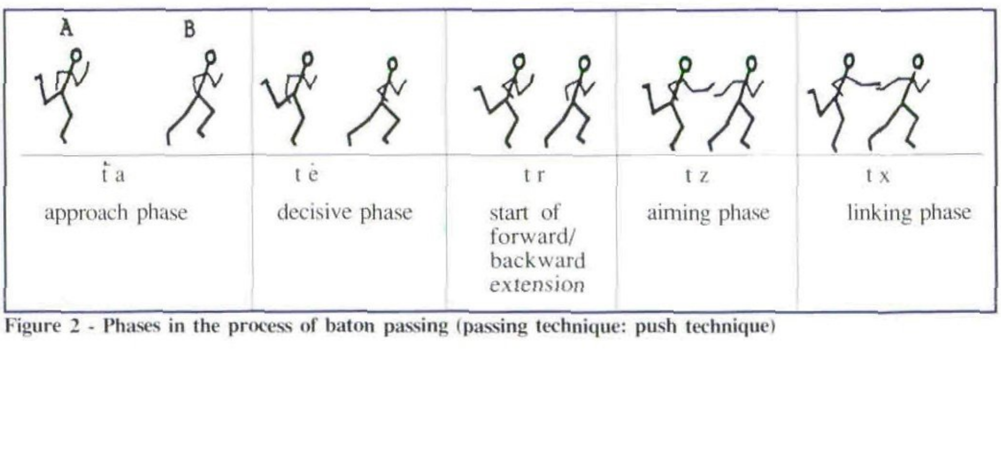

Figure 2 - Phases in the process of baton passing (passing technique: push technique)

Table 2: Systematics of internal and external influencing factors in the movement of baton passing

Neurophysiological and psychological	Characteristics of the aiming movement	Characteristics of the aiming movement
Ability to perceive movement visually	Kinematics	Size
Attention	Dynamics	Position (vertical/ horizontal)
Local and central strain	Control and regulation	Placement (fixed/ moving)
Training state/ level of technique	Passing technique	

requires a well-developed ability to perceive movement visually. Tidow, Wühst and De Marées (1985) find that athletes have significantly lower dynamic visual acuity than sportsmen who participate in events which are more visually demanding; however, these results are not transferable to the present study and are therefore not valid here.

3.1.2 Attention

'Attention', i.e. the selective character of perception, is dependent upon a number of internal and external factors (Oberste, 1979; Ritzdorf, 1982; Prinz, 1983). These include such elements as experience, knowledge, attitude, motivation, level of central- nervous-system activation and 'stimulus characteristics' (for example physical characteristics, action relevance, situation pertinence). The runner carrying the baton, in particular, must selectively 'filter out' from this range of stimuli the information he requires in order to make his decision - in other words, for the beginning and the regulation of the pass (Von Hofsten, 1985).

3.1.3 Local and central strain

Local metabolic strain is great during the pass. This is shown in the report of Hollmann and Hettinger (1980/De Marées, 1989), which shows a blood lactate concentration of 16 mmol/l after 100m of sprinting. It is conceivable that the arms would also show a high lactate concentration as a result of high movement frequency, and that this could negatively affect the co-ordination of baton passing. Because of the great frequency of the efferent (motor) and afferent (sensory, particularly the tactile-kinesthetic) impulses, the occurrence of a high degree of central strain is probable (Azan/ Wiemeyer, 1990), and this can impair performance. The formatio reticularis, in particular, seems to play an important role here (De Marées, 1989).

The influence of various intervening factors and the effect of strain on manual aiming movements of great precision have not yet been sufficiently examined. Figure 3 gives a list of the potential effects of strain which could influence manual aiming movements.

Another important influence on the targeting precision during baton passing is stress. Given certain conditions it can play a role in training (Oberste, 1979), but it is obviously far greater during a competition. Here the rising reticular-activating system (Hackfort and Schwenkmezger, 1980) acts in an unspecific way on the cerebral cortex.

