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# EDITORIAL

Welcome to the June issue of the Journal of Australian Strength and Conditioning. This issue of JASC is jammed packed full of really practical information. The original research article by Naruhiro Hori and colleagues from Western Australia provides some interesting data on the use of lifting straps; while the paper from Steven Donaldson from the University of Canberra provides some clear evidence for the performance benefits of a flexibility program for kicking distance in AFL. Two articles are contributed by Tim Mosey from the Tasmanian Institute of Sport and Tim provides some great figures and videos higlighting the specificity of the single leg squat action to a number of sports. While Richard Lynch provides a very thorough analysis of the 2 legged squat and outlines the effects that different techniques have on the muscle activitation produced in this popular strength and conditioning exercise.

As we move from watching the French Open to Wimbelton, Philippa Coombes contributes a very detailed training program for the development of Tennis athletes. While my personal favourite in this outstanding issue is the article entitled: “The role of increased dietary protein when training for muscular hypertrophy” by Thomas Kempton from the University of Technology in Sydney. Tom provides a great deal of clarity to this important area for the Strength and Conditioning coach and I would encourage all readers to have a good look through this article.
I hope you enjoy the contents of this issue of JASC and find the information to be of great use in its application to your athletes.

Best regards
Dr Greg Wilson, PhD
Editor-in-Chief JASC

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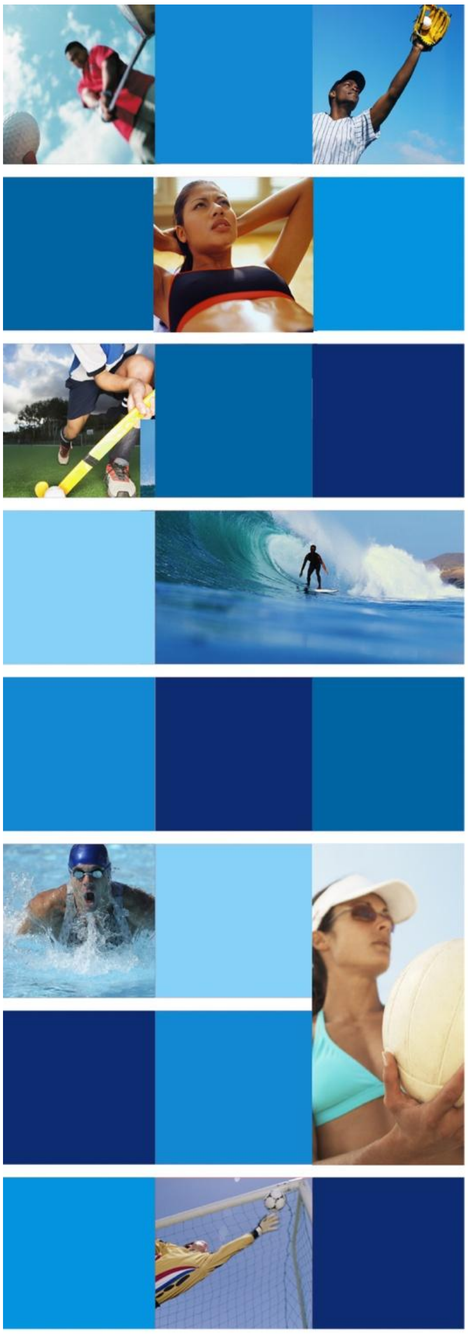

The Effect Of Lifting Straps On Peak Velocity, Force, And Power During Clean Pull. J. Aust. Strength Cond. 18(2)4-9. 2010 © ASCA.

PEER REVIEW

# THE EFFECT OF LIFTING STRAPS ON PEAK VELOCITY, FORCE, AND POWER DURING CLEAN PULL

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**ABSTRACT**
The clean pull is a common exercise among athletes. Some athletes use lifting straps in this exercise, but efficacy of lifting straps has not been examined. The purpose of the present study was to examine the effects of lifting straps on velocity, force and power during the clean pull. Five male professional Rugby Union players performed two sets of two repetitions of the clean pull with a 140-kg barbell under two conditions: with and without the lifting straps, in a counterbalanced order. An optical encoder was attached to the barbell, and peak velocity of the barbell, and force / power applied to the barbell were obtained through an inverse dynamics approach. The highest value amongst four trials (two sets of two repetitions) in each condition for each subject was used to compare between the two conditions by effect size. Four out of five subjects showed greater peak velocity (10.1-28.5%), force (2.9-34.4%), and power (6.5-46.5%) with the lifting straps, but one subject did not show a difference between conditions. The effect sizes for the velocity, force, and power were 1.22, 1.52, and 1.31, respectively, showing large effects. It is concluded that using lifting straps is beneficial for athletes who wish to enhance velocity, force and power during clean pull.

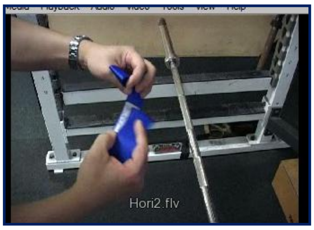
**KEY WORDS** - Weightlifting, Optical Encoder, Grip Strength, Reliability

## INTRODUCTION

The clean pull is an exercise that weightlifters commonly use in their training to enhance their performance (e.g. one repetition maximum [1RM], velocity of the barbell at a given load) of the clean. In the clean pull, an athlete initially grasps a barbell with flexed hips and knees, accelerates the barbell rapidly in a vertical direction through hip and knee extension as well as ankle plantar flexion, and shrugs their shoulders once the barbell reaches its peak velocity (9). Many athletes and coaches believe that the clean pull is a suitable exercise to develop the capability of power output for some sport tasks (10). In fact, this exercise is used for strength and power training, and to test strength and power in many sports (13, 15, 16). For example, several studies have measured velocity, force, power as well as rate of force development during isometric and/or dynamic mid-thigh clean pull (3, 4, 12, 15, 16). The mid-thigh clean pull is a variation of the clean pull which is started from the athletes' mid-thigh height.

During the aforementioned mid-thigh clean pull measures (3, 4, 12, 15, 16), it was described that the subjects used lifting straps. Lifting straps assist the athlete in holding the barbell, especially under high load and/or high volume (Videos 1-3). It is anecdotally observed that grip strength is one of the limiting factors for clean pull performance, which results in the lifter being unable to maximally overload the lower extremity muscles. To overcome this limitation, lifting straps appear to be effective for enhancing the performance of clean pull and maximising training stimulus. However, there is limited scientific evidence to support the benefit of lifting straps.

Video 1




Video 2


Video 3

To the best of the authors knowledge, only one study (17) has documented the effect of lifting straps on the number of repetitions completed during resistance training exercises. Stoppani (17) reported that a group of trained bodybuilders were able to complete several more repetitions with lifting straps when they performed pull up at their body weight, and dumbbell row, wide grip lat pull down, and seated cable row at their ten repetition maximum. Practically speaking, the exercises and the range of repetitions used in the study by Stoppani (17) are typically for hypertrophy. Although the number of repetitions performed at a given load is important for hypertrophy, coaches usually do not prescribe clean pull for such purpose. Rather, clean pull is considered as the exercise to enhance the ability to exert high force rapidly against a given load. Generally athletes perform the clean pull with up to 120% of 1RM power clean (5). No previous study has examined the effect of lifting straps on peak velocity, force, and power in clean pull. Therefore, the purpose of the present study was to compare the velocity, force and power during clean pull between lifting strap condition and control condition in which no lifting straps were used.

## METHODS

### Approach to the Problem

Five subjects who were familiar with clean pull performed four sets of two repetitions of the clean pull at 140 kg. Subjects were instructed to take as much rest as they needed between sets. As a result, all subjects took at least two minutes, but no subjects took more than five minutes rest between sets. Amongst the four sets, two sets were performed with lifting straps, and other two sets were performed without lifting straps in a counterbalanced order. An optical encoder (GymAware, Kinetics, ACT) was attached to the barbell, and kinematic and kinetic performance of the clean pull was assessed by the vertical component of the peak barbell velocity and peak force / power applied to the barbell. To examine the effects of lifting straps, the values obtained from the two conditions were compared. Thus, the independent variable was the condition (with and without lifting straps) and the dependent variables were peak velocity, force and power. The protocol of four sets of two repetitions was chosen to provide the subjects sufficient numbers of attempts to perform their best and to examine reliability through two sets in each conditions based on earlier work(8). Previous studies (5, 12) normalised the intensity of the clean pull based on each subject's 1RM power clean; however, the present study used the load of 140 kg for all subjects, since the subjects in the present study did not perform the power clean in their usual training, and their 1RM power clean was unknown. This load was recommended by the strength coach at the province, and this was considered as the most appropriate load to perform four sets of two repetitions for this particular group of subjects. This load was expected to be challenging for all of the subjects, but the subjects should be able to perform all repetitions with correct technique. To minimise the effects of the order of these two conditions, two subjects performed with the lifting straps in the first two sets and without the lifting straps in the last two sets, and vice versa for the other three subjects.

### Subjects

All five subjects were professional male Rugby Union players (forwards) within a Super 14 province, and had been participating in structured strength and conditioning programmes for at least four years. Their age, height, body mass and grip strength are presented in Table 1. Grip strength of the right and left hands were measured twice for each arm by using a handgrip dynamometer (Lafayette Hand Dynamometer Model 78010, Lafayette Instruments, Lafayette, Indiana, USA). The subject held the dynamometer vertically above his head, and gripped as hard as possible while he extended the shoulder 180 degree with straight arm (2). The higher value of each arm is presented in Table 1. All subjects had regularly performed the clean pull. However, none of them had ever used lifting straps prior to the present study. To familiarise themselves with the testing conditions, all subjects performed the clean pull with lifting straps during the resistance training session four days prior to the data collection.

### Procedures

All data was collected 30 minutes after a light Rugby skills session. As a warm-up, all subjects performed two sets of up to four repetitions of the clean pull at 100 and 120 kg without the lifting straps. The clean pull was performed in a squat rack in which the barbell was placed on the safety rack at a height of 0.54 m from the floor (Video 4). This was approximately at the knee height of the subjects. Although the clean pull can be performed from the floor, it was performed from the knee height because of the following three reasons. First, subjects needed to place the barbell on the floor after every repetition if the exercise started from the floor, which might cause a damage to the optical encoder. Second, if the barbell was placed on the floor, the impact force from the floor might have affected the reading of the optical encoder. Third, it was necessary to make the task as simple as possible. Gripping the bar with a slightly wider than the shoulder width, the subject pre-contracted the muscles surrounding the shoulder, hip and knee joints, and then performed the clean pull as described earlier. Subjects were asked to accelerate the barbell as fast and hard as possible in the vertical direction.


Video 4

The optical encoder was placed directly under the barbell, and the cable end was attached to the right hand side of the barbell, 0.60 m from the mid-point of the barbell. Detail of the equipment has been described elsewhere (1, 8). The optical encoder recorded the vertical component of displacement at a rate of 50 Hz through a dedicated software (GymAware, Kinetics, ACT) operated by a palmtop computer (Tungsten E2, Palm, Inc., Sunnyvale, California, USA). From this displacement-time data, velocity and acceleration at each time point were obtained by differentiation and double differentiation, respectively. At each time point, force was obtained from known barbell mass (140 kg) and acceleration, thus the power was obtained from force multiplied by velocity. Peak velocity, force, and power were defined as the highest values over the barbells' ascending phase in each repetition as shown in Figure 1. Displacement was zeroed prior to each set for every subject, and the investigators ensured the cable was perpendicular to the floor before every repetition.

To examine reliability of dependent variables within each condition, the coefficient of variation (CV) was determined using the repetitions with higher values of the two repetitions from each of the two sets in each condition (Table 2).

**Statistical Analyses**

To compare the values obtained in two different conditions (with and without lifting straps), the highest values of the four repetitions (i.e. two sets of two repetitions in each condition) were used. For each subject, percent (%) difference was obtained from the difference between the two conditions divided by the value obtained without lifting straps and multiplied by 100. The group mean values were compared by using an effect size that was obtained from the difference between the two conditions and the SD of the values obtained without lifting straps (7). Results were interpreted as trivial if less than 0.2, small if 0.2 or larger but less than 0.6, moderate if 0.6 or larger but less than 1.2, large if 1.2 or larger but less than 2.0, and very large if 2.0 or larger (6).

## RESULTS

As presented in Table 3, four subjects (Subjects 1, 3, 4, and 5) showed greater peak velocity values with lifting straps, and one of them (Subject 4) had a relatively large difference between the two conditions. In contrast, one subject (Subject 2) showed no difference in peak power between the two conditions. This was also the case for peak force (Table 4) and peak power (Table 5). The effect sizes showed that there were large effects between the two conditions for peak velocity, force, and power (Tables 3-5.

**Table 1 - Age, height, body mass, and grip strength of subjects.**

| Subject | Age (y) | Height (m) | Body Mass (kg) | Grip Strength Right (kg) | Grip Strength Left (kg) |
|---|---|---|---|---|---|
| 1 | 28 | 1.87 | 113.5 | 65 | 63 |
| 2 | 23 | 1.98 | 113.3 | 65 | 65 |
| 3 | 23 | 1.96 | 112.2 | 66 | 62 |
| 4 | 26 | 1.83 | 114.0 | 55 | 58 |
| 5 | 20 | 1.89 | 113.2 | 61 | 53 |
| Mean ± SD | 24.0 ± 2.5 | 1.90 ± 0.06 | 113.2 ± 0.6 | 63.0 ± 3.0 | 59.6 ± 4.7 |

**Table 2 - Coefficient of variation (%) of peak velocity, force, and power for each condition based on the two sets.**

| | With Lifting Straps | Without Lifting Straps |
|---|---|---|
| Velocity | 1.5 | 5.3 |
| Force | 2.8 | 2.7 |
| Power | 2.8 | 5.0 |

**Table 3 - Comparison between two conditions for peak velocity (m/s) during the clean pull and effect size.**

| Subject | With Lifting Strap | Without Lifting Strap | % Difference | Effect Size |
|---|---|---|---|---|
| 1 | 1.70 | 1.53 | 11.1 | |
| 2 | 1.25 | 1.29 | -3.1 | |
| 3 | 1.42 | 1.29 | 10.1 | |
| 4 | 1.58 | 1.23 | 28.5 | |
| 5 | 1.61 | 1.45 | 11.0 | |
| Mean ± SD | 1.51 ± 0.18 | 1.36 ± 0.13 | 11.5 ± 10.0 | 1.22 |

**Table 4 - Comparison between two conditions for peak force (N) during the clean pull and effect size.**

| Subject | With Lifting Strap | Without Lifting Strap | % Difference | Effect Size |
|---|---|---|---|---|
| 1 | 2162 | 1988 | 8.7 | |
| 2 | 1842 | 1818 | 1.3 | |
| 3 | 2102 | 2043 | 2.9 | |
| 4 | 2427 | 1805 | 34.4 | |
| 5 | 2197 | 2088 | 5.2 | |
| Mean ± SD | 2146 ± 210 | 1948 ± 130 | 10.5 ± 12.2 | 1.52 |

**Table 5 - Comparison between two conditions for peak power (W) during the clean pull and effect size.**

| Subject | With Lifting Strap | Without Lifting Strap | % Difference | Effect Size |
|---|---|---|---|---|
| 1 | 3125 | 2625 | 19.0 | |
| 2 | 2087 | 2107 | -1.0 | |
| 3 | 2491 | 2340 | 6.5 | |
| 4 | 2856 | 1950 | 46.5 | |
| 5 | 3042 | 2610 | 16.5 | |
| Mean ± SD | 2720 ± 430 | 2326 ± 300 | 17.5 ± 16.2 | 1.31 |

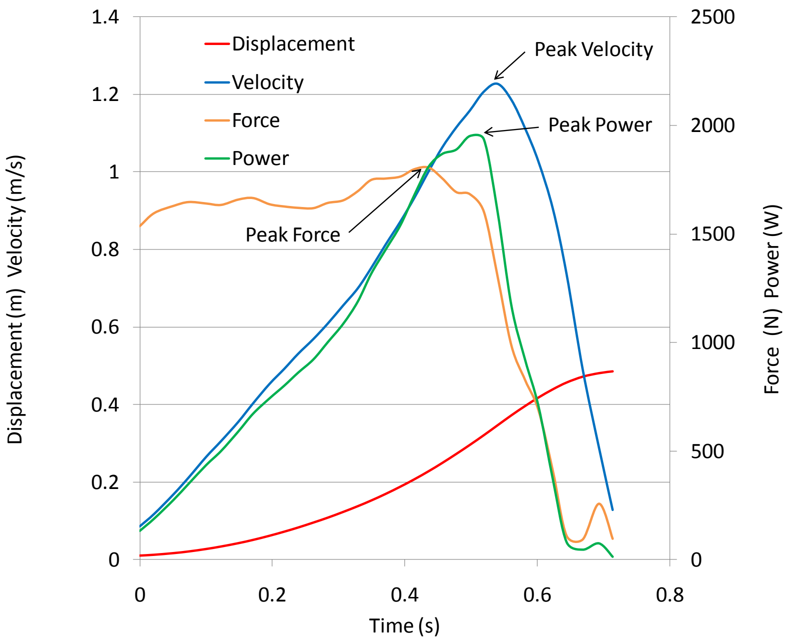



**Figure 1 - Typical changes in displacement, velocity, force, and power during ascending phase of the clean pull. Time is plotted on X-axis, dispalcement and velocity are plotted on left hand side, and force and power are plotted on right hand side of Y-axes.**

## DISCUSSION

The present study compared peak velocity, force and power during clean pull performed with and without the lifting straps. Although the effect of the lifting straps on peak velocity, force and power during clean pull varied among subjects, four out of five subjects showed higher values with the lifting straps compared with the control condition, and the effect sizes indicated that there were large effects between the two conditions. Importantly, the lifting straps did not decrease the performance of clean pull. Although one subject showed 3.1% and 1.0% lower values with the lifting straps for peak velocity and peak power respectively, the differences were within CV values (Tables 2, 3 and 5). Therefore, it seems reasonable to suggest that lifting straps are effective for maximizing the peak velocity, force and power during the clean pull.