According to the Yerkes-Dodson rule, there is an inverse U-shaped connection between stress and performance (Yerkes and Dodson, 1908; Hackfort and Schwenkmezger, 1980).

3.1.4 Training state and technique level

'The training state is characterized by the degree of development of the individual physical capacity, co-ordinative and intellectual abilities, sport-technical and tactical skills as well as psychological characteristics.' (Thiess, Schnabel and Baumann, 1978).

The 'harmonious unity and combination of the performance factors' (Thiess, Schnabel and Baumann, 1978) to which athletes aspire is made more difficult by variations in the area of physical capacity. As a result, the precision of performance is often impaired, especially when the athlete is under pressure - as is the case during the relay pass.

In order to avoid undesired variations in the baton-carrying runner's speed in the exchange zone, speed endurance must be particularly well developed and as 'stable' as possible. The level of technique is of particular importance for the quality of the pass.

During the learning of manual aiming techniques, the movements are at first carried out only under visual control (closed-loop regulation via the outer control loop). As training progresses there is a shift in favour of the proprioceptive emphasis (inner regulation system).

'The position of the limbs is reported back by the tension receptors of the muscles, the movement of the limbs and their alteration by the receptors in the joints, but also by the receptor bundles in the muscle fibres. The coincidence existing in the learning stage between the outer, visually perceptible effect of a movement and the proprioceptive effect of the same movement creates a sort of proprioceptive standardization (recognition pattern or error-labelling according to Schmidt, 1975) which takes on the control function of the movement execution suitable to the surroundings. A sort of gradation or inner standardization of proprioceptive movement effects results, which makes the decreasing importance of feedback from outside understandable when there is learning progress.' (Klix, 1971)

3.2 Characteristics of the aiming movement

3.2.1 Kinematics and dynamics of the aiming movement

Ideally, during the pass, the baton-receiving and the baton-passing hands move towards each other. This results in an arm position which is unfavourable to the running action, thus leading to a loss of speed. The faster the baton is passed, the smaller the loss of speed will be (Oberste, 1979). During the pass, accuracy is dependent on the regulation of muscle strength and thus on the movement speed of the aiming arm-hand system.

Local and central strain

Visual system	**Tactile kinesthetic system**	**Central nervous system**	**Muscles**
- sight path	- muscle spindles	- spinal motor system	- intra-/intermuscular co-ordination
- eye muscles	- joint receptors	- formatio reticularis	- energy provision
	- skin receptors	- motor/sensory cortex	

Figure 3 - Possible effects of strain on manual aiming movements

Yerkes-Dodson rule: refers to the relationship of strength of a stimulus to the rapidity of habit formation.

Saccade: a brief rapid movement of the eye between fixedpoints.

Formatio reticularis: network of tissue, the function of which is to filter out particular matter,such as bacteria.

Closed loop: refers to a stimulus-response theory of skill learning which stipulates that feedback is present during a specified activity and moderations are made accordingly. The outer closed loop refers to this system of feedback.

Open loop: refers to a motor programme theory, in which there is no response to feedback during the activity. The motor programme contains a detailed set of instructions for coordinative muscular activity.

Ballistic response: this is a response in which no corrections are made by virtue of sensory information (feedback). Often the movement is so fast that corrections are impossible.

Proprioception: this is the sense which informs us where our limbs are when we cannot see them.

Guided response: this uses the closed loop system, and feedback is used to make adjustments.

From the point of view of phenomenology there are several differences between the three passing techniques. The upsweep pass is practised with the elbow joint and wrist almost stretched out. The regulation primarily affects - apart from the radial abduction in the wrist - the muscles of the shoulder joint. By contrast the downsweep and push techniques demonstrate an obvious activity in the elbow joint and the wrist in the targeting phase. Because of the considerably greater moment of inertia, movement regulation is made more difficult if the upsweep technique is used. This statement is supported by the tests done by Schmidtke (1961), according to which movements that exert stress upon the forearm are finally more accurate than those during which stress is exerted on the upper arm.