It should be noted that the effects of the lifting straps on peak velocity, force and power varied among subjects such that Subject 4 showed the largest improvement (28.5 - 46.5%) with the lifting straps, but no such effect was seen in Subjects 2. The present study recruited the subjects with similar clean pull experiences, but their age, height, body mass and grip strength were not the same. It does not appear that the height and body mass were the factors that determined the effects of the lifting straps on peak velocity, force and power. For instance, the height and body mass were similar between Subjects 1 and 4, but the effects of the lifting straps on peak velocity, force and power were largely different between the two. In the present study, the same absolute load of 140 kg was used for all subjects. In theory, the greater the one's maximum strength, the easier to accelerate a given object with the same absolute load (14). Thus, the peak velocity values shown in Table 3 could imply their maximum strength during the clean pull. Initially, it was hypothesized that the effects of lifting straps would be larger if relative intensity was higher. However, it did not appear that the difference in peak velocity of the control condition between the subjects explained the difference in the effect of the lifting straps. Conversely, the grip strength might be a factor that determines performance of the clean pull without the lifting straps. As shown in Tables 1, 3, 4 and 5, the grip strength was relatively lower for the subject who showed a larger difference for peak velocity, force and power between the two conditions.

The reason why peak velocity, force and power were higher with lifting straps compared with the control condition was unanswered in the present study. It may be that the lifting straps eased the difficulty of holding the barbell, so that the subjects could focus on extending the lower extremities more explosively. In the present study, ground reaction force (GRF) was not measured, thus it was not possible to examine how the lifting straps actually influenced the explosive extension of lower extremity. If GRF was higher when the subject performed the clean pull with the lifting straps, it could suggest that the lifting straps allowed the subject to extend their lower extremities more explosively. Furthermore, if the subjects hold the barbell without lifting straps, they may need to focus on holding the barbell more, which might compromise their lifting technique. To identify what technical errors occurred during each subject's attempts (e.g. bending elbows before the barbell reached its peak velocity), it is necessary to collect kinematics of the barbell and each joint of the subject. Thus, further studies are necessary to collect GRF and kinematic data of the barbell and the lifter's body simultaneously. It is also important to investigate how the effects of lifting straps on peak velocity, force and power are affected by using a range of light to heavy loads.

In weightlifting, the use of lifting straps is not permitted in competition (Page 71, 4.4.6 (11)). Therefore, weightlifters obviously need to familiarize themselves with attempts of 1RM snatch and clean without lifting straps. However, it is common that weightlifters use lifting straps when they attempt snatch pull and clean pull with heavier loads than their 1RM snatch and clean, especially for sets of multiple repetitions. For example, in the study by Haff et al. (5), subjects performed sets of five repetitions of the clean pull at 90% and 120% of their 1RM power clean. Also, athletes often attempt more sets and repetitions of clean pull than the protocol used in the present study in both weightlifting and other sports. For instance, a world class sprint swimmer performed four sets of six repetitions of the clean pull off blocks (13). In such set configuration, the effects of lifting straps could be larger than the present study in later repetitions of the set and/or later sets of the session.

## PRACTICAL APPLICATION

The present study showed that peak velocity, force and power during the clean pull were higher if it was performed with the lifting straps, although the magnitude of the effect was vary among the subjects. Therefore, the use of lifting straps would be recommended for athletes who wish to enhance velocity, force and power during clean pull. However, it should be cautioned that over-reliance on lifting straps could negatively affect grip strength, thus the use of lifting straps require a caution, if grip strength is an important quality. The results of the present study might be applicable to other weightlifting exercises such as snatch pull. However, athletes and coaches need to be cautioned if they attempt snatch, power snatch, clean, and power clean with lifting straps. Some weightlifters do not use lifting straps for clean and power clean because lifting straps limit range of motion of the wrists. With limited range of motion, execution of proper receiving could be difficult in clean and power clean. In snatch and power snatch, necessary range of motion in wrists is not as large as that of clean and power clean, thus many weightlifters comfortably perform snatch and power snatch with lifting straps. However, it should be noted the barbell can be thrown to behind the athlete in the snatch and power snatch if those exercises are performed incorrectly. When the barbell is thrown to behind the athlete, it can cause a serious injury in the shoulder if the barbell is not released from the hand due to the lifting straps.

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*The Effects Of A Hamstring Stretching Program On Hamstring Flexibility And Kicking Distance In Australian Rules Football.*
*J. Aust. Strength Cond. 18(2)10-13. 2010 © ASCA.*

PEER REVIEW

# THE EFFECTS OF A HAMSTRING STRETCHING PROGRAM ON HAMSTRING FLEXIBILITY AND KICKING DISTANCE IN AUSTRALIAN RULES FOOTBALL.

**Steven J Donaldson**
University of Canberra

**ABSTRACT** In the game of Australian Rules football the difference between kicking a goal (6 points), touched (1 point) or turnover (0 points) can be centimetres. The purpose of this investigation was to examine the implementation of a hamstring flexibility program and its effects on kicking distance and flexibility improvement. This study was conducted on male Australian Rules football players from the Canberra competition (*N* = 11). Maximal kicking distance was measured over 6 consecutive weeks with a hamstring flexibility program given to 6 players after the first week. Hamstring flexibility testing was conducted on weeks one, four and six to monitor any improvements and adaptations. Repeated measures ANOVA found no significant improvements in kicking distance for the non-stretching group, but did show significant gains for the stretching group. The same analysis revealed significant improvements in hamstring flexibility for only those participating in the flexibility program. The average gains in kicking distance for the stretching group was 4.17 m. compared to a loss of 0.5 m. in the non-stretching group. These results show that hamstring flexibility can be enhanced by hamstring stretching programs and that improvements in hamstring flexibility have a significant relationship with increases in maximal kicking distance in Australian Rules Football. These findings indicate the importance of hamstring flexibility and its positive impact on kicking effectiveness. Coaches and strength and conditioners can incorporate this information into training programs to improve performance.

**KEY WORDS** - Australian Rules Football, Kicking Distance, Hamstring Flexibility

## INTRODUCTION

The sport of Australian Rules football is a complex sport that requires many skills, however none more important than kicking. Greater emphasis may be placed on kicking for distance with new rule changes looming with regards to the Australian Football League's (AFL) scoring system. The amount of points scored for goals kicked from outside fifty-metres has increased for the AFL's pre-season competition which will make the long range punt the ultimate scoring achievement. These developments show the need to identify trainable areas to enhance an individuals' maximal kicking distance. Flexibility refers to the range of motion or movement of a joint or group of joints (7). It can be measured in either static or dynamic dimensions and is commonly improved by stretching (1).

The aim of this investigation is to determine the effects of a hamstring stretching program on flexibility and maximal kicking distance. It is expected that significant improvements in hamstring flexibility will be shown for players in the stretching group due to their participation in the flexibility program. It is also predicted that those players in the control group will see no significant gains or deficits in hamstring flexibility from their pre experimental results. This hypothesis is based on findings regarding hamstring stretching and its effects on flexibility in military basic trainees (9). Three hamstring stretching sessions were added to fitness programs for the experimental group and results showed a significant increase in hamstring flexibility when compared to the control group. Another expectation of this investigation is that maximal kicking distance will significantly improve for the stretching group whilst the non-stretching group will record no significant changes. Limited research has been done specifically on kicking distance in conjunction with hamstring flexibility programs, however a study finding results on peak torque supports this hypothesis. Findings revealed proprioceptive neuromuscular facilitation (PNF) stretching and static stretching resulted in significant increases in peak torque during both concentric and eccentric phases of hamstring contraction (14). This suggests that increasing hamstring flexibility is an effective method for increasing hamstring muscle performance, and will have a positive effect on maximal kicking distance.

Stretching has many different variations and investigations have been carried out to identify which methods produces the most significant improvements in overall flexibility. This study uses both static and dynamic stretching methods in the flexibility program as previous research suggests that neither one is more effective than the other. One such review looked at 28 studies on the effects of hamstring stretching on range of motion. Results showed that a variety of stretching techniques and durations were attributed to significant flexibility gains and that no specific technique was more effective than another (6).

## METHODS

### Subjects

The investigation involved 11 male, 1st grade players from the 2009 premiership winning team in the ACT division 1 competition. The participants ranged in player positions and all right footed kickers. Ages ranged from 19 to 28 years, all with a similar skill level.

### Design

The first session of analysis consisted of measurements of maximal kicking distance and hamstring flexibility. A football field with large surrounding cover was used to reduce wind interference during testing and although some wind was present, it was minimal. Maximal kicking distance involved 3 attempts of straight line drop punt kicking. The attempt that achieved the greatest distance for each subject was measured and used for data collection. Testing was conducted for the following 5 weeks every Wednesday to avoid muscle soreness from the previous weekends competition. Hamstring flexibility was tested by 3 different measures. These were a sit and reach test, a neuromuscular slump test and a lying hip angle test. The neuromuscular slump test requires subjects to be seated at a standardized height throughout the entire investigation to achieve consistency. The subject is asked to link their fingers together behind their lower back and round their shoulders forward and down into a slump. Once this position is achieved, the athletes' kicking leg is raised in a straight position until it reaches its maximal range of motion. The distance from the subjects' heel to the ground is the measurement recorded. The lying hip angle test determines hamstring flexibility by measuring the angle between the lower trunk and femur. Subjects' are to lie flat on their back and raise their kicking leg in a straightened position until it reaches maximal range of motion. These tests were conducted in the first week to obtain initial hamstring flexibility of participants. After the first week players were divided into a stretching group ($N$ = 6) and a non-stretching group ($N$ = 5). Subjects in the stretching group were required to carry out a two minute hamstring flexibility program on a daily basis. These stretches included dynamic leg swings through the normal kicking range of motion and a static sitting hamstring stretch performed with foot internally, then externally rotated. The dynamic leg swings were performed for 20 repetitions whilst static stretching was carried out using 2 sets of 15 second intervals. All stretching was only done using the subjects' kicking leg. This method was only used for the purpose of this study and it is recommended that athletes should perform the stretching program on both legs to prevent flexibility imbalances. Testing on hamstring flexibility was carried out on weeks 1, 4 and 6.

### Statistical Analysis

Analysis was carried out using a repeated measures ANOVA in SPSS version 17.0. The objective of this was to identify the impact of the independent variables, being the use or non-use of the hamstring flexibility program, on the dependent variables, maximal kicking distance and hamstring flexibility. Significance was set at $P<0.05$.

## RESULTS

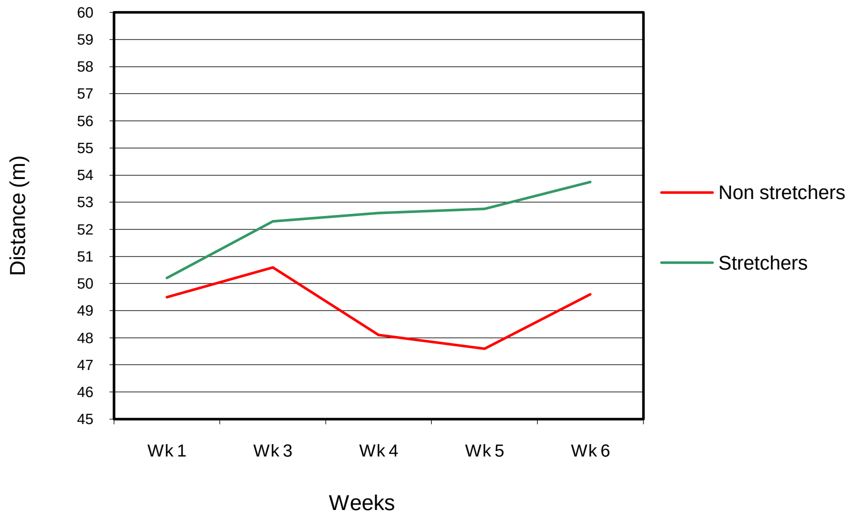


**Figure 1 - Mean kicking distance (m) for non stretchers and stretchers on a week by week basis.**

Figure 1. shows the mean progressive kicking distance for both the stretching and non stretching groups over the duration of the 6 week program.

A repeated measures ANOVA was conducted to assess whether there were differences in kicking distance between the stretching and non-stretching groups. Results indicated no significant improvement in kicking distance for the non-stretching subjects ($p > 0.05$). Significant improvements in kicking distance were found in stretching group ($p < 0.05$).

To measure the effectiveness of the hamstring flexibility program a repeated measures ANOVA was carried out. Results showed no improvement in hamstring flexibility for the non-stretching group ($p > 0.05$). The same analysis showed a significant progression in hamstring flexibility for the neuromuscular and sit and reach tests ($p < 0.5$), however there was no significant improvement found in the hip angle flexibility test for the stretching group ($p > 0.05$).

**Table 1- Mean gain/loss between stretching and non-stretching groups for kicking distance and flexibility tests.**

| Test | Non Stretchers | Stretchers |
|---|---|---|
| Kicking Distance (m) | -0.5 | 4.17 |
| Sit and Reach Test (cm) | 1.02 | 4.32 |
| Neuromuscular Slump Test (cm) | 1.2 | 25.7 |
| Hip Angle Test (degrees) | 1.9 | 9.83 |

## DISCUSSION

Results confirmed the hypothesis that players in the stretching group would realise significant improvements in hamstring flexibility. They also revealed no significant differences in pre and post experiment flexibility for the control group as expected. Identical findings were reported in a hamstring flexibility study on young adults (5). Results showed that hamstring static stretching programs of four and eight weeks in duration achieve significant achievements in hamstring flexibility. It also showed that a stretching program only four weeks in length achieved the same range of motion gains as an eight week program. The post-test mean knee range of motion was measured at 170.1 degrees for the eight week stretching group and 175.7 degrees for those subjects in the four week program. This finding suggests there could be a threshold that is reached during this period whereby no further improvements in flexibility can be achieved, however no direct comparison can be made with the present study due to the different measures of hamstring flexibility.

Previous research has also suggested that hamstring flexibility can be improved by methods other than stretching programs. A study on eccentric training and static stretching on high school males showed that gains in hamstring flexibility were equal for both static stretching and eccentric training (10). This finding could see coaches altering strength sessions to include more eccentric resistance exercises with the hope of improving both strength and flexibility.

Kicking for distance in Australian Rules football is an important skill (3). The ability to kick the ball long distances allows goals to be scored from greater distances and for passes to be longer which increases the difficulty of defending due to more options being available to the kicker (2). It has been shown that the number of effective long kicks during a game was the major predictor in score difference between AFL teams (8). The results of this investigation confirmed the hypothesis that a significant improvement in maximal kicking distance would be present in the group that completed the six week stretching program. It was also confirmed that no significant increase in maximal kicking distance would be shown in the non-stretching group. These results could be due to the increase in hamstring flexibility, which has been shown to result in an increase of peak torque. Another explanation for the improvement in maximal kicking distance is an improvement in force production. A review published in 2004 looked at many aspects of stretching before concluding that regular stretching improves force production, jump height and speed (12). All of which are very important skills in an elite Australian Rules athlete.

Although it is not a specific objective of this investigation, the benefits of increasing hamstring flexibility can been seen through reducing injury. As previously mentioned, it is suggested that hamstring injuries are often caused by over-striding at a high speed (11). Previous research on the incidence of hamstring injuries in the AFL found positive results (13). It indicated that stretching whilst the muscle is fatigued and implementing sport specific training drills significantly reduces the number and consequences of hamstring injuries. Similar findings were revealed in a military setting for new recruits (9). Results showed 12.4% higher incidence of hamstring injury in the control group which indicated that the stretching intervention was effective. This could be due to the hamstring muscle becoming more flexible and being able to move through a greater range of motion without any degree of rupture.

Due to research on the effects of static stretching and dynamic range of motion training on flexibility of the hamstring muscles, a limitation of the current investigation may have emerged (4). Although results from this study indicate that both static stretching and dynamic range of motion exercises significantly improve hamstring flexibility, it was found that 30-second static stretching increased flexibility more than two times that of dynamic range of motion training. This is a limiting factor on the present study because dynamic range of motion exercises were included in the stretching program given to the stretching group.

It was seen that hamstring stretching programs do improve both hamstring flexibility and maximal kicking distance. The quality of players in the ACT competition is of quite a high standard however there may be restrictions when applying these findings to elite athletes in the AFL. Further limitations can also be avoided in future studies by obtaining a larger sample size. Although previous research has suggested that there is no significant difference between a 4 or 8 week stretching program, further gains in maximal kicking distance and flexibility may have been seen with a longer duration. Further research could analyse the effects of hamstring flexibility training in the AFL to find out if these results are consistent between sub-elite and elite sport. An ongoing hamstring flexibility study longer in duration could also identify whether flexibility improvements plateau or continue to increase as time goes on.

## PRACTICAL IMPLICATIONS

Players and coaches can take very important messages from the results achieved in this investigation. A very basic, time friendly but consistent hamstring flexibility program was shown to benefit sub-elite Australian Rules football players through increasing both hamstring flexibility and maximal kicking distance. It should be extremely encouraging that significant improvements were realised from this program in just six weeks. This is a short period of time that can easily allow a hamstring flexibility program to be incorporated into pre-season training so that optimal performance can be present for the start of competition. The easy nature of this program can be largely responsible for its success. The regime in the present study took subjects' just two minutes per day to complete. For professional teams that train every day, this brief duration would allow stretching sessions to be supervised and instructed upon to ensure the program is carried out correctly by each team member, while taking little time away from other training components. Hamstring flexibility programs should be incorporated by Australian Rules coaches and players to maximise performance in a very time and effort saving manner.

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Single Leg Bent Over Squat. J. Aust. Strength Cond. 18(2)14-16. 2010 © ASCA.

# FROM THE FIELD
# SINGLE LEG BENT OVER SQUAT

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## INTRODUCTION

The benefits of plyometric exercises and dynamic stabilisation movements in decreasing injury risk in sportspeople have been documented (1). The single leg bent over squat and its progressions involve strength, power and dynamic stabilisation components of the hip, knee, ankle and foot. This exercise can be programmed effectively for athletes and players that require a certain degree of strength and stability in a flexed hip, bent over position. I currently employ this exercise with a skeleton athlete and rowers. It mimics the position of the push start in skeleton and the flexed position of the catch in the rowing stroke (Figure 1 and 2). In the Winter sport of Skeleton, the athlete accelerates a sled down a bobsleigh track. The initial start has the athlete sprinting in a bent over position. The bent over single leg squat may also have application to other sports such as hockey and Australian based contact sports like AFL, rugby union and rugby league where players may get into a bent over position to pick up a loose ball, enter a ruck or make a tackle. The strength and conditioning professional can assess the athlete's position during the exercise in order to determine whether or not progression can be made within the exercise. A qualitative assessment of valgus at the knee, excessive pronation at the foot and ankle, and general hip control around the pelvis are three factors the strength and conditioning coach should focus on to ascertain the player's or athlete's competency in the exercise. I generally begin with this exercise as a supplementary in the back end of the program after the "heavy" lifts have been completed, or as a warm up exercise intertwined with other stability type exercises. Once the athlete or player has graduated to the "power" version (Borzov Jump), I generally use it is a contrast exercise with deadlifts or squats.

**Figure 1 – Bent over position employed during a dry sled push start by a skeleton athlete.**


**Figure 2 – The catch position of the rowing stroke (1).**

## TECHNIQUE

The first progression of the single leg bent over squat has the player or athlete with their back leg on a box, "working" leg underneath their hip, and torso flexed forward at the hip, attempting to be about parallel with the floor and maintaining a "neutral" spine. The ideal technique sees the athlete begin with extension at the knee. They then drop toward the floor by flexing the knee, whilst maintaining the torso angle to the ground. The athlete then returns to the initial starting position. When they are competent at this exercise – perhaps use a qualitative assessment of 10 "efficient" reps per leg as a guide (efficient being strong posture, minimal knee valgus and ankle pronation, good pelvic control) – the player can increase the load by incorporating dumbbells in each hand or placing an elastic band around the foot and up over the shoulders. The bonus of using a band is it gives variable resistance throughout the exercise. Note that when performing the exercise (as demonstrated in the videos) it is recommended the athlete perform it in a clear space or on a platform without a bar in close proximity. The propinquity to the bar in the video demonstrations is not recommended.

The first video illustrates the unloaded version with a stable surface for the balancing leg.


Video 1.

The second video highlights two methods of increasing load by incorporating dumbbells and a band for resistance.

Video 2.

The third video illustrates the incorporation of the stability component by adding a swissball underneath the back leg. This can also be loaded with the same methods shown in video 2.

Video 3.

The fourth video shows the progression of the exercise into the Borzov Jump for explosive power. The explosive version can be completed from either a static position or in a repeated fashion in order to utilise the stretch shortening cycle. Briefly, during the eccentric phase (downward phase of the movement) potential energy is stored within the tendon/aponeurosis. The quick transference from eccentric contraction to concentric contraction (the upward phase of the movement) sees this potential energy released as the musculo-tendinous unit shortens, resulting in a more powerful and explosive movement than if it were being performed from the stationary position (video 4). The repeated version can be the final progression as the ability to perform the exercise repeatedly with minimal fault is quite complicated.


Video 4.

The fifth video depicts a faulty technique. The coach should note excessive knee valgus (knee collapsing to the middle), foot pronation (foot rolling inward) and a poor spine alignment (a hunched over appearance).

Video 5.

I like this exercise to complement the general and max strength work completed with squats, deadlifts and Romanians. It also gives a good explosive single leg alternative that a strength and conditioning coach can use in contrast to double leg exercises. Creative thinking within a program can result in excellent variety and challenging progressions for athletes.

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*The Effects of German Volume Training on Lean Muscle Mass and Strength and Power Characteristics in Elite Wild-Water Canoeists. J. Aust. Strength Cond. 18(2)17-25. 2010 © ASCA*

FROM THE FIELD

# THE EFFECTS OF GERMAN VOLUME TRAINING ON LEAN MUSCLE MASS AND STRENGTH AND POWER CHARACTERISTICS IN ELITE WILD-WATER CANOEISTS

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## ABSTRACT

The purpose of this investigation was to report on the changes in lean muscle mass and upper body strength and power following a high volume, low intensity German Volume Training (GVT) cycle of resistance training on elite wild-water kayakers. Three elite level wild-water kayakers with high levels of resistance training experience undertook a five week linearly periodised GVT cycle. Upper body strength and power, sum of seven skinfolds and lean mass index were determined pre and post intervention with strength measures of three repetition maximum recorded in the bench press, bench pull and prone chin up. Upper body power was measured in the bench pull via the use of a linear position transducer. Changes were determined via effect size calculation. Large effects were seen in the change of sum of seven skinfolds, bench pull force at thirty, forty and fifty kilograms, and bench pull power at fifty kilograms. Small to medium effect sizes were observed over the three strength exercises of bench press, bench pull and prone chin up. These findings demonstrate that a linearly periodised cycle of high volume, low intensity resistance training produced effective changes in anthropometric measurements (sum of seven skinfolds) and force producing capabilities in the bench pull at certain loads, but minimal effective change in upper body strength and power measurements in elite wild-water kayakers.

## INTRODUCTION

Wild-water kayaking is a sport focussed in popularity within Europe and North America and the southernmost Australian state of Tasmania. Races are contested over a classic distance of between 3.5km and 6.5km – completed in around 20 minutes (depending on actual course distance) and a sprint course held over a distance between 300m and 800m – completed in 60 to 90 seconds. Similar to flat-water and slalom paddlers wild water contestants require the high levels of aerobic capacity combined with good levels of anaerobic power that their flat-water counterparts display (6-8), to successfully pilot courses at high intensities. Anthropometrically, competitors display above average levels of relative lean muscle mass, larger upper body girths compared with the untrained population and tend toward a more robust compact physique (1). The most common injuries occur at the shoulder and wrist joint, with tendinitis being the most common acute injury seen in elite paddlers (14). Races are completed on rivers with large volumes of white-water which the paddler must negotiate in order to complete the course in the quickest possible time. Subsequently, the need for upper body strength and power to overcome the force of moving water are key physiological characteristics a paddler must possess. Indeed the performance of paddlers can be improved by increasing the propulsive forces acting on the blade during the stroke (13). Away from on-water training, resistance training programs can assist in improving this force producing capability of the athlete, utilising high and low velocity specificity programs (12), and improve lean muscle mass by specifically targeting muscle hypertrophy.

The importance of increasing lean muscle mass in order to improve strength and power has been well documented (5, 9). Thus for strength and conditioning professionals working with athletes that require higher than average levels of upper body strength and power – in particular water based paddling or rowing sports – it is necessary to understand and highlight the varying methods that can illicit improvement in these qualities. Despite the Olympic level of on water sports such as flat-water and slalom kayaking and rowing, and the internationally competitive level of wild water canoeing, there is paucity in the literature regarding the most effective ways to improve lean mass, strength and power in the upper body of this mode of athlete. Previous studies have elucidated the necessity for high aerobic capacities of paddlers (6-8), however there is minimal peer reviewed literature on the effects of resistance training interventions on lean mass, and upper body strength and power in this style of athlete. Results of previous studies have suggested improving lean muscle mass (i.e. hypertrophy of muscle) is necessary in order to increase levels of strength and power (5, 9, 15), and many strength and conditioning professionals use specific cycles during the training year to attack the development of muscle hypertrophy in an attempt to increase the size and strength, and – as a by product – possibly the power producing capabilities of their athletes. In attempts to manipulate resistance training program variables, strength and conditioning professionals are continually looking toward alternative methods to add variety to programs and ultimately improve the athletic conditioning of athletes.

An option to traditional hypertrophy training has recently gained interest within the literature in the form of German Volume Training (GVT). Although not a new technique directly, this form of training has – until recently – previously been unassessed by researchers (4). Briefly, a GVT session involves 10 sets x 10 reps of a major muscle group super-setted with an agonist muscle group exercise, with the athlete starting each new complex every 3 minutes (e.g. barbell bench press super-setted with incline dumbbell bench row). Speed of movement is recommended as 3-1-1 (eccentric, pause, concentric components of the lift). This high volume time efficient workout is posited to increase lean muscle mass and improve strength more effectively than traditional methods of hypertrophy training (3). After considering the need of the Tasmanian paddlers to improve their overall lean muscle mass and upper body strength, it was deemed appropriate to introduce a training intervention aimed at improving these physiological characteristics. Hence a GVT cycle was implemented on Tasmanian based Australian team elite wild-water kayakers, which was posited to improve lean mass index (LMI) and upper body strength. Power characteristics were also ascertained to determine if changes were possible after a period of this form of training.

## METHODS

### Experimental Approach to the Problem

Subjects performed power testing on consecutive occasions separated by a single day so as to become familiar with testing protocols. Results on the second day of testing were used as base measurements. Strength testing and anthropometrical testing was conducted one week prior to the intervention beginning and three days after the conclusion of the intervention to determine whether or not improvements had been made within these characteristics. The intervention was implemented with all subjects over a five week period, with all sessions completed (fifteen in total) by subjects. It was determined that strength and lean mass index be the primary dependant variables, with changes in power and force output monitored as secondary dependent variables. The independent variable of total training load per session was controlled to be fixed from session to session once the allocated 10 x 10 was reached in week three. This approach resulted in determining whether or not changes had been made from the beginning to the end of the cycle. No control group was assigned throughout the study and was one fundamental flaw in the design, however due to low subject number of three, sufficient participants for the inclusion of a control group were not available. Therefore results may have been different with larger subject numbers and/or a control group.

### Subjects

Three elite wild-water kayak athletes – two ranked in the world top 10, the third in the top 20 – with a mean and standard deviation (SD) age, height, and body mass of 29.3 (3.9) years, 180 (2.7) cm and 76.4 (4.5) kg respectively were tested pre and post intervention for measures of upper body power, upper body strength, body mass, sum of seven skinfold score and lean mass index (LMI). Subjects each had at least 5 years experience in resistance training and were therefore considered experienced level trainers. Testing was undertaken at the start and conclusion of the 5 week training intervention, which was undertaken post 2009 World Cup competition. Athletes reported for the beginning of the training cycle in a refreshed state, having taken a reduction in training loads post competitive period.

### Procedures

Skinfold measurement was conducted by a Level 1 International Society for the Advancement of Kinanthropometry (ISAK) accredited anthropometrist using calibrated Harpenden Skinfold callipers. The typical “sum of 7” skinfold sites were used for statistical analysis – triceps, subscapular, bicep, supraspinale, abdominal, thigh (quadriceps) and medial calf. Measurements were taken on the right side of the subject. The athlete’s Lean Mass Index (LMI) was also calculated with the LMI formula previously discussed by Appleby et al (2). The LMI exponent used was 0.14.

Upper body power was assessed by peak force and mean power during the bench pull exercise at loads of 30, 40, 50 and 60kg. To perform the bench pull exercise, subjects lay prone on an adjustable bench pull bench (Maxxis, Adelaide, South Australia). Chest, chin and legs were required to remain in contact with the bench at all times throughout each lift. The subject picked up the loaded bar from the ground at a self selected width into the “hang” position (bar not touching the ground). Once in this position the subject pulled the bar with a maximal effort into the bench, before lowering back to the start position with the assistance of gravity. Once back at the initial start position, a pause was taken before the ensuing repetition was performed. In total 3 repetitions were performed at each load. The bar must have touched the bench in order for the repetition to be counted. A 3 minute passive break was enforced between successive lifts at heavier loads. Measurements were taken via the use of a linear position transducer (Gymaware, Belconnen, ACT) which was attached to the right hand side of the bar 15cm from the centre. Prior to performing the working sets, subjects were required to warm up with one set of 6 repetitions at 30kg and one set of 5 repetitions at 40kg at a moderate speed of 201 (eccentric – pause – concentric times of the lift). Dynamic upper body stretches were also performed at the subject’s discretion. Power measurements were measured via bench pull and not ergometer to keep conformity and familiarity with training techniques used during the intervention.

Upper body strength was assessed in the prone chin up, bench press and bench pull. Subjects performed a 3 repetition maximum (3RM) at each exercise. Subject’s were required to perform warm up sets of <10 repetitions at 60% of estimated 1RM, <5 repetitions at 70-80% of estimated 1RM and <3RM at 90-95% of estimated 1RM with 3 or more minute recovery between sets. The prone chin up was performed on a straight bar with subject’s assuming a grip width of just outside shoulder width. A complete repetition was regarded as the chin reaching the highest edge of the bar to lowering back to full arm extension in a hanging position. Subjects were allowed to extend their neck at the top of the repetition in order to have their chin reach the top of the bar. The bench press was completed in a supine position on a flat bench press. Subjects self selected their grip width which was instructed to be just outside shoulder width, but not to far as to be deemed in a “wide grip” position. A complete repetition resulted in the subject lowering the bar in a smooth motion to chest touch, and returning to a locked out position at the top with full extension at the elbows, and not having bounced the bar off the chest. The bench pull was conducted as described earlier. A complete repetition was defined as the bar audibly touching the base of the bench pull bench, and returning to the hang position without the subjects chin, legs or shoulders leaving the bench.

Training sessions were conducted on Monday, Wednesday and Friday afternoons after 4pm and before 7pm of each week with session A completed Monday, session B Wednesday and session C Friday (table 1). Briefly, subjects completed a dynamic warm up including 4 min rowing ergometer, ballistic stretching of the upper body and mobility exercises for the thoracic spine. One warm up set was completed prior to the commencement of the working sets. On both Monday and Friday sets and reps were progressed up to 10 x 10 over the course of the cycle. Subjects initially started with a load at 60% of their 1RM for chin up or bench press. A self selected load was chosen for dumbbell size in the dumbbell bench press and dumbbell bench pull exercises. Each ensuing set was completed at that load. When the subject felt that their next set would not result in 10 reps being completed they reduced the load by 2.5-5kg on the barbell, or used the next set down in dumbbells. If bodyweight chin ups were not completed for the allotted reps, assisted chin ups were completed with the use of resistance bands (Iron Woody, USA).This ensured that the total load volume (10 x 10 = 100 reps) was maintained across the entire session and cycle, once 10 x 10 was reached in week 3 of 5. On Wednesday (session B) subjects completed cluster sets of all exercises. For the chin up complex, subjects completed maximum repetitions with a 10kg load, rested 10 seconds, completed maximum repetitions with bodyweight, rested 10 seconds then completed maximum assisted chin ups with a resistance band. This was followed by a 30 second rest before the push up combine was completed. This involved maximum push ups with a blue resistance band, 10 seconds recovery, maximum push ups with the red resistance band, rest 10 seconds, maximum bodyweight push ups then move to exercise C after a 30 second recovery. Hand width during the push up was self selected by each subject, and was positioned just outside shoulder width in a prone position for the chin up. Cable trunk twist (figure 1) involved the subject beginning with cable at mid trunk height, rotating away from the stack with arms straight in front of the body and finishing across the body, shoulders facing away from the stack.

For exercises 2a – 2c subjects began the incline dumbbell row with each dumbbell equating to approximately 30% of their 1RM bench pull. They completed maximum reps with this load, 10 second rest, maximum reps with the next dumbbell set down, 10 second rest, maximum reps with another set down, rest 30 seconds (e.g. 15kg - 12.5kg - 10kg sets) before moving to 2B. 2B involved a dumbbell shoulder press for maximum reps at a self selected load (so the subject could complete at least 10 reps), rest 10 seconds, maximum lateral dumbbell raise with the same load, rest 10 seconds, maximum upright row with same load, rest 30 seconds before moving to 2C. 2C – hanging leg raise plus rotation (figure 2) – had subjects hanging from the chin up bar, raising their legs in the air by flexing at the hip joint and rotating so they touched their feet on each hand i.e. rotate to the left rep 1, rotate to the right rep 2.