The amount of effort in terms of strength cannot be quantified because the amplitude of the arm-hand movement is also an influencing factor. When the decision phase (te in Figure 2) falls in the final part of the forward-sweep phase of the baton-carrying hand, the target is about 0.5m nearer than at the end of the backward-sweep phase. The same applies to the movement amplitude of the baton-receiving hand.

In addition, the required horizontal movement amplitude for the upsweep technique is about 0.5m shorter than for the other two passing techniques (Wiemeyer and Oberste, 1990), because here the baton-receiving hand is positioned beside the body and not - as is the case with the push technique and the downsweep technique - at the side of and behind the body.

There are indications that the strength effort increases with the distance of the target (Schmidt, 1984). In the transport phase (tr in Figure 2) a relatively large effort is necessary, whereas towards the end of the targeting phase it is necessary to brake so that the baton reaches the target under reduced pressure. The pressure must, however, be strong enough to ensure that adequate stimulation of the tactile receptors of the palm of the hand leads to a fast closing of the hand (gripping reflex).

The connection between speed and accuracy during manual aiming movements has been examined several times in ergonomics. The results can be summarized as follows:

- A high degree of accuracy can only be achieved if the aiming arm-hand system

Table 3: Selected conditions from laboratory experiments in comparison with baton passing in the 4x100 metres relay

Characteristic/condition	Situation	
	Baton passing	Laboratory experiment
Type of movement	Ballistic	Ballistic
Movement complexity	Category 3 (Table 1)	Category 1(Table 1)
Movement time	160 - 580 milliseconds	Usually over 500 milliseconds
Regulation	Via the outer control loop almost impossible, via the inner control loop or programme	Two-phase structure (first the inner, the outer control loop) or programme
Movement dynamics	High strength effort, late braking and perceptible pressure on the target	High strength effort, early braking and little pressure on the target area
Distance between the aiming person and the target	Variable distance, at the moment of tx about 1 to 1.5m	Constant distance in the region of mm or cm
Time factor	Time pressure	No time pressure
Target	Varying positions, *size: 5 x 8 cm²* shape: trapezoid	Constant position, *size: in the region of* millimetres shape: circular
Condition of the experimental subject	Great local and central strain	Rest, laboratory atmosphere

comes into action at the optimal moment; i.e. movement speeds in the upper and lower limits lead to less accurate results. In his experiments, Schmidtke (1958) finds that the greatest hitting accuracy lies between 20 and 25 cm/sec.

- Falling below a movement-specific tempo increases, not only when targeting, movement unsteadiness and the proportion of errors ... (Hacker, 1978).
- The athlete cannot aspire to a minimization of movement time owing to a negative influence on the movement accuracy (Schmidtke, 1958; Ivanova and Maumova, 1971).

However, the applicability (external validity) of the above-mentioned results and of those referred to later on in the text is questionable when the test conditions for these laboratory experiments are compared with the conditions during actual exchanges in races (see Table 3). Thus, in order to be able to make accurate statements, it is necessary to carry out experimental studies specifically relating to the relay.

In related literature, only scanty information can be found on the dynamic structure of aiming movements. According to tests done by Timpe (Klix, 1971), in simple aiming movements in which the target leading object has mass or inertia characteristics the movement is started with maximal strength effort and quickened to half of the required movement time. After that, a 'maximally-expended braking' (Klix, 1971) is put into action, so that the targeted object comes to rest at the end of the movement.

The dynamic characteristics of the aiming movement are not identical to those of the baton-passing movement, because in the latter the baton does not come to rest but must be passed on by means of a particular pressure, which cannot be more closely quantified, on the target area.

The factor of time plays an important role in relay running. As we have already discussed, the unavoidable, unfavourable position of the arm leads to a loss of speed. In order to minimize this loss, the optimum time intervals illustrated in Figure 2 must be targeted.

a) Reaction time of the outgoing runner (te up to the start of reach back of the arm:

The outgoing runner must bring the target area as quickly as possible into the suitable position; i.e. the reach back of the arm should be begun at once, even if the arm is in its forward-sweep phase.

The regulation of the reach-back movement is, in principle, subject to the same influencing factors as the aiming movement which has already been discussed. As the movement takes place without visual contact, it is probable that tactile-kinesthetic feedback from the shoulder joint, the elbow joint and the wrist areas is used to reproduce the trained space co-ordination of the baton-receiving hand (see Schmidt, 1975).

b) Movement time (from the beginning of the reach back of the baton-receiving hand, or the forward movement of the baton-passing hand, up to the beginning of the coupling phase; tr up to the beginning of tx):

In order to clarify which spatial-temporal parameters characterize the baton-passing movement, an evaluation of video films with superimposed time (1/100 sec.) of the best German relay runners passing the baton twenty times was carried out. High-speed film analyses (see Table 4) were also processed in a case study (Wiemeyer and Oberste, 1990).

c) Length of the coupling phase (tx):

The length of the coupling phase depends on the aiming accuracy and the pressure of the baton on the palm of the hand.

3.2.2 Control and regulation of aiming movements

A differentiation can be made between 'guided' (closed loop) and 'ballistic' (open loop) movements (Hacker, 1978). Baton passing belongs to the latter movement category. The available studies on the control and regulation of trained aiming movements (Rüssell, 1978) enable more accurate statements to be made on the regulation of kinematic and dynamic movement

Table 4: Mean values for the path characteristics and time characteristics of the baton-passing hand during the baton exchange (n1 = 20; n2 = 3; values of the high-speed analyses in brackets)

Movement time up to the reaching of the target (tr to tx- beginning) [sec.]	Linking phase [sec.]	Total time of the aiming movement [sec.]	Length of the movement path [m]	Movement speed [cm/sec.]
0.20	0.16	0.36	0.90	450
(0.40)	-	-	(1.32)	(352)

Table 5: Running times of the control loops involved in manual aiming movements		
Author(s)	**Running times**	
	Inner control loop [m/sec.]	Outer control loop [m/sec.]
Küpfmüller & Poklekoswski (cited according to Russel 1978, 99)	50	200 (also Pew, 1974)
Vossius (1957)	26 - 30	100 - 110
Schmidtke (1958)		93

parameters. The visual analyser registers the space co-ordinates of the target and of the path of the hand movement, and in this way is able to update the movement plan or the realization specifications of the movement programme (Hacker, 1978; Schmidt, 1975). The necessary data are probably ascertained by a saccade of the eye towards the target (Bujakas, 1980).

The first part of a trained aiming movement (transport phase) is regulated by the inner control loop, while the outer control loop takes over the direct target approach up to the target contact (Vossius, 1957; Vossius and Poklekowski, 1957; Vossius and Choudry, 1958; Stier, 1968; Heuer, 1981). However, even with automated actions the visual control function remains, and this should not be underestimated (Hacker, 1978).

The share of the inner and of the outer movement regulation is obviously learning-dependent or training-dependent. By means of intensive training it is apparently possible to enlarge the programmed or proprioceptively controlled part of the movement path, i.e. the visually regulated movement sections move closer and closer to the target (Smyth, 1977). According to the studies of Küpfmüller and Poklekowski (Rüssell, 1978), the share of an internally regulated targeting can be up to 75 % of the movement path. Vossius (1957) calculates for a hand-target distance of 150 mm a share of the internal regulation of 50 % (4 mm target) or of 66 % (2 mm target) of the distance.

We need to understand the significance of the times set down in Table 5 for the assessment of the possibilities of movement regulation.