**Figure 1 – Cable Trunk Twist (figure taken from VisualCoaching© Pro, Melbourne Australia).**

**Figure 2 – Hanging Leg Raise + Rotation (figure taken from VisualCoaching© Pro, Melbourne Australia).**

**Statistical Analyses**

Statistical analyses were conducted on two of the subjects (n=2) for upper body power, and all 3 subjects for upper body strength (n=3), skinfold and LMI changes (n=3). The standard deviation and mean were obtained on the limited subject number, with effect size being used to determine worthwhile changes from test to re-test (10). Effect sizes were interpreted as: >-0.15 – 0.15 negligible, >0.15 – 0.40 small, >0.40 – 0.75 medium, >0.75 – 1.10 large, >1.10 – 1.45 very large and >1.45 huge effect. Due to an injury unrelated to the strength training intervention, only two subjects were able to complete test – re-test on upper body power. Caution should be taken when observing these statistical changes due to the low subject number.

**Table 1 – Program Outline**

| Day | Order | Exercise | Tempo | Rest (min) | Intens % 1RM | Week 1 Sets x Reps | Week 2 Sets x Reps | Week 3 Sets x Reps | Week 4 Sets x Reps | Week 5 Sets x Reps |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 1a | Wide Grip Chin Up | 311 | Start cycle every 3 mins | 60% | 5 x 10 | 8 x 10 | 10 x 10 | 10 x 10 | 10 x 10 |
| | b | DB Bench Press | 311 | | 60% | 5 x 10 | 8 x 10 | 10 x 10 | 10 x 10 | 10 x 10 |
| | c | Hanging Leg Raise | 311 | | BW | 5 x 10 | 8 x 10 | 10 x 10 | 10 x 10 | 10 x 10 |
| B | 1a | Chin Up Combine (load, BW, band) | 111 | Rest 10 sec between cluster 45 sec after c | | 3 x Max, Max, Max | 3 x Max, Max, Max | 3 x Max, Max, Max | 3 x Max, Max, Max | 3 x Max, Max, Max |
| | b | Push Up Combine (band, band, BW) | 111 | | | 3 x Max, Max, Max | 3 x Max, Max, Max | 3 x Max, Max, Max | 3 x Max, Max, Max | 3 x Max, Max, Max |
| | c | Cable Trunk Twist | 111 | | | 3 x 10 ea | 3 x 10 ea | 3 x 10 ea | 3 x 10 ea | 3 x 10 ea |
| | 2a | Incline DB Bench Row | 111 | Rest 10 sec between cluster 45 sec after c | DB = 30% 1RM | 3 x Max, Max, Max | 3 x Max, Max, Max | 3 x Max, Max, Max | 3 x Max, Max, Max | 3 x Max, Max, Max |
| | b | DB Shoulder Press/Lat Raise/Up Row Combo | 111 | | | 3 x Max, Max, Max | 3 x Max, Max, Max | 3 x Max, Max, Max | 3 x Max, Max, Max | 3 x Max, Max, Max |
| | c | Hanging Leg Raise + Rotation | 111 | | BW | 3 x 10 ea | 3 x 10 ea | 3 x 10 ea | 3 x 10 ea | 3 x 10 ea |
| C | 1a | Bench Press | 311 | Start cycle every 3 min | 60% | 5 x 10 | 8 x 10 | 10 x 10 | 10 x 10 | 10 x 10 |
| | b | DB Bench Pull | 311 | | 60% | 5 x 10 | 8 x 10 | 10 x 10 | 10 x 10 | 10 x 10 |
| | c | Sit Up with MB Reach Overhead | 311 | | 5kg MB | 5 x 10 | 8 x 10 | 10 x 10 | 10 x 10 | 10 x 10 |

Notes – MB = medball, DB = dumbbell, sec = seconds, lat = lateral, BW = bodyweight, max = maximum repetitions

## RESULTS

The results are presented in Table 2. Huge and very large effects were found in absolute bench pull Peak Force at 50kg, and absolute bench pull Peak Force at 30kg and 40kg respectively. Large effect sizes were found in skinfolds (sum of 7mm) and absolute bench pull Mean Power at 50kg. Table 3 indicates individual changes in each subject. Figure 3 illustrates the change in relative peak force and mean power from test to re-test.

**Table 2 – Strength, Power and Anthropometric Mean Changes (Standard Deviation)**

| Subject Number | Test | Pre Test Score | Post Test Score | % Change in Score | Effect Size |
|---|---|---|---|---|---|
| | | **Anthropometry** | | | |
| N = 3 | Skinfolds (sum of 7mm) | 31.37 (2.75) | 28.7 (2.8) | 8.5% | 0.96 Large |
| N = 3 | Lean Mass Index | 47.17 (2.7) | 47.43 (2.93) | 0.6% | 0.09 Negligible |
| | | **Strength** | | | |
| N = 3 | Bench Press 3RM Absolute | 90 (19.53) | 94.17 (19.42) | 4.6% | 0.30 Small |
| N = 3 | Bench Pull 3RM Absolute | 75 (9.01) | 78.33 (12.58) | 4.4% | 0.21 Small |
| N = 3 | Chin Up 3RM Absolute | 30 (15) | 33.75 (16.91) | 12.5% | 0.23 Small |
| N = 3 | Bench Press 3RM Relative | 1.17 (0.22) | 1.24 (0.2) | 6.0% | 0.33 Small |
| N = 3 | Bench Pull 3RM Relative | 0.98 (0.08) | 1.03 (0.11) | 5.1% | 0.52 Medium |
| N = 3 | Chin Up 3 RM Relative | 1.39 (0.2) | 1.45 (0.23) | 4.3% | 0.28 Small |
| | | **Relative Bench Pull Force (PF) and Power (MP)** | | | |
| N= 2 | PF 30kg (N/kg) | 8.9 (0.2) | 11.4 (2.7) | 28.0% | 1.31 Very Large |
| N = 2 | PF 40kg (N/kg) | 11.1 (0.2) | 14.3 (3.4) | 28.8% | 1.33 Very Large |
| N = 2 | PF 50kg (N/kg) | 12.3 (0.3) | 15.3 (2.5) | 24.4% | 1.68 Huge |
| N = 2 | PF 60kg (N/kg) | 14.2 (0.2 | 13.8 (1.5) | 0% | -0.37 Negligible |
| N = 2 | MP 30kg (W/kg) | 7.2 (0.5) | 8.0 (1.7) | 11.1% | 0.64 Medium |
| N = 2 | MP 40kg (W/kg) | 7.3 (0.6) | 7.8 (1.4) | 6.8% | 0.46 Medium |
| N = 2 | MP 50kg (W/kg) | 6.6 (0.6) | 7.7 (1.7) | 16.7% | 0.86 Large |
| N = 2 | MP 60kg (W/kg) | 6.3 (1.1) | 6.4 (1) | 0% | 0.10 Negligible |

Notes - PF = peak force, MP = mean power, mm = millimetres, N = number of subjects

**Table 3 – Individual Changes in Performance**

| Subject | Bench Press (relative) | | | Bench Pull (relative) | | | Chin Up (relative) | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Pre** | **Post** | **% ±** | **Pre** | **Post** | **% ±** | **Pre** | **Post** | **% ±** |
| | | | | **Strength** | | | | | |
| **1** | 0.99 | 1 | 0 | 1.02 | 0.9 | -11.8 | 1.20 | 1.22 | 1.7 |
| **2** | 1.26 | 1.33 | 5.6 | 1.01 | 1.1 | 8.9 | 1.37 | 1.42 | 3.6 |
| **3** | 1.34 | 1.35 | 0 | 1.04 | 1.08 | 3.8 | 1.64 | 1.67 | 1.8 |
| | | | | **Anthropometry** | | | | | |
| | **Sum of 7mm Skinfolds** | | | **Lean Mass Index (LMI)** | | | **Body Mass (kg)** | | |
| **1** | 33.6 | 27.5 | 18.2 | 44.8 | 45.5 | 1.6 | 73.3 | 72.4 | -1.2 |
| **2** | 32.2 | 31.9 | 0 | 50.1 | 50.8 | 1.4 | 81.5 | 82.6 | 1.3 |
| **3** | 28.3 | 26.7 | 5.7 | 46.6 | 46.8 | 0 | 74.4 | 74.1 | 0 |

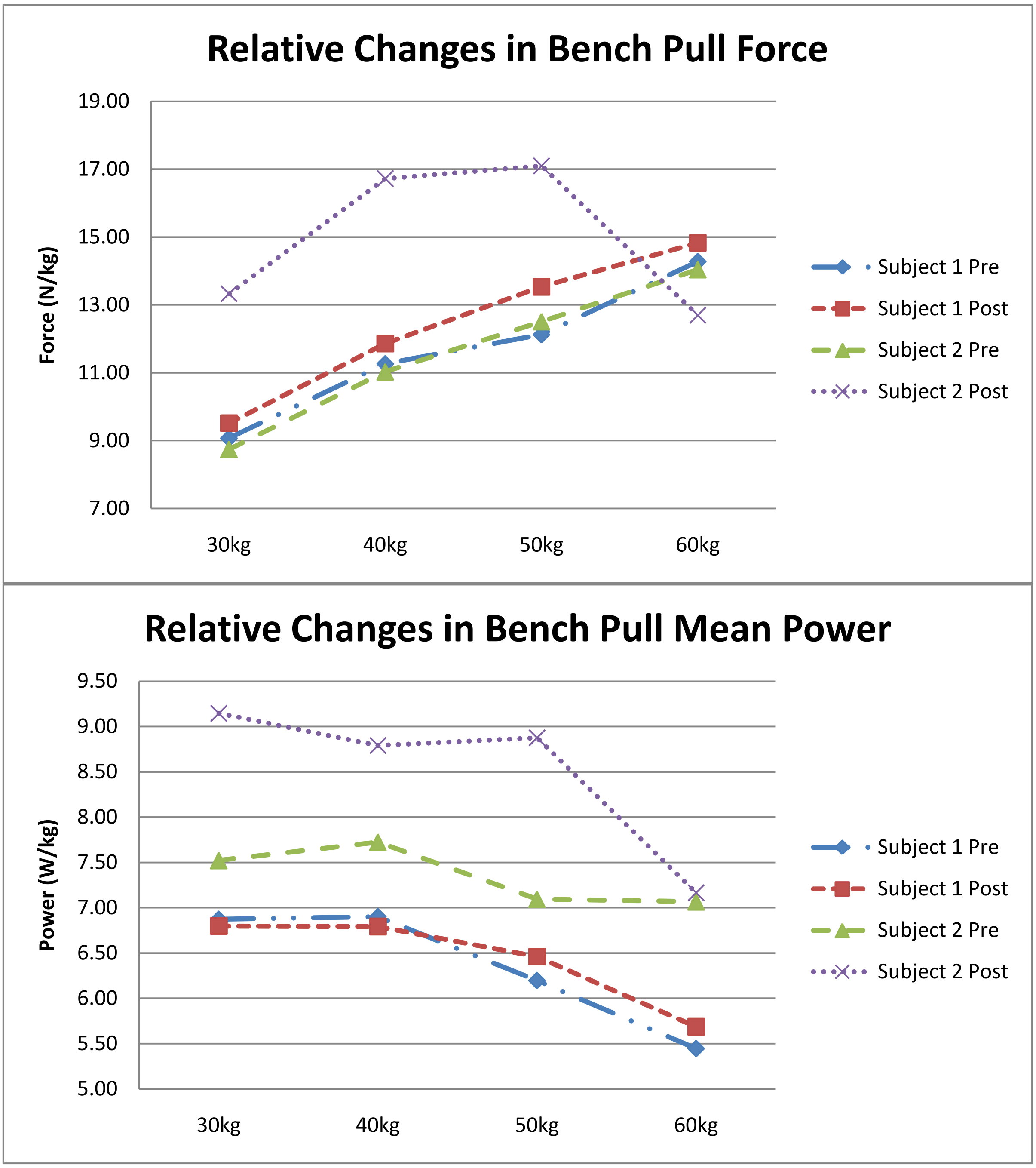


**Figure 3 - Changes in bench pull mean power and peak force of subjects 1 and 2.**

## DISCUSSION

The results of this training program have been illustrated with changes in various performance characteristics of elite wild-water canoeists. The major findings of this program were 1) huge and very large improvements seen in bench pull peak force at 30, 40 and 50kg and large improvements in mean power in bench pull at 50kg, 2) a large decrease in sum of 7 skinfolds, 3) small improvements in upper body strength in the bench pull, bench press and chin up and 4) no change in LMI. Particular note should be made that due to very small subject numbers, the statistical results of this study should be viewed with extreme caution and more attention paid to the individual differences displayed within the athlete compared to between the athletes. Large changes in an individual's mean result can skew low subject statistical analysis quite drastically and result in misinterpretation of data.

The results following this program seem to indicate that a 5 week cycle of German volume based training are effective in improving upper body force production capabilities of elite wild-water canoeists in the bench pull and decreasing sum of seven skinfold scores, but minimally effective in improving upper body strength and anthropometric characteristics such as lean muscle mass. These results are only shown on a small number of subjects and may not be extrapolated accurately to larger populations. Due to low subject numbers, it is preferable to look at individual results opposed to average results of either 2 or 3 subjects.

Throughout the cycle, aerobic conditioning and endurance training was still being undertaken and was not accounted for in the results. Subjects were undertaking between 7 and 10 on water sessions per week outside of resistance training times. This high amount of on-water training may have had detrimental effects on the improvement in lean muscle mass and upper body strength. Improvements in bench pull force and mean power at 50kg may have resulted due to subjects performing the DB bench pull exercise at the combined load of 50kg (2 x 25kg DB's). The majority of GVT sessions performed during the intervention by the two subjects that were analysed started with a 50kg load. Subsequently as the cycle went on – and due possibly to adaptation – the subjects were able to perform more subsequent sets with the same load as opposed to it diminishing quicker, as per earlier sessions in the cycle. Results in bench pull power profile suggest that subject 1 displayed superior adaptation to the training intervention than subject 2. This may be due to individual differences between the subjects, with these subjects exhibiting different anthropometrical characteristics and varying adaptation levels to resistance training interventions in general.

Changes in skinfold thickness were found to be large, however the typical error of measurement (TEM) was not calculated and subsequently changes must viewed with caution. It was hypothesised that skinfold thickness would decrease and that lean muscle mass would improve. The limited changes displayed in LMI after the intervention may have been improved over a longer period of time and a 5 week training cycle may not have been enough to see worthwhile changes in the levels of LMI. As previously stated, the on water training of the subjects was not monitored during the intervention and subsequently the concurrent nature of endurance training combined with resistance training may not have been ideal in eliciting gains in lean muscle mass. Indeed the physiological nature of the subjects may have also contributed to the minimal improvements in lean muscle mass, with subjects (due to the nature of their sport) displaying physiological characteristics more conducive to aerobic based sports. Indeed the subject's susceptibility to increasing muscle mass may not be as high as athletes who compete in sports that require higher levels of muscle mass such as contact sports, and athletes who display a higher propensity to muscle hypertrophy. Another reason may well be the relatively low loads used due to the high volume and short rest periods involved in the GVT cycle were not enough to force adaptations in muscle hypertrophy – particularly for athletes who already do such high volumes of on water training.

Gains in strength were found in subject 2 but were negligible in subjects 1 and 3. Izquierdo-Gabarren and colleagues (11) recently showed that an 8 week linearly periodised concurrent strength and endurance program using a moderate number of repetitions favourable at increasing strength and power in male rowers compared with completing high volume sets with repetitions to failure. Indeed this current program consisted of high volume sets with repetitions to failure on day 2, and endurance training was completed throughout the program – as previously stated. Perhaps if set and rep ranges were used in accordance with the recommendations for strength gain, then strength gains may have been more favourable for all subjects. The length of the intervention may not have been long enough to see any real improvements in strength or any worthwhile changes. Further programs that incorporate a more undulated approach to resistance training and incorporate differing variables to accommodate for specific strength and power gains may be warranted if larger improvements are to be made in the areas of upper body strength and LMI. Scope exists for researchers to incorporate specific GVT sessions within carefully undulated resistance training programs in order to see more beneficial adaptations over time in the measured variables of LMI, strength and power. Extended interventions over longer periods of time may also deliver greater changes in variables than those displayed here over 5 weeks.

## PRACTICAL APPLICATIONS

It is apparent after looking at the mean results of the study that a five week linearly periodised GVT cycle resulted in improvements being made in particular characteristics measured within this study. Of practical note, the differences in changes of variables within subjects were erratic, however individual results favoured one subject more than the other. The overall training intervention did not elicit large gains in the whole subject group. The use of GVT within elite wild-water kayakers may not be of any great benefit in the short term in gaining improvements in the characteristics of strength, power and LMI.

Strength and conditioning coaches may find the use of GVT more applicable to sports that possess a lesser need for high levels of aerobic capacity compared to those required for wild-water kayaking. Sports with a less pronounced number of aerobic conditioning sessions undertaken each week in conjunction with high volume resistance training work, may find results more beneficial in terms of hypertrophic and strength gains. A cycle such as the one used in this study may be incorporated directly into a pre season phase – where traditionally a focus is placed more heavily upon strength and hypertrophic gains compared with developments in explosive power. Alternatively, individual sessions of GVT may be incorporated into a more undulated approach to training that coaches may deem appropriate during the off, pre and in season phases of traditional team sports. For the purpose of incorporating a cycle of physically demanding, high work rate resistance training, GVT is a realistic option a strength and conditioning coach can consider prescribing their athlete's in order to physically and mentally push them to their limits in the gymnasium setting.

The high volume and time efficient nature of a single session creates an efficient method that a practitioner can administer to his or her squad or athlete, and creates options for cycling athletes through limited gymnasium training spaces and timeframes. Due to the time restrictions on exercise complexes, a strength coach can plan efficiently for groups to complete full sessions within a specific time period, and can bracket specific lifting groups based on similar strengths in each exercise within his or her squad or group of athletes.