With a movement time of between 200 and 400 ms (see Table 4), the outer control loop can be run through 2-4 times at best (Pew, 1974), the inner control loop 8-16 times (see Table 5). Thus one can by no means speak of a visual regulation. The various theoretical ideas on the quality of motor regulation processes (for example continuous versus discontinuous regulation; motor versus action approach; impulse-timing versus mass-spring theory) are still of a speculative nature as the empirical results are partly contradictory and some empirical studies have yet to appear (for example Pew, 1974; Schmidt, 1975; Glencross, 1976; Pardew, 1976; Smyth, 1977; Glencross and Gould, 1979; Quinn, Schmidt, Zelaznik, Hawkins and McFarquhar, 1980; Sullivan and Christina, 1983; Schmidt, 1984; Roth, 1989, 1991). As a result they cannot yet be taken into consideration for the explanation of the regulation processes in eye-hand co-ordination.

3.2.3 Passing technique

Indications were found in a case study, on the basis of an analysis of the kinematic characteristics of the three baton-passing techniques already described, that the push technique is superior to the other two tech-

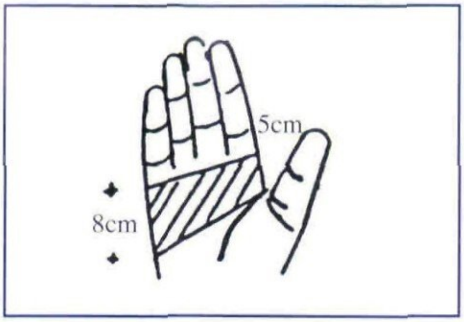

Figure 4 - Target area of the baton receiving hand

niques and particularly to the upsweep technique.

3.3 Characteristics of the target area

During the passing of the baton, the arm-hand system must perform a fast, precise aiming movement towards the target area of the baton-receiving hand, shown in Figure 4.

This target area can be described by the following characteristics.

3.3.1 Size of the target area

The gripping function of the thumb and the finger is only complete when the grasped object can rest in the palm of the hand (shaded area in Figure 4).

3.3.2 Position of the target area

The complexity of the target-bound movement is a result of the necessity for a high degree of accuracy by the target-guiding object, i.e. with a defined part of the baton to a defined part of the hand (see Figure 5).

The position of the target area is an important influencing factor on the accuracy of manual aiming movements. Schmidtke (1961) proves that a horizontal target area can be hit more accurately than a target area in a vertical position. This results in a preference for the push technique and the downsweep technique.

The height of the target area and the distance between the aiming person and the target area are also important factors. Schmidtke ascertains that a target height of 60-70 % of the body height is the area of maximal accuracy of aiming movements whilst standing, whereas the most favourable distance is about 20 % of the body height. The manual aiming movements were more accurate when performed sitting down than when standing. Unfortunately, these test results cannot be applied directly to baton passing, for the reasons given in Table 3.

Synchronization between the reach forward and reach back is necessary so that the baton and the target first come to rest at the moment of contact (tx). This means that the aiming must always occur towards a moving target.

4 Conclusions regarding the baton exchange for the training process

Baton passing should be regularly practised in training because of its high degree of complexity; this also applies to indoor training.

4.1 Training goals

4.1.1 Goals for the incoming runner

- An optimally developed, reproducible sprint endurance ability;
- accurate assessment of the distance to the outgoing runner and precise fixing of the moment when the oral signal is to be given;
- carrying out of the baton pass at the opti-

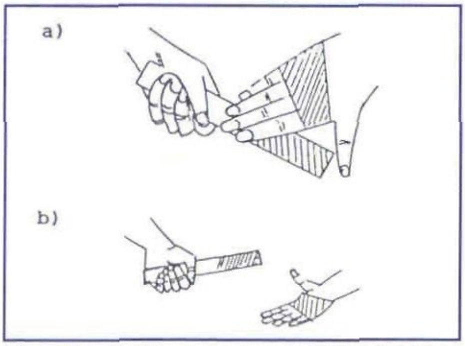

Figure 5 - contact areas of baton and hand when the receiving hand uses an *overgrip* (a: upsweep technique) and when it uses an *undergrip* (b: push technique and downsweep technique)

mal moment, i.e. high speed of the arm-hand system in the transport phase, reduced speed in the targeting phase.