For increases in power, results varied between the two subjects tested. Looking at the statistical rationale applied in this study should be done so with caution, though it would seem that GVT is not the most ideal option for the strength and conditioning professional to rely on if indeed power improvements are the main outcome goal of the intervention or training program. However if hypertrophic gains are required and a limited training time frame is available within an extended training block, this option may be considered as an alternative to traditional hypertrophy training methods.

## CONCLUSION

A 5 week linearly periodised high volume low intensity GVT resistance training program was implemented upon elite level wild-water canoeists. Results were variable upon measures of upper body strength and power and anthropometric variables. Best results were demonstrated on skinfold thickness and bench pull peak force at 30, 40 and 50kg and mean power at 50kg. Future programs could be altered to target the variables of strength and power more accurately in order to illicit greater gains in these varying characteristics of elite wild-water paddlers. Testing of intervention effects may also be conducted over a more prolonged period, over which athletes have more time to accumulate training effects, and training program stimuli continually altered to illicit greater improvements in the areas of strength and LMI – particularly in elite level experienced trainers.

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*A Literature Review of the Roles and Potential Effects of Testosterone and Cortisol on Athletic Performance: With Recommendations Made For Rugby Union. J. Aust. Strength Cond. 18(2)26-30. 2010 © ASCA.*

LEVEL 2 – LITERATURE REVIEW

# A LITERATURE REVIEW OF THE ROLES AND POTENTIAL EFFECTS OF TESTOSTERONE AND CORTISOL ON ATHLETIC PERFORMANCE: WITH RECOMMENDATIONS MADE FOR RUGBY UNION

**Dave J.F Wildash**

**ABSTRACT** The purpose of this review is to highlight the role and influence of two important steroid hormones (testosterone and cortisol) on athletic performance and how these hormones are affected by acute and chronic exercise. The findings in this literature review are to be used to make recommendations on how rugby union training can then be made more effective.

Specific criteria identified for the inclusion of the studies in this review were (1) Testosterone (T) (2) Cortisol (C) (3) published within the last twenty years (4) research studies with human participants.

The review highlighted that duration and intensity are the two most influential training variables for change in C and T levels. Reduction in T levels are likely to occur from both endurance and team sports, especially when exercise is over the one hour mark or of a high intensity nature; however it must be acknowledged that acute resistance training increases testosterone levels. C levels increased when exercise is endurance by nature or when intensity was above 80% of maximal aerobic effort. The majority of work on the chronic exercise effects of these hormones has found no real change in resting values.

In conclusion, assessment of the changes in T and C may reflect the physiological stress of prolonged training as previously found by Hoffman (19). This provides a means of avoiding the performance decrements associated with the rigors of practice, conditioning and competition.

**KEY WORDS** - Testosterone, Cortisol, Rugby Union

## INTRODUCTION

Many athletes complete large volumes of intensive physical training to improve performance Coutts et al. (7). Unfortunately for the athlete, excessive physical training, incomplete recovery or high general stress may manifest in short term performance reduction and altered mood states. Kraemer et al. (25) stated that the ability of bodily systems (neuromuscular and endocrine systems) to recover and regenerate following composite stress including strenuous activity, psychological stress of practice and competition can also influence physical performance. For instance the decreased ability to produce force may manifest itself in concomitant performance reductions in speed and strength as stated by Kvorning et al. (26).

Considering the physical and aggressive nature of rugby union, the potential for muscle damage or injury clearly exists and may also limit the athlete's ability to maintain physical performance. Hormonal concentrations in the blood have been widely used to study the association of training programmes with performance. The main hormones that have been studied are T and C and these have been recognised as accepted markers of physiological stress associated with training (23, 3, 28, 24).

The purpose of this review is to highlight the role, influence of these hormones on athletic performance and the effect acute and chronic exercise has on these hormones. The findings in this literature review can be used to make recommendations on how rugby union training can be made more effective.

## METHODS

Specific criteria identified for the inclusion of the paper in the review was (1) T (2) C (3) published within the last twenty years and (4) research studies with human participants. In total twelve studies met the above criteria and are detailed in Table 1 & 2 see appendix. The papers that were selected for the review were placed under six specialized headings based on the hormone being reviewed, the effect it had on exercise (acute or chronic) and/or its relationship to athletic performance. An introduction on each hormone is provided to allow the reader to gain a basic understanding of its function and the implications it has on athletic performance.

## DISCUSSION

### Testosterone

T is an anabolic hormone. Therefore if low levels of T are present within an athlete, it is unlikely that there is an adequate or optimal anabolic stimulation to offset the catabolic effects consequent to chronically elevated C levels (e.g. protein catabolism, immune suppression). This notion is supported in a number of studies including a recent study by Kvorning et al. (26). They found suppression of endogenous testosterone decreases strength, muscle mass gains and promotes fat storage over an eight week strength training period as seen in Table 1 see appendix. However, it must be acknowledged the subjects had no strength training experience and thus makes it difficult to apply the findings to the majority of athletes. A more relevant meta-analysis for rugby players was performed by Elashoff et al. (11) and concluded that androgen usage of T leads to approximately five percent increase in strength performance. Various different modalities of training are employed by conditioning coaches to raise the performance of their athletes. One goal of these coaches is to maintain high circulating levels of T in their athletes and keep circulating levels of catabolic hormones to a manageable level.

### Testosterone and Acute Exercise Effects

It has been reported that mild sessions of endurance activity, such as leisure running or cycling have shown little effect on the levels of T in the blood. This suggestion comes from the work of Smilios et al. (31). Exercise longer than the three hour mark showed significant decreases in T values as demonstrated in Table 2 see appendix. This information is invaluable to the strength and conditioning coach when designing aerobic recovery sessions for athletes. It provides general guidelines on duration and intensity to allow the session to produce the desired T response. However, acute resistance training has been shown to induce large amounts of T levels as found by Hakkinen et al. (18). Beaven et al. (4) found similar results using four different resistance exercise protocols and also found a trend towards an increase in T. However the increase was not bigger enough to be significant. This particular investigation is pertinent to the athletic population as it used a sport specific and compound exercise protocols commonly used in high performance conditioning. The training goal of the team sport athlete can often revolve around being bigger, stronger and faster. Since T is an anabolic hormone it is essential that resistance exercise prescription incorporates large compound exercises that encourage T release.

### Testosterone and Chronic Exercise Effects

Hackney et al. (17) have concluded that levels of T are suppressed, through continued participation in endurance activities when compared with sedentary controls. A reason for this change could be due to a peripheral adaptation that results in a suppressed testosterone responsiveness of the testis. However, there is no clear consensus with respect to chronic changes in T due to resistance or other forms of anaerobic exercise in either men or women (22).

### Testosterone and Athletic Performance

The challenge to improve athletic performance is seen when the duration of high or moderate intensity exercise increases, as T appears to decrease (34, 13, 23, 24) and can lead to a negative change in the T/C ratio. This ratio provides information concerning the recovery ability of the athlete as well as the athlete's ability to synthesise protein and to maintain muscle mass. One solution to this dilemma is to monitor training loads based on the actual T levels.

An alternative and non-invasive way to measuring T other than blood samples is via saliva samples. This method is preferred over conventional blood sampling because it is painless and relativity stress free. Salivary testing requires fewer resources to collect samples and therefore makes repeated sampling easier. The simplest and most cost effective way to determine an individual's hormone level using this method is to collect saliva via drooling into a plastic collection device. The sample is then frozen at -20degrees or below before being sent to a company like Stratech Scientific (Australia) for analysis (4). It costs approximately $15 AUD per sample but this can change dependent on volume and the cost of transport.

A recent longitudinal study found that in NCAA III intercollegiate American Footballers, T remained at baseline levels throughout the entire competitive season as shown in Table 1 see appendix. Hoffman et al. (20) considered this to be a desired outcome because the subjects were able to maintain their normal resting anabolic hormonal concentration despite prolonged high intensity training. This was likely to have occurred due to the periodisation of the training program (limited number of high intensity practices followed by lower intensity practices with less physical contact) which provided adequate recovery time. As seen in this study monitoring and planning training sessions appropriately is critical to prevent over or under training for any athlete.

In summary, reductions in T are likely to occur following both endurance and team sport activities (12, 25). It is recommended that coaches endeavour to produce longitudinal T profiles for their athletes so they can have an indication as to how low is deemed too low as this will assist in facilitating athlete's recovery. Medical staff and coaches should be striving to see an increase in T when recovery is scheduled between sessions and competitions. If this is observed, it may represent a potential rebound of physiological function with stress reduction. There appears to be a need for future studies to investigate whether an increase in T actually increases performance or whether a trend similar to an inverted 'U' is more apparent.

**Cortisol**

Previous research (14, 30) has identified that C plays a major role in metabolism and immune function of the human body. It is considered to be catabolic in nature because of its effects on protein and carbohydrate metabolism as seen in previous studies (33, 35). Stimulation of gluconeogenesis by C spares blood glucose and reduces protein stores. Such diminution of stored protein may lead to a wasting of skeletal muscle. This hormone is commonly measured in saliva or plasma and serum from blood samples obtained during exercise (8, 15, 10). It is possible that very high levels of C will have major implications on athletic performance as it will prevent an athlete from fully recovering between exercise sessions and thus lead to reductions in performance.

**Cortisol and Acute Exercise Effects**

The release of C appears to be simulated by endurance exercise as it is positively correlated with the duration and intensity of exercise (6). Secretion of C generally occurs when the intensity of aerobic exercise is above 80% $VO_2$ max or when exercise duration is longer than 60 minutes as shown in Table 2 see appendix. It can appear in the blood 15 minutes following the onset of exercise (1). An exploratory investigation by Acevedo et al. (1) supported this research, and added that as exercise intensity increases above 80% $VO_2$ max to 100% $VO_2$ max C also increases. A study by Dearman et al. (9) used three different running protocols on marathon runners as seen in Table 2 see appendix. This study found that as the duration of exercise increases, the amount of C produced also increases. In resistance training, recent work demonstrated the detrimental effects of C by showing that muscle mass gains increased when C release was reduced through nutritional supplementation as found by Bird et al. (5). As expected this finding confirms previous research that protein synthesis is greater when the environment was less catabolic. Furthermore a study by Ahtiainen et al. (2) demonstrated how the manipulation of acute training variables can influence the response of C. This particular study found that in physically active men, there were significant differences in C concentrations between voluntary maximal repetitions (12RM) and forced repetitions (the last four to five repetitions are assisted to make 12 repetitions). Both protocols induced significant increases in C with the forced protocol producing the highest concentrations. This highlights how slight variations within resistance exercise prescription can dramatically alter hormonal responses. This difference could be due to the extra mental stress (concentration/focus) produced by an athlete when maximum or forced efforts are required as stress promotes C release.

**Cortisol and Chronic Exercise Effects**

The majority of work on the chronic effects of exercise on C concentrations has found no real change in resting C values. A study on untrained and endurance trained athletes (5yrs of training) by Hackney et al. (16) as presented in Table 2 see appendix found that C concentrations were almost identical in untrained and trained subjects. The authors of this study concluded that there is no change in C from chronic exposure to aerobic activities. Current research examining resting C levels suggests that there does not appear to be a consistent pattern of C secretion in chronically resistance trained subjects (22).

**Cortisol and Athletic Performance**

Acevedo et al. (1) found it logical to hypothesise that during exercise, those individuals who perceive greater levels of stress release higher levels of stress hormones. From a coaching perspective it has been found that increasing anxiety during exercise has elicited higher C than trials performed at the same workload without emotional stress. Consequently it should be recommended that in practices the pressure that athletes perceive themselves to be under be monitored and conditions of practices carefully considered. This will prevent C from getting to levels which will have catabolic effects. Although it is not always possible or desired, it is recommended that coaches seek to implement strategies that will decrease the emotional stress associated with training at various points in the training week to help prevent C levels reaching high levels. It is important that longitudinal data is collected on individuals to establish accurate player profiles on tolerance levels to C as well as assisting in monitoring a squad in its entirety. C data can be collected and measured in the same way as T for the same price. However limitations have been reported when measuring steroid hormones which include collection technique, the variable matrix of saliva, the sensitivity, the stability, the presence of binding proteins and the identification of reliable reference ranges. These must all be acknowledged when measuring these hormones (28). Tietz et al. (32) reported an upper reference limit of 230ng $ml^{-1}$ at rest as being a value that would be indicative of catabolic processes being present in the muscle. It is imperative to gain an indication as to what is an acceptable level of C within each individual. This will help to prompt interventions to mediate the effects, for example of any anticipatory elevations that are likely to occur as competition draws closer (21). Dearman et al. (9) hypothesised these elevations to reflect a psychophysiological mechanism used by athletes to increase pre-competition arousal and as part of a coping mechanism to combat the stress of impending competition. It is recommended that any investigations seeking to determine the acute influence of cortisol on rugby union players choose valid and quantifiable measures of both speed and strength commonly performed by these athletes.

## CONCLUSIONS & PRACTICAL APPLICATIONS

The relationship between hormonal concentrations and physical performance standards during the course of a competitive season remains unclear. If the physical demands of practice, conditioning and competition are too great, it might be hypothesised that catabolic activities will predominate. Consequently it is recommended that measurement of hormonal changes take place in elite rugby union players in order to ascertain that the programmes prescribed do cause the expected adaptations. Perhaps equally important though is that measurements of changes are reported to technical coaches who have been educated as to the cumulative effect of high impact training and practices.

Assessment of the changes in T and C may reflect the physiological stress of prolonged training as stated by Duclos et al. (9) and therefore provides a means of avoiding the performance decrements associated with the rigors of practice, conditioning and competition. Enhanced knowledge of each individual and their hormonal profiles through studies of a longitudinal design will allow coaches to more readily monitor a playing squad and thus permit the athletes to more successfully cope with the demands of training and competition. This will allow players to maintain or improve performance over the course of a competitive season. The timing of assessment for players will be dependent on what type of feedback the strength & conditioning coach requires. Hormonal monitoring is not cheap and blind monitoring is not only expensive but also ineffective.

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*Designing Off-Season Training For Tennis Aiming To Improve Strength & Preventing Injury To Improve Performance Throughout The Season.*
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LEVEL 2 SUBMISSION

# DESIGNING OFF-SEASON TRAINING FOR TENNIS AIMING TO IMPROVE STRENGTH & PREVENTING INJURY TO IMPROVE PERFORMANCE THROUGHOUT THE SEASON.

**Philippa V Coomes.**

**ABSTRACT** This review is of available literature discussing the demands of singles tennis play and the ways in which this impacts pre-season training aiming to maximise potential and minimise injuries. Articles discussing physiology, tennis injuries and strength and conditioning programs were reviewed. Articles related to current individual players were not reviewed.

The concept of periodisation, aiming to maximize performance and using strength and conditioning training to prevent injuries requires significant planning when used in relation to the professional tennis circuit. This is not only because daily, weekly and monthly playing schedules can change dramatically by loss of a game, rain delays or an injury, thus requiring a plan to be flexible, but also due to the long duration of the season. Off-season periodised training in tennis is essential to prepare for the lengthy competitive season again. Players need to maximise agility, speed, flexibility, power, endurance and strength as well as rehabilitating any injuries and scheduling some active rest. Technically, tennis at the elite level can be played almost every week of the year due to a large number of tournaments throughout the year spread across many countries. While both Association of Tennis Professionals (ATP - men) and Women's Tennis Association (WTA) tournaments start in the first week of January, ATP tournaments run until the third week of November and WTA until the second week of November. For the purpose of this article the length of the off-season discussed will be 6 weeks.

For the purpose of this paper I will be focusing on strength and injury prevention in the off-season.

## DEMANDS OF TENNIS

Tennis requires short burst of explosive activity followed by rest periods between points of between 20 to 25 seconds (20, 27, 33). This leads to a work to rest ratio of between 1:3 and 1:5 which can be changed fairly significantly depending on the court surface with a slower clay court tending to have a ratio closer to 1:3. When planning training for the tennis season, work to rest ratios need to be considered along with the fact that players can be required to produce high power shots while maintaining agility, shot accuracy and speed over the course of a 5 set match which can exceed 5 hours. For this reason adequate off-season training is vital for the tennis player, not only to progress individual ability and recovery from any injuries, but also to train for the demands of a sport that does not easily allow for a great deal of in-season training so that the player can endure the long season ahead. To get the best results and minimise injuries during the season, a player needs to build an adequate strength base from which to train for power, endurance and speed while training the appropriate energy systems. This is in addition to training sport specific skills.

Kovacs (2004) showed that 93% of points play, irrespective of surface type, lasted less than 15 seconds. With standardised rest times between points of 20 seconds and 90 seconds at change of ends as governed by the ITF, tennis is generally considered to use anaerobic metabolism (not quite to maximum levels generally) with glycolosis, with the ATP PCr system providing energy for play and being recovered aerobically during changeovers or between points (7, 13, 28, 31). This pattern of play, or work to rest ratio, has implications on blood lactate levels seen in players. However, issues with this area of study are that elite players often find regular testing of lactate between service and return games disruptive to focus and as such most studies look at simulated game play. Most notably studies demonstrate higher blood lactate concentrations after service games (4.6 mmol/l) when compared to return games (3.2 mmol/l) with a mean of 3.8mmol (24). These results from Mendez-Villanueva et al (2007), when compared to previous studies in non-elite players, who demonstrated lower, more stable lactate readings (1.5-3.0 mmol/l), suggest that professional players, during actual match play are more intense which ultimately influences energy system dominance.

Traditionally, one of the main goals of off-season training has been to train the endurance systems (20, 30, 31).

Often this has been done in the off-season by repeated 400m sprints and 1.5 mile runs, both of which are not very sport specific method for developing aerobic endurance and can be used to increase tolerance to lactic acid. In theory, 400m sprints may not be sport specific but are often used at the elite level to train with a similar work to rest ratio as would be seen in the game itself. This style of sprint or interval training can be used to train aerobic recovery of ATP (18). A training program can not exclusively use repeat 400m sprints to train athletes due to the game requiring exceptional agility which needs to be trained specifically with some focus on sort distance sprints e.g. 10m before directional change.

**COURT SURFACE**

The court surface the player is to begin the season on is also of significant importance to the type of training done by a player. If the first tournaments are on hard courts the player needs to train differently than if the first match was on clay where the player needs to slide and be able to cope with changes in surface speed within a match itself depending on if the clay is damp or dry. On hard courts players need to be able to accelerate and decelerate while rapidly changing direction, which requires high elastic and reactive strength (31, 32). Clay court play requires significant lower limb concentric and eccentric strength in order to play longer points as well as strong core and stabilising muscles to maintain balance while sliding over longer periods of play. Grass court tournaments, traditionally seen mid year, require the player to repetitively manage dynamic movements through a minimal range with high number of isometric contractions. As the ball tends to bounce lower in grass court tournaments the use and efficiency of the stretch shorten cycle (SSC) is reduced (32), thus demonstrating the need for different off-season training depending on the surface of the first tournaments of the year.

Due to the lower frictional resistance seen on clay courts when compared to hard courts, a lower rate of injuries is reported, particularly knee injuries, seen over the course of a career (11). The shock absorption component is also a significant factor in overuse injuries. Court surface can make a significant difference to energy system dominance. However, generally the anaerobic system is the dominant supplier of energy followed by a combination ATP-PCr system and the glycolytic system (20, 39) with aerobic recovery promoting endurance.

**PLAYER TESTING**

As a player needs to repeatedly produce high powered shots, change direction, accelerate, decelerate, stop quickly, maintain balance while returning the ball, it is essential that a needs analysis includes some sport specific tests that replicate game style play. Incremental court test of short duration with short rest periods can be used to replicate the stresses placed on the energy systems when playing. While VO2 max testing can give an indication of a player's aerobic fitness, with players generally having a reading of at least 50ml/min/kg, Girard et al (2006) suggested that VO2 max testing alone was insufficient when attempting to test maximal aerobic capacity of a player. VO2 max and incremental treadmill testing should be used in conjunction with sport specific testing methods as they have been shown to have similar load increments to field testing but significantly different heart rate responses (8, 9).

Regular testing of aerobic capacity allows assessment of a player's endurance and also of their ability for recovery between points and, therefore, maintains power output and delay fatigue. Fatigue has been shown to reduce shot accuracy by up to 81% (19) and therefore it is important that a player is as physically fit as possible to try and maximise on-court performance.

Fartlek and Beep testing are common tests used in many sports including tennis, however, The Hit and Turn Tennis Test has been shown to be a more sport specific alternative to the Beep test and other incremental tests for player testing (8, 9). The test uses the dimensions of a tennis court with the player running from the forehand to backhand sides along the baseline to an audio CD to strike a ball on a pendulum. It is a progressive, 20 level test allowing testers to measure blood lactate and allow an estimation of VO2max (8).

Testing for strength can be performed by such exercises as a clean and jerk, squats, dead lifts, grip strength, chin ups, counter movement jumps and vertical jump tests. While there is some debate about the safety of doing 1RM vs. 3RM testing, elite players are generally fairly experienced in the use of weight training and can safely be tested using 1RM protocols with supervision and appropriate warm up. Realistically by the third repetition in 3RM the effort should be close to equal to that of a 1RM test except there are three repetitions, compared to just one, in which the athlete could players potentially be injured. In players with less experience with weightlifting 3RM testing may be more appropriate. Tests should not only assess maximal strength but also assess a player's ability to use the power generated through use of the stretch shorten cycle (SSC). Speed, agility and flexibility should also be tested.

**STRENGTH TRAINING**

The goals of strength training are to maximise muscular strength and power while preventing injury and therefore maximising performance while minimising time lost due to injury throughout the season (30, 34). Strength-hypertrophy training aims to create a base of maximal strength before adding a velocity component to train for muscular power. This involves high loads and low volume initially to gain a base strength, with a moderate emphasis on velocity (31). Manipulation of the acute variables will dictate the training adaptations seen.

Periodisation during the off-season should involve planning to peak at important tournaments as well as scheduling mini breaks to allow for appropriate recovery. Periodisation in tennis needs to be flexible due to frequent international travel and the fact that it is completely impossible to accurately predict a player's form, illnesses, injuries and how far a player will progress into each tournament or determine when a player is forced to play two matches in one day.

When the player begins power training the velocity, or the intention to move quickly, is vital in order to train maximal muscle power. Ballistic training is usually characterised by a lower load (30-50%) (7, 17, 31) or it can also be effectively trained using body weight exercises that maximise use of and train SSC. In order to maximise the neuromuscular changes in this type of power training it is vital that the player builds up an appropriate level of strength before moving into the power training stage. Cluster training can be used for the development of explosive power and can allow PCr replenishment between reps, which is appropriate for training tennis. Cluster set training can also act to train endurance simultaneously while including sport-speed specific exercises.

Initial stages of an off-season training plan will involve an active recovery stage to allow players to recover from a long season while avoiding a detraining effect. It is also important to allow the player to mentally unwind after a demanding season. During these initial stages some players will undergo hypertrophy training and some will aim to maximise muscle strength without increasing muscle mass too significantly. All programs also need to include flexibility, coordination, speed, agility and skills based training.

When developing strength, players initially need to develop maximal strength by training at higher loads, such as 80-90% 1 RM with 2-4 sets per exercise, aiming to recruit fast twitch fibres while power is generally trained between 30-50% (31) although individual variations may be seen due to variations in the skills of the individual. Neuromuscular adaptations seen in power training can only be maximised when maximal strength has been trained first (13, 31). In a power sport like tennis, training of rate of force development (RFD) is as vital as a player's ability to repeatedly produce high power movements. Body weight exercises should also be initiated early in the program to ensure optimal execution and knowledge of progression for continued training on the road, particularly if a player does not travel full time with a trainer, as can be the case with lower ranked players.

Players should perform split sessions working on upper and lower limbs in separate sessions. Sufficient rest needs to be planned, not only between individual exercises, with longer rest periods when doing power exercises during the transformation phase to allow complete recovery, but also between sessions. Strength-power or strength-endurance sessions should ideally have a day between sessions with 3-4 sessions per week (7, 28, 30, 32, 33). Split sessions aim to allow adequate recovery between training sessions to gain maximal strength benefits. Major muscle groups should be worked before the smaller groups and skills based training can benefit from following resistance training in order to facilitate some training under somewhat fatigued state (7, 13). The amount of training should be tapered to roughly 2 sessions per week in the lead up to competition. Sufficient time needs to be allowed for flexibility, agility, skills and endurance sessions as well as strength sessions.

Local muscular endurance (LME) is vital to a tennis player and the very nature of the game requires the athlete to repetitively perform strokes at a high power output to generate higher speeds. It is also necessary to have muscular endurance to be able to continually play appropriate spin on the ball while maintaining shot accuracy over the course of 2 or more hours (19). LME is generally trained by using a low intensity, high volume of work with a shorter rest period roughly equivalent to 50-80% 1 RM. Using resistance training and sport specific game play or shot practice will assist in development of LME. Volume and intensity of exercises performed should be noted to monitor training load to avoid overtraining.

It is important to include eccentric training as well as plyometrics, such as medicine ball training, into strength training programs. Medicine balls can be used to simulate forehand and backhand strokes and be done in standing of sitting on a swiss exercise ball. Plyometric training can provide a smooth transition from maximal strength and hypertrophy training to strength-power and strength-speed training. Ellenbecker (5, 33) showed trunk rotation and flexion is strongly associated with forehand and backhand medicine ball throws. Smaller weighted balls of roughly 1 kg can be used to strengthen the rotator cuff effectively and at high speed and can easily be replicated by the player on the road. Ballistic style exercises, such as jump squats, should also be trained to overcome the deceleration phase that can be seen near the end of range in some exercises (31). Such plyometric exercises can be useful to a player as they often already have a reasonable strength base and can begin plyometric exercises at the start of the off-season and maintain the training technique through the year (32).

Overload training can be extremely useful in the tennis off-season due to the time restrictions. The aim of this training is that the adaptations seen will make it easier to meet the demands of match play. This can be an effective means of training anaerobic metabolism and the glycolytic energy pathway while still training the aerobic energy system to aide endurance training to promote the stamina needed to succeed in some matches. In order to train these systems while gaining super-compensation training effects, work to rest ratios still need to be sport specific.

Electrical stimulation can also be used effectively in competition or off-season training. It has been shown to have a significant effect on quadriceps strength as well as tests of muscle strength and power such as a counter movement jump. Maffiuletti et al (2009) suggested that a short period of 3-4 weeks of combination electrical stimulation and active resistance training could optimise results seen in an athlete. Various frequencies can be used to train fast twitch fibres at a maximal contraction. Due to the fact that integration of an electrical stimulation component to a program requires less time that executing a standard strength session, it can be used effectively to maximise minimal available time during the short tennis off-season. However, for the most part, specific weight training is sufficient, and equipment widely available for all players, including those with less financial assistance.

**INJURY REHABILITATION AND PREVENTION**

Coaches and trainers should ensure proper equipment as a variety of racquet properties can influence the distribution of forces throughout the upper limbs and contribute to various injuries in the hand or play a role in the development of 'tennis elbow'. Players should also have appropriate footwear for different surfaces. All players should be regularly assessed by coaches for any biomechanical abnormalities that may contribute to injury.

All off-season training should aim to rectify any imbalances in strength and aim to globally increase strength to prevent injury using a variety of methods to avoid monotony of training (5), as programs will have to be continued throughout the year to avoid loss of benefits. It is vital that all imbalances in the player are rectified so as to avoid any disruption to the kinetic chain of force transference. For example, the serve can place more need for another component to compensate, possibly causing the shoulder to have to produce more torque to maintain service speed and accuracy and can lead to injury of a segment (5). Rotator cuff strengthening is a vital part of any program as is rectus abdominus (RA) training as RA is commonly injured from frequent eccentric overload when serving (23). The shoulder is frequently a site of imbalance that needs to be addressed. Both the shoulder and abdominal region are vital for the transference of forces developed to optimise strokes. All strengthening should involve an eccentric component to strengthen the muscle in a sport specific manner while including plyometric exercises. Yoga has also become increasingly popular in tennis to train core and flexibility.

A prehabilitation program is vital to a player and is designed to target the areas frequently most injured, as well as correcting imbalances, and aims to provide strength to assist optimal joint movement and control. This also includes establishment of appropriate warm up, cool down, and general recovery techniques.

**SHOULDER INJURIES**

Avoiding injury in the shoulder is important and difficult in tennis due to the dynamic activity requirements of tennis and the frequent overhead stresses placed on the joint and the surrounding soft tissue. This requires balanced rotator cuff strength as well as the intact ligaments and capsule (40). Strengthening of the external rotators and scapular stabilisers will assist a player in maintaining optimal shoulder joint stability which will reduce the likelihood of injury and impingement issues (5).

The high prevalence of shoulder injuries, both acute and overuse injuries, due to the repetition of combined abduction and external rotation, indicates the importance of a rotator cuff strengthening program to optimise the control of the humeral head and scapula to avoid impingement injuries. Sport specific and speed specific exercises for the shoulder can be easily performed anywhere with theraband or other exercise tubing (28, 40).

Johnson and McHugh (2005) showed that the serve was the most played stroke when analysing Grand Slam play. This study demonstrated the extreme demand of the shoulder through repetitive overhead activity and its need for a prehabilitation program to avoid injury.

The deceleration component of the serve, seen during the follow through, can be the cause of a significant amount of damage as muscles work eccentrically. The dominance of the serve in tennis, when combined with the eccentric component of deceleration, can lead to repetitive microtrauma, tightening posterior capsule, loss of internal rotation (GIRD) (38) and ultimately to an overuse injury. This repetitive microtrauma often leads to a loss in internal rotation range when compared to the non-dominant arm and a weakness in the external rotators on the service arm (5). Professional tennis players tend to show, over time, a tightening of the shoulder joint capsule, thereby limiting internal rotation. Professional players are therefore at a risk of shoulder impingement, capsular pain, labral tears or rotator cuff tendinopathy or tears. For this reason the shoulder absolutely must be trained not only in pre-season training but throughout the season to avoid serious injury and loss of play time.

The shoulder is at most risk of overloading during the service motion. If the entire chain of movement that contributes to a serve with good technique are not in place it can lead to shoulder overload via the player trying to generate more torque through the shoulder to compensate for a loss somewhere else throughout the kinetic chain (40).

## LOWER LIMB INJURIES

Lower limb injuries are the most common injuries seen in tennis. This is followed by upper limb injuries and then back injuries (29). Distribution of foot pressures differs depending on the court surface due to different running styles (11, 25). On clay courts sliding is used more frequently which means that players must work on their lower limb strength and balance in order to minimise injury. It is also related to the different frictional coefficients. Girard et al (2007) showed different loading patterns in the foot depending on surface type. They showed more loading though the front portion of the foot when on hard or fast courts, requiring more aggressive style of play. This has implications for possible nerve entrapment, ligamentous strain and muscle injuries in the ankle and foot, with a higher degree of muscular fatigue being seen on fast courts.

The higher friction coefficient on hard courts tends to predispose the player to more ankle sprains, knee ligament injury, Achilles tendonitis and various toe complaints due to higher loading, faster play style, higher friction and demand for fast changes in direction (3, 25, 27). On clay courts, there is less jarring and stop/start play style due to the ability of the players to slide to decelerate and the slower game style allowing for more time to change direction which can lead to a higher rate of fatigue or muscular strain injuries on clay courts. Groin injuries and calf injuries can sometimes be seen more on clay courts. Sliding on a hard court can often be seen in elite level tennis as a means of deceleration but, if used excessively, can cause injury in the player due to the high friction component of play and the increased likelihood for jarring injuries or ankle sprains.

Lower limb strengthening needs to be performed not only to minimise the risk of injuries, provide stability and balance, but also to maximise the results of conditioning, which can help minimise the effect of high temperatures, and therefore issues like heat cramps, that can be seen playing in the hot environments like those frequently seen at the Australian Open. However, most lower limb injuries, including knee injuries, are caused by repetitive use and the high demand on joint, ligaments and muscles with repeated stop/start play. Rapid changes in direction also exert significant forces through the leg, the initial large amounts of power being generated in the legs and transferred through a kinetic chain to produce high power shots. The importance of not only training for strength, flexibility and local muscular endurance as well as power in the lower limbs cannot be underestimated. Improving flexibility and strength will help avoid patellofemoral or patellar tendinitis problems, which can significantly affect players (32). Such a program would be designed to optimise patella tracking and muscular control, avoiding the reflex inhibition that can occur as a result of pain.

## BACK INJURIES

The serve and the changes seen in the modern groundstroke require a high degree of rapid lumbar rotation repetitively throughout a match resulting in a large amount of stain on the lumbar spine facet joints. Depending on the style of serve, a degree of extension can be seen that can lead to disc issues. This highlights the need for thorough assessment of the lumbar spine and its musculature to identify any areas of weakness or imbalance that could predispose a player to injury under such a high, repetitive demand. Core stability should be a regular part of a tennis players training on a daily basis, being used as a minimum in warm up and cool down.

Players can often be screened for asymptomatic abnormalities through the use of MRI or to identify areas of weakness as seen, particularly in the facet joints of the lumbar spine in asymptomatic patients as seen in the work of Alyas et al (2007).

Core strength and eccentric training of the RA muscle is important as the abdominal muscles are used in the service motion to help create the trunk flexion that occurs as the player strikes the ball in the acceleration and follow through stages (5). Core strength and stability assists the transference of forces throughout the kinetic chain. Core stability and dynamic balance practice is a vital part of an overall strengthening program to promote injury free movement around the court and balance when sliding, changing directions quickly or reaching at maximal stretch (27, 28).

Hibbs et al (2008) stated that it is believed that core training is vital to an athlete whose chosen sport requires repetitive flexion/extension as well as rotation, as with all tennis strokes. They also stated that optimal core strength, enhanced by incorporation of core stability training into a periodised program, can enhance the use of the upper and lower limbs and transference of power, as is necessary in tennis to maximise speed and accuracy of shots without causing undue stress on the body (15). Core training needs to ensure that local and global musculatures are stressed at varying loads in order to gain not only improvements in muscle control and strength but also neurological coordination. Core training should be varied regularly to stress the muscles in different positions and to ensure oblique and RA are included training at different speeds in both concentric and eccentric ways.

**UPPER LIMB INJURIES (EXCLUDING SHOULDER)**

Overuse injuries of the wrist are commonly seen amongst the pro circuit and can be quite debilitating and have a significant effect of ability to control the racquet and strike the ball accurately and forcefully.