4.1.2 Goals for the outgoing runner

- Maximal, reproducible acceleration ability (from a standing start);
- fast, reproducible positioning and fixation of the baton-receiving hand.

4.2 Training methods

4.2.1 Basic training

The following conditions should be practised according to the 'from-easy-to-difficult' principle:

- Baton-passing practice with the partners running at a low speed (and at a constant distance);
- baton-passing practice, at first with the dominant hand to the fixed target (baton-receiving hand), i.e. 'challenge' the hand at first, then pass on;
- (controlled) medium movement speed of the arm-hand-baton system, with pronounced activity in the shoulder and elbow joints in the passing and in the wrist (ulnar/radial abduction or palmar flexion) in the targeting or coupling phase;
- reach back and positioning of the baton-receiving hand as a reaction to an oral signal at a medium speed run;
- consideration of all three baton-passing techniques.

4.2.2 Build-up training and top-level training

- Gradual increase in running speed in accordance with the level attained;
- baton-passing practice with the non-dominant hand (contralateral transfer);
- training of 'catch-up running': the incoming runner, at maximum speed, tries to catch up with his partner, who is running at sub-maximal speed (training goal: precise fixing of the moment for the oral signal);
- steady reduction in the time interval between the oral signal and the completion of the baton-exchange. Immediately after

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the acoustic signal, the baton-carrying and the baton-receiving hands move towards each other. At the same time, the share of the fast transport phase should be increased at the expense of the slower targeting phase;

- by means of time measurements a check must be made to find out whether the outgoing runner can achieve his maximal acceleration in spite of a fast, reproducible reach back of the arm as a reaction to an oral signal;
- choice of training conditions characterized by a high affinity with competition: baton-exchange practice on the bend; simulation of background noise (using a loudspeaker system); training under competition conditions (several pairs of runners passing at the same time); baton-exchange practice after local and/or central demands on the incoming runner (for example, at the end of a training workout or at the end of a sprint of about 120m);
- mental and/or observation training should be included. For this, it is recommended that baton passing after 'catching-up runs' with different outgoing partners should be filmed (from the point of view of the incoming partner) and then shown to the members of the relay group;
- when choosing a baton-passing technique, the push technique should be preferred. The upsweep technique should not be used;
- in order to adapt to the differing physical and co-ordinative abilities of the members of a relay group, all possible combinations should be considered in baton training.

5 Summary

The passing of the baton should enable the exchange to be quick, thus minimizing the loss of speed resulting from an unfavourable arm position. Therefore an aiming movement, taking place at the optimum moment in the timing of the arm-hand-baton system, must bring the baton to the palm of the receiving hand precisely.

The kinematic and dynamic characteristics of the three baton-passing techniques (push technique, upsweep technique and downsweep technique) were analysed. For various reasons (lower mass moment of inertia, more favourable target position, greater space-bridging) the push technique and the downsweep technique are favoured.

The average movement time of the aiming arm-hand-baton system is, according to tests on two small random samples, so small at 200 to 400 ms that an outer (visual) regulation of the movement can be ruled out. This means that the movement regulation is carried out by means of an inner control loop or with the help of a motor programme.

For a quick triggering of the gripping reflex, the baton must hit the palm of the baton-receiving hand with a pressure which has yet to be quantified.

The influence of local and central strain factors can contribute to a worsening of the eye-hand co-ordination during baton passing.

The conditioning factors in baton passing differ so considerably from those in similar studies done in the fields of work physiology and industrial psychology that the applicability of the results of empirical tests is highly problematical.

Several basic questions remain unanswered. These can only be clarified by means of tests specifically relating to relay running.

Against a background of theoretical results, an attempt was made to give some practical tips for relay training.

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