Tennis elbow, like many tennis injuries, is an overuse injury, also caused by repetitive microtrauma resulting from frequent eccentric usually in the deceleration of most strokes but most particularly in high topspin strokes. It tends to be seen more frequently in players that use single handed backhands as, when compared to a double handed backhand, the single arm absorbs the energy that can be shared between two in the case of a double handed backhand.

The high rate of overuse injuries throughout the entire body, not just the upper limb, highlights the extreme demands of tennis and the needs for optimal conditioning as well as technique modification. Stroke practice needs to be included in strength training in the off-season.

**Table 1 - Example of heavy training week in pre-season training block.**

| Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
|---|---|---|---|---|---|---|
| AM<br>Agility<br>Court skills* | AM<br>Physio<br>Speed/ Repeated Sprint | AM<br>Strength (lower body) | AM<br>Court skills<br>Agility<br>Plyometrics | AM<br>Court skills | AM<br>Court skills (short)<br>Endurance (match play) | AM<br>Off |
| Lunch | Lunch | Lunch | Lunch | Lunch | Lunch | Lunch |
| PM<br>Strength (upper body) | PM<br>Power lifting<br>Prehab weights<br>Massage | PM<br>Endurance | PM<br>Speed/ Repeated Sprint | PM<br>Strength (whole body)<br>Massage | PM<br>Prehab weights<br>Hydro | PM<br>Flexibility (self) |
| EVENING<br>Flexibility | | EVENING<br>Yoga | | | | |

- Court skills include foot work, technique and tactics as per coach discretion.

**Table 2 - Example exercise and training variables for week in Table 1.**

| Day | Training Type | Example Exercises | Volume/Time | Intensity | Work : Rest |
|---|---|---|---|---|---|
| Mon, Wed, Fri | Strength | Legs: Front squat, leg press, hamstring curls, walking lunges with hand weights, body weight gluts, calf raises, Bosu ball hop on/off ankle stability | 8-10 reps<br>3 sets<br>Bosu 3 x 30sec per leg | 70 – 80% 1 RM | 60 sec rest |
| Tues, Sat | Prehab weights | Push ups, sit ups, shoulder internal and external rotation, wrist flexion, extension, radial and ulnar deviation, knee extension, calf raise, Bosu hop on/off | 12-15 reps<br>3 sets<br>Bosu 3 x 30sec per leg | 60-70% 1 RM | 30sec rest |
| Mon, Thurs | Agility | Lateral alley drills, Z-ball game, reaction sprints based on court position, medicine ball tennis | 6-8 reps<br>3 sets | Max effort sprints. 60-75% 1RM for weight based exercsie | 1:4 |
| Tues, Thurs | Power/Plyometrics | Power cleans, bench throws, box jumps, countermovement jumps, medicine ball forehand/backhand/throws | 6 reps<br>3 sets | ~30% 1RM | 1:5 |
| Tues, Thurs | Speed/Repeated Sprint* | MAS based sprint protocol<br><br>Repeated 400m sprints | 15 sec sprint<br>14 reps<br>2 sets<br><br>400m x 10reps<br>1 set | 120% MAS<br><br>90-100% effort | 4min between sets (MAS)<br><br>1:1 (400m) |
| Wed, Sat | Endurance | 1) Match play<br>2) Continuous run<br>3) Hill runs | 1) 2-3 hours<br>2) 60 min<br>3) 40 min (4 x 10 min) | ~70% effort | As per ITF rules* |
| Mon, Thurs, Fri, Sat | Court Skills | At coach discretion | - | 90-120min | 1:4 |
| Mon, Wed, Sun | Flexibility/Yoga | Sleeper stretch, back rotation, pectorals, glut and piriformis, Thomas stretch, hamstring, wrist flexors and extensors | 3 reps<br>1 set per side<br>Whole body | 20-30sec hold<br><br>50min yoga class | - |

- * Speed/Repeated Sprint exercises to become shorter and more court based as player progresses through training block e.g. suicide line drills, resisted sprints, and cone weave or touch drills.
- * As per International Tennis Federation (ITF) rules. 30 seconds at change of ends, 90 seconds between sets.
- Any times given for intensity include warm up only.

## CONCLUSION

Optimal conditioning in the short tennis off-season can assist a player in avoiding injuries and therefore maximise season productivity and potentially career longevity. Equipment selection, identification of biomechanical errors and identification and correction of areas of muscular imbalance or weakness play a significant role in avoiding injuries (5, 6). Imbalances in a player, when combined with the repetitive load on the body, varying court surfaces and physiological demand, can lead to decreased performance, muscular fatigue and over use injuries. Overuse injuries, the most frequently seen type of injury in tennis, can also occur as a result of insufficient or improper rehabilitation following an acute injury.

Strength training in the off-season should be designed to enhance on-court performance and focus on developing strength and then power as well as muscular endurance and appropriate training of the anaerobic and aerobic energy systems. Training in the off-season should challenge the anaerobic and aerobic systems while increasing strength and power and maximising on court performance (13, 17, 18, 19, 32). Plyometric training, particularly body weight exercises, should be introduced early to maximise power benefits and train the SSC. The hypertrophy stage of training is vital in order to develop maximal strength and, therefore, optimise power training in subsequent stages while also ensuring development of rate of force development, which is vital to successful tennis play. Heavy resistance training enhances the ability of the muscle to develop maximal force, power and enhances RFD. However, it should be remembered that is not considered ideal for significant increases in muscle mass to be seen.

When training in the off-season, consideration needs to be given to the type of court the player will be playing on, and an appropriate training program developed. Strength training is not only focused on improving synchronization of motor units and appropriate order of muscle recruitment but also stability of the joint throughout varying ranges of motion. Prehabilitation, as well as complete rehabilitation from any injuries, should also be the focus of off-season training. It is also important that trainers and coaches recognise the significance of various stressors and schedule sufficient rest, both immediately at the end of the season and during the off-season training in order to maximise training adaptations without a player entering an overloaded state.

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*The Role of Increased Dietary Protein when Training for Muscular Hypertrophy. J. Aust. Strength Cond. 18(2)40-47. 2010 © ASCA.*

LEVEL 2 SUBMISSION

# THE ROLE OF INCREASED DIETARY PROTEIN WHEN TRAINING FOR MUSCULAR HYPERTROPHY

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**ABSTRACT** This brief review examines whether increased protein intakes are justified for athletes seeking muscular hypertrophy. Twenty-one journals were selected for review following a search of recent literature using the 'Sportsdiscus' and 'Pubmed' databases. Protein requirements for individuals are thought to vary depending on the training and performance goals of the athlete. There is a general consensus that athletes engaged in resistance training may have elevated protein requirements compared to the general population. However, most athletes that are meeting their daily energy requirements through a balanced diet are found to usually consume sufficient amounts of protein. Evidence exists for a ceiling effect on the amount of protein that is required and intakes above this threshold result in an increase of leucine oxidation, which indicates excessive protein intakes. Research suggests that other factors such as timing of protein ingestion and the nature of protein are more important than ingesting increased protein levels. Athletes seeking muscular hypertrophy are advised to follow a balanced diet and maintain a positive energy balance, which should ensure the athlete meets their protein requirements (1.2-1.7 $g \cdot kg^{-1} \cdot day^{-1}$). Concurrent regular resistance-training is essential for facilitating muscular hypertrophy, and evidence suggests that quality protein (~20 g) should be available immediately after resistance exercise when muscle protein synthesis is elevated.

**KEY WORDS** - Muscular hypertrophy, Protein requirements, Resistance training

## INTRODUCTION

Many individuals involved in resistance training for muscular strength and hypertrophy are convinced of the need for large protein intakes in their diet to complement their training. However, information from research into the value of elevated protein intake, as well as protein requirements for elite athletes is currently limited. Sport and exercise practitioners are presently interested in whether consuming more or less protein will lead to enhanced athletic performance. As yet there is no strong consensus on the importance of elevated protein consumption for the athletic population.

Additionally, recent research has had difficulty in determining protein requirements for athletes. Studies examining nitrogen balance suggested that strength and speed athletes required about 1.2-1.7 $g \cdot kg^{-1} \cdot day^{-1}$ (8). It is problematic to prescribe generic protein requirements for all athletes in this manner, appropriate determination of protein intake must consider the demands of the individual goals and training regime of the athlete (21).

The components of protein, known as amino acids enter the free amino acid pool located in the body's fluids and tissue. Amino acids can come from ingested protein foods, the breakdown of body protein or are synthesised from carbon sources and ammonia. In non-growing humans, there is equilibrium between muscle protein degradation and muscle protein synthesis (8). Muscle hypertrophy occurs when muscle protein synthesis is stimulated to a rate that exceeds muscle breakdown, inducing an overall positive protein balance (1,12). Manipulating the rate of either protein degradation or protein synthesis will change the overall protein balance. A positive protein balance results from a combination of protein consumption, which stimulates muscle protein synthesis, and the acute performance of resistance exercise, which increases both muscle protein synthesis and muscle protein degradation (12,16). In the period following resistance exercise, the absence of protein intake will induce a negative protein balance. The presence of adequate amounts of amino acids (which are derived from protein) to stimulate muscle protein synthesis is necessary to create an anabolic environment for muscle hypertrophy (15).

Heavy resistance training damages muscle fibres which stimulates a remodelling repair process (6). Fielding et al (3) stated that the protein requirements for athletes involved in resistance training are increased compared to the general population. This increase in protein requirements is related to the costs of structural remodelling associated with muscle hypertrophy. Both Lemon (8) and Rennie and Tipton (15) suggested that the increased rate of muscle protein synthesis is responsible for stimulating muscle growth. The response to resistance exercise is an increase of at least 50 percent in muscle protein synthesis, the effect of which lasts for up to 48 hours after exercise (15). Current literature strongly suggests that appropriate regular resistance training is an important factor in increasing protein synthesis which in turn stimulates muscular hypertrophy (3,6,8,15,16).

## METHODS

A search of academic literature was conducted using PubMed and SportsDiscus databases using the following terms: 'protein requirements', 'muscular hypertrophy', 'protein supplementation' and 'amino acids'. The search was limited to English language papers and human subjects. Literature was also sourced from links to cited research papers and the bibliographies of academic papers. Specific inclusion criteria included 1.Protein Supplementation, 2.Resistance training, 3.Detailed explanation of procedures and methods, 4.Research studies with human participants, 5.Healthy young individuals as participants. Twenty-one articles which met the criteria were selected to be included in the review. These consisted of twelve original research articles and nine review and position stands relating to the topic. Five of the original research articles used experienced resistance trained athletes, while the remaining seven studies used recreationally active but not resistance trained healthy young subjects.

## DISCUSSION

### Protein Requirements for Resistance Trained Athletes

No definitive position currently exists on the protein requirements for resistance athletes, although it is thought that resistance athletes do have a higher protein requirement compared to the current recommended dietary intake of 0.8 $g \cdot kg^{-1} \cdot day^{-1}$ for the general population (9). Tarnopolsky et al (18) stated that protein requirements were increased in strength athletes compared to sedentary individuals. Using leucine kinetic and nitrogen balance methods to measure protein synthesis, Tarnopolsky et al (18) found that muscle protein synthesis was increased in strength trainers when protein intake was increased from 0.9 $g \cdot kg^{-1} \cdot day^{-1}$ to 1.4 $g \cdot kg^{-1} \cdot day^{-1}$. Yet no significant increase in synthesis occurred when protein intake was increased from 1.4 $g \cdot kg^{-1} \cdot day^{-1}$ to 2.4 $g \cdot kg^{-1} \cdot day^{-1}$. Similarly a four week trial conducted by Fern et al (2) tracked protein synthesis using metabolic tracer techniques, and found strength trained athletes that took a 3.3 $g \cdot kg^{-1} \cdot day^{-1}$ protein supplement experienced greater gains in body mass than those who took only 1.3 $g \cdot kg^{-1} \cdot day^{-1}$, while undertaking a resistance program. Results of the two studies suggest that protein requirements are elevated in strength athletes when compared to sedentary individuals, although by exactly how much remains unclear.

Phillips (12) agreed with the elevated protein requirement of resistance trained athletes, and concurred that the optimal level of protein intake is not yet known. Following a review of current literature including research provided by the American College of Sports Medicine (ACSM), Fielding & Parkington (3), recommended that protein intake for resistance trained athletes should be 1.6-1.7$g \cdot kg^{-1} \cdot day^{-1}$. The ACSM guidelines have recently been updated and it is now recommended that athlete's protein intake should be between 1.2-1.7 $g \cdot kg^{-1} \cdot day^{-1}$ (9). From the available evidence, it is likely that resistance trained athletes have a limited increased dietary protein requirement.

**Table 1 - Effect of amino acid intake on physiological response to resistance training**

| Study | Problem Statement | Participant Description | Project Design | Measurement | Findings |
|---|---|---|---|---|---|
| Kraemer et al (6) | Hormonal responses to resistance training with and without nutritional supplementation. | 9 resistance trained males. | Subjects consumed either a protein-carbohydrate supplement or placebo for 1 week in a cross over design. Resistance training was performed on the last 3 days of each week. | Serum hormone levels | Protein-Carbohydrate supplementation after resistance training increases concentration of glucose, insulin, growth hormone and IGF-1. |
| Roy et al (16) | Macronutrient Intake and protein metabolism following resistance exercise. | 10 healthy resistance trained young males. | CHO, CHO/Protein/Fat, and Placebo supplements were provided immediately and 1hr after resistance training. | Leucine turnover determined ~4hr post exercise | CHO or a CHO/Protein/Fat supplement significantly increased Nonoxidative Leucine Disposal. |
| Moore et al (11) | Response of muscle (MPS) and albumin (APS) protein synthesis after resistance training. | Six healthy young moderately trained males | Each participant received either 0,5,10 , 20 or 40g whole egg protein after performing resistance training. | Protein synthesis and leucine oxidation were measured 4hr after exercise by infusion of [1-$^{13}$C] Leucine. | MPS was maximally stimulated at 20g. APS was also maximally stimulated at 20g. Leucine oxidation was significantly increased after 20-40g protein was ingested. |
| Rasmussen et al (14) | Oral amino acid carbohydrate supplement enhances muscle anabolism after resistance exercise | Six recreationally active but not resistance trained subjects (three male, three female) | Participants randomly received either a placebo or amino acid (6g) and carbohydrate supplement (35g) 1 and 3 hr after performing resistance exercise. | Blood samples and muscle biopsy. | Ingesting 6g amino acid with carbohydrate 1 or 3hr after resistance exercise increased phenylalanine and insulin concentration and muscle protein synthesis. This suggests that the supplementation promotes anabolism by increasing muscle protein synthesis. |
| Tipton et al (19) | Ingestion of whey and casein proteins after resistance training. | Twenty-three healthy young males and females who were not resistance trained. | Subjects were randomly assigned to one of three groups receiving either casein (20g) or whey (20g) protein or a placebo. All subjects received their solution 1 hr after performing a heavy bout of resistance leg exercise. | Femoral arteriovenous samples to determine leucine and phenylalanine concentrations. | Ingestion of casein and whey proteins stimulated muscle protein synthesis after resistance training compared to placebo. Results didn't demonstrate a clear difference in response between casein and whey. |
| Fujita et al (4) | Amino acid and carbohydrate before resistance exercise doesn't enhance muscle protein synthesis. | Twenty-two healthy young male and female participant who were recreationally active but resistance trained. | Subjects were randomly assigned to one of two groups. Group one received an amino acid and carbohydrate solution 1 hr before heavy resistance training. The fasting control group did not ingest nutrients. Subjects were studied pre-exercise, exercise, 1 hr post exercise and 2 hr post exercise. | Stable isotopic methods and muscle biopsy. | Performing resistance exercise in a fed state did not further promote muscle protein synthesis during post exercise recovery compared to the fasted state. |
| Tarnopolsky et al (18) | Evaluation of protein requirements for strength trained athletes | Young resistance trained males. | Subjects were randomly assigned to low (0.86g protein · kg$^{-1}$ BW· day$^{-1}$), moderate (1.4g protein · kg$^{-1}$ BW· day$^{-1}$) or high (2.4g protein · kg$^{-1}$ BW· day$^{-1}$) protein group for 13 days. | Nitrogen balance (NBAL) and leucine turnover. | Protein requirements for strength trained athletes were greater than for sedentary individuals and above current US recommended dietary intakes. |
| Poortmans et al (13) | Effects of regular high protein diets on kidney function | Body Builders and other well trained athletes | Participants followed either high protein (2.8 g protein · kg$^{-1}$ BW· day$^{-1}$) or moderate (1.26g protein · kg$^{-1}$ BW· day$^{-1}$) protein diet for 7 days. | Blood sample and urinary analysis | Intakes under 2.8 g protein · kg$^{-1}$ BW· day$^{-1}$ do not impair renal function in well trained athletes. |
| Tipton et al (20) | Effect of timing of amino acid and carbohydrate supplementation on anabolic response to resistance exercise. | Six recreationally active participants, three male and three female | Participants performed two trials where an amino acid-carbohydrate solution was ingested either immediately prior to and immediately after intense resistance exercise. | Femoral arteriovenous and muscle biopsy samples to determine phenylalanine concentrations | Net muscle protein synthesis response to consumption of an amino acid and carbohydrate solution immediately before exercise is greater than when the solution is consumed after exercise. |

In summary of the research presented Table 1, it is suggested that protein requirements for resistance trained athletes are elevated compared to sedentary individuals (18). By consuming at least 20g protein following resistance exercise an anabolic muscle environment was created by increasing serum hormones (6), or muscle protein synthesis (11,14,16,19). There appeared to be no additional benefit from intakes greater than 20g (11). However, there was no evidence that relatively high intake (~2.87 g · $kg^{-1}$ ·$day^{-1}$) impaired renal function in athletes (13). It was claimed that there was no benefit in terms of post exercise muscle protein synthesis from performing resistance exercise in a fed state (4), which is in contrast to the findings of Tipton et al (20) that post exercise muscle protein synthesis is higher if an amino acid solution is consumed before resistance exercise compared to after.

**Ceiling Effect of Protein Requirements**

While there is an apparent need for increased protein requirements during resistance training, there is good evidence to suggest a ceiling effect on the required amount of protein (2,3,7,8,12). Phillips (12) reported that large protein intakes in excess of the maximal requirements to stimulate muscle protein synthesis provide no additional benefit. Surplus amino acids resulting from excessive protein intake are either converted to fats or carbohydrate, or are oxidised with excess nitrogen and excreted as urea (8). Fern et al (2) found athletes who took 3.3 g · $kg^{-1}$ ·$day^{-1}$ protein supplement had a 150% increase in amino acid oxidation. A significant increase in amino acid oxidation suggests that at 3.3 g · $kg^{-1}$ ·$day^{-1}$ the optimal protein intake had been exceeded. There does appear to be a ceiling effect on the amount of protein a strength-trained athlete requires for muscle protein synthesis. A recent study involving young moderately trained males found that 20 g of protein was sufficient to maximally stimulate muscle protein synthesis and albumin protein synthesis after resistance exercise (11). Protein intake of 40 g after exercise was found to be in excess of the rate in which it can be incorporated into muscle tissue and stimulated the level of leucine oxidation, which indicates an excess of protein. Although the protein requirement is likely to be higher for strength-trained athletes compared to sedentary individuals, Kreider (7) concluded that consuming additional protein above the required level does not appear to promote further muscle growth.

**Effects of Protein Intake and Resistance Training on Body Composition**

Recent studies suggested that the greatest gains in muscular hypertrophy occur when an individual combines sufficient protein intake with regular resistance training (1,17). A study of 22 young non-trained men by Andersen et al (1) examined the effect of a 14- week resistance-training program combined with the ingestion of a iso-energetic protein (25g) supplement compared to a carbohydrate supplement on muscle fibre hypertrophy and mechanical muscle performance. The results showed an increase of 18% in Type I and a 26% increase in Type II muscle fibre size for the protein group. There was no significant change observed in the carbohydrate group. The authors found that there were similar gains in mechanical performance between the two groups, however only the protein group experienced significant gains in muscular hypertrophy.

An earlier study by Rozenek et al (17) compared the effectiveness of high calorie nutritional supplements containing an iso-caloric carbohydrate or carbohydrate and protein blend on their abilities to alter body composition and muscular strength during an 8-week resistance-training program. The results showed that both supplement groups experienced a significant increase in body mass and fat free mass compared to the control group. Interestingly, the group with the highest protein intake did not make significantly greater gains in body mass or fat free mass than the carbohydrate group. The authors suggested that the carbohydrate group were apparently meeting their daily protein requirements in their normal diet (17). This study gives further support to the theory of the protein ceiling, as discussed in the previous section. In agreement with Andersen et al (1), Rozenek et al (17) found no significant difference in strength gains between the supplement groups and the control. Rozenek et al (17) concluded that in addition to achieving daily protein requirements, which are suggested to be 1.2-1.7 g · $kg^{-1}$ ·$day^{-1}$ (9), overall energy intake was the most important factor affecting body composition.

While both studies support an increased intake of protein for muscular hypertrophy, increased protein intakes appears to have no effect on muscle strength. It is important to note that the subjects used in both studies were novice weightlifters. During the initial stages of a resistance program most of the strength gains occur as a result of neural adaptations (17). This may explain why there was no significant difference in strength gains between the supplement and control groups. If either of the studies had continued for an extended period of time, they may have shown a greater increase in strength in the supplement groups due to their increased overall muscle size.

**Table 2 - Effect of amino acid intake on body composition following resistance training**

| Study | Problem Statement | Participant Description | Project Design | Measurement | Findings |
|---|---|---|---|---|---|
| Andersen et al (1) | Effect of resistance training and protein ingestion on muscle fibre size and strength. | 22 young, healthy active males. | Resistance training 3days per week for 14 weeks. Participants received a isoenergetic protein (25g) or carbohydrate supplement before and immediately after training. | Muscle Biopsy | Resistance training and protein supplementation resulted 18% and 26% increase in type 1 and type 2 muscle fibre cross sectional area respectively. No significant change for the carbohydrate group. |
| Kerksick et al (5) | The effects of protein and amino acid supplementation on performance and training adaptations during 10 weeks of resistance training. | 36 resistance trained males. | Participants followed a split body part resistance training program for 10 weeks. Three groups of supplements, a CHO placebo (P), Whey protein (40g) + Casein (8g) (WC), or Whey protein (40g) + BCAA (3g) + L-glutamine (5g) (WBG). | Dual-energy X-Ray Absorptiometry | Significant increase in fat-free mass for the WC group compared to the P and WBG group. |
| Rozenek et al (17) | Effects of high calorie supplements on body composition and muscular strength following resistance exercise. | 73 healthy young males with minimal resistance training history. | Group 1 received CHO (356)/Protein (106g) supplement, group 2 received a CHO supplement, and group 3 was control group. All subjects performed resistance training 4 times per week for 8 weeks. | Hydrostatic weighing | CHO/Protein and CHO gained significantly more fat-free mass than control. No significant difference between CHO/Protein and CHO group. |

In summary of the findings presented in Table 2, it was demonstrated that consuming 25 to 48g of protein immediately after resistance exercise (1,5), or maintaining a high calorie diet supplemented with 106g protein per day (17) in conjunction with regular resistance training results in an increase in muscle fibre cross sectional area or an increase in fat-free mass.

**Timing of Protein Ingestion**

There is evidence to suggest that an optimal time for protein intake exist immediately after a period of resistance training (3,12,15). Fielding and Parker (3) asserted that the timing and nutritional content of the post exercise meal are known to have synergistic effects on protein synthesis. Rasmussen et al (14) demonstrated that the ingestion of essential amino acids (6g) and carbohydrate (35g) 1 or 3 hours after a bout of resistance exercise promotes muscle anabolism by increasing muscle protein synthesis. Phillips (12) stated that protein intake immediately after resistance exercise provides an optimal environment for anabolism. Ingesting protein (and carbohydrates) after exercise has been shown to increase insulin output, thereby decreasing exercise induced catabolism. It has been reported to hasten recovery, promote anabolic hormones while decreasing myofibrillar protein breakdown and urea excretion (7). In support, Kraemer (6) found that protein and carbohydrate supplementation after resistance exercise increased the concentration of glucose, insulin, growth hormone and IGF-1, while decreasing lactate accumulation. The study by Kraemer (6) involved nine resistance-trained men who consumed a protein and carbohydrate supplement or an iso-caloric placebo for week, while undertaking resistance training, in a cross over design separated by seven days.

It remains unclear whether ingesting amino acids prior to resistance training stimulates muscle protein synthesis post exercise. Tipton et al (20) found that ingesting small amounts of essential amino acids before exercise stimulates muscle protein synthesis more than when essential amino acids are consumed after exercise. In contrast Fujita et al (4) later reported that uptake of essential amino acids following resistance exercise was not significantly different between pre and post exercise intake of essential amino acids. Fujita et al (4) recently reported that essential amino acids and carbohydrates consumed 1 hr before resistance training does not enhance post exercise muscle protein synthesis. In consultation with current literature the authors concluded that essential amino acids and carbohydrate consumed post exercise are more effective then when consumed pre exercise at inducing further increases in the rate of muscle protein synthesis during the early stages of post exercise recovery (4).

**Protein Intake and the Athlete's Diet**

Dietary analysis of athletes engaged in resistance training rarely report a deficiency of protein intake. Although there is evidence to suggest an increased need for protein for athletes involved in resistance training, the elevated protein requirements can be met as part of a nutritionally balanced diet (8). No conclusive evidence was found to dispute the general consensus among many researchers that almost all athletes ingest sufficient protein as part of their usual diet. By eating enough food to maintain a positive energy balance, athletes will usually meet their daily protein requirements (3,7,8,12). There is no need for an athlete to deviate from the recently updated ACSM guideline of 10-35% of total daily energy intake from protein (9). Even though resistance athletes may require more total protein than sedentary individuals, an increase in total dietary energy intake will accommodate the need for increased protein. Phillips (12) goes further to suggest that meeting energy intake requirements may have a greater overall impact on body composition than increased protein intake alone. This position is supported by the results of the study by Rozenek et al (17).

**Table 3 - Protein intakes at 10%. 15% and 20% of various energy intakes.**

For a 70kg Athlete

Recommended intake: 1.2-1.7 g·kg·day or 84-119g

| %EI | 12600kj[1] | | 16800kj[1] | | 21000kj[1] | |
|---|---|---|---|---|---|---|
| | g[2] | g·kg·day[3] | g[2] | g·kg·day[3] | g[2] | g·kg·day[3] |
| 10% | 74 | 1.1 | 99 | 1.4 | 123 | 1.8 |
| 15% | 111 | 1.6 | 148 | 2.1 | 185 | 2.6 |
| 20% | 148 | 2.1 | 197 | 2.8 | 247 | 3.5 |

For a 90kg Athlete

Recommended intake: 1.2-1.7 g·kg·day or 108-153g

| %EI | 12600kj[1] | | 16800kj[1] | | 21000kj[1] | |
|---|---|---|---|---|---|---|
| | g[2] | g·kg·day[3] | g[2] | g·kg·day[3] | g[2] | g·kg·day[3] |
| 10% | 74 | 0.8 | 99 | 1.1 | 123 | 1.4 |
| 15% | 111 | 1.2 | 148 | 1.6 | 185 | 2.1 |
| 20% | 148 | 1.7 | 197 | 2.2 | 247 | 2.7 |

%EI: Percentage of total overall energy intake coming from protein

[1] Sample dietary energy intake

[2] Absolute protein intake (g)

[3] Relative protein intake (g·kg·day)

Protein intake outside of recommended range (1.2-1.7 g·kg·day)

A 70 kg athlete who consumes 12 600 kj per day from a balanced diet with 15% of total energy intake from protein will consume 111 g of protein. This represents a relative protein intake of $1.6\ g \cdot kg^{-1} \cdot day^{-1}$, which would be sufficient for their needs (9). For a larger athlete (90 kg) to achieve the same relative protein intake, a balanced diet of 16 800 kj per day with 15% of total energy intake from protein is required, which would provide the athlete with 148 g of protein or $1.6\ g \cdot kg^{-1} \cdot day^{-1}$.

Recent ACSM (9) guidelines recommend that protein should contribute between 10-35% of the athlete's total energy intake. The majority of energy intake should be derived from carbohydrates (50-65%), and fat should contribute the remaining 20-35%. Protein and carbohydrate oxidation are closely regulated by their respective intakes, and oxidation occurs preferentially to the oxidation of fat, which does not exhibit a relationship between rate of oxidation and intake (10). This suggests that excess protein and carbohydrate can be readily used as energy, while excess dietary fat intake is more likely to be stored as adipose tissue. While fat is an important source of energy, fat-soluble vitamins and essential fatty acids, high fat diets are not recommended for athletes (9).

Athletes pursuing a positive energy balance should increase intake of quality carbohydrates and proteins while limiting their fat intake to the recommended range of 20-35% of total energy intake, otherwise a concurrent increase of fat mass may accompany muscle hypertrophy.

Supplements were used extensively throughout the studies referred to so far in this review (1,5,6,16,17). They are useful for providing a significant increase in protein intake for the purpose of the respective studies. However, in the practical sense where most athletes already meet their daily protein requirements there appears to be little need for protein supplements. Tipton et al (19) compared the effects of whey and casein protein on muscle protein synthesis following resistance exercise. In comparison to a placebo solution both whey and casein proteins stimulated muscle protein synthesis by providing essential amino acids. However, the results failed to demonstrate a clear difference in the response of muscle protein synthesis between whey and casein protein following resistance training. There is no evidence that supplements are more effective than protein from standard dietary sources (12). Kerksick et al (5) agreed that protein does not have to come from supplement, however, they advocated the consideration of protein supplements due to their convenience, comparative low cost and low fat content.

**CONCLUSION**

Protein has an important role in tissue growth and repair in the body. When undertaking a resistance training program, it is apparent that muscular hypertrophy requires an increased protein requirement compared to the non-training population. The need for extra protein arises from the increase in both muscle protein synthesis and degradation that occurs after resistance exercise. However, there is good evidence to suggest that there is a limit to the amount of extra protein required, known as the ceiling effect of protein. Additional protein intakes above this threshold appear to be of no extra benefit and the excess amino acids are not utilised.

Athletes meeting their protein requirements and undertaking resistance training experience significant gains in body mass, fat free mass and strength. Strength gains usually occur as a result of resistance training irrespective of nutritional status. Muscle hypertrophy however, is most profound in those athletes who have sufficient dietary protein (1.2-1.7 g · $kg^{-1}$ ·$day^{-1}$). Protein intake immediately following resistance intake appears to have a synergistic effect, as it is during this time period that muscle protein synthesis is elevated to its highest level.

As long as important concurrent nutritional requirements are not compromised, there appears to be little harm in consuming relatively high amounts (~2.5-3.0 g · $kg^{-1}$ ·$day^{-1}$) of protein (21). In support, a study of 37 well trained athletes found that protein intakes under 2.8 g · $kg^{-1}$ ·$day^{-1}$ did not impair renal function (13). Furthermore, these elevated amounts of protein may be realistic for athletes that require high energy intakes. As shown in Table 3, protein intake of only 15% total energy intake would provide 2.1 g · $kg^{-1}$ ·$day^{-1}$ for a large athlete (90kg) and 2.6 g · $kg^{-1}$ ·$day^{-1}$ for a smaller athlete (70kg) consuming a 21000 kj diet. And while evidence suggests that individuals involved in resistance training have an increased physiological requirement for protein, it does not necessarily translate to a direct need for increased dietary protein. Most individuals do meet their daily protein needs as part of their usual diet. Providing that the minimum protein requirements are met as part of a balanced diet, there is no need for increased dietary protein when training for muscular hypertrophy. It is possible that other factors such as the timing of protein intake in relation to exercise and the intake of other nutrients are more important factors related to producing muscular hypertrophy.

**PRACTICAL APPLICATIONS**

- Athletes seeking muscular hypertrophy are advised to combine a regular resistance-training program that allows sufficient recovery time between sessions, with a balanced diet that provides a moderate positive energy balance.
- Protein requirements are moderately elevated above that of the general population, with a suggested daily intake of 1.2-1.7 g · $kg^{-1}$ ·$day^{-1}$. It must be noted that this generic recommendation may not apply to all athletes, and it is likely that optimal protein intake will vary depending on the sport, the athlete, and the training and competition goals of the athlete.
- Athletes are advised to maintain a positive energy balance whilst also ingesting adequate amounts of other macronutrients to meet their nutritional requirements. The magnitude of the positive energy balance is dependent on individual factors, although a general recommendation is 2100 to 4200 kj. This may be of greater importance than a high protein intake, and athletes who are reaching their energy requirements also generally meet their protein requirement.
- Timing of protein ingestion is important, therefore athletes should consume a meal rich in protein and carbohydrates (eg. ~20 g protein & ~60 g carbohydrates) immediately after resistance exercise.
- Protein supplements are only necessary if the individual's diet is deficient in protein, or the athlete

does not have time to consume a protein meal after exercise.

- Casein and whey protein after resistance exercise resulted in similar increases in muscle protein net balance resulting in net muscle protein synthesis.
- There is no benefit to the athlete from protein intakes greater than 2g/kg, which are deemed to be an excessive intake of protein.

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Controversy Around "Heavy Weight" Power Training. J. Aust. Strength Cond. 18(2)48-51. 2010 © ASCA

# LEVEL 2 SUBMISSION
# CONTROVERSY AROUND "HEAVY WEIGHT" POWER TRAINING

**Quentin Pongia**

**ABSTRACT** The aim of this review was to determine the advantages and disadvantages of heavy weight power training (HWPT). Articles on the topic, published within the last eight years, were identified via MEDLINE and the National Sports Information Centre at the Australian Institute of Sport. From the 12 articles that were found their reference lists were also searched to locate more articles, and other relevant articles were sourced. In total 14 were used for the review as some did not contain relevant information. The studies showed a variety of results with some suggesting HWPT is advantageous while others felt it was not so useful. From the research it can be concluded that HWPT has both advantages and disadvantages if it is the sole training method, but when used in conjunction with other methods it can be an extremely valuable method of training.

**KEY WORDS -** Power Development, Velocity Specificity, Muscular Strength, High Force Low Velocity.

## BACKGROUND

It is well documented by Lyttle et al (11) that both power and strength have vital roles across a wide range of sporting events. Underpinning this concept is an understanding of the difference between strength and power. Strength is defined by Baker and Nance (1) as the maximum amount of force that can be produced by a muscle at any given speed. Whilst power is regarded by Baker et al (1,11) as the product of strength and velocity/speed of movement within a muscle/s. The two methods employed to develop power in athletes are through heavy weight/slow velocity / or Light weight power training (LWPT), Dalziel et al (4).

The focus of this review is to look at the advantages and disadvantages of HWPT. HWPT involves the use of weights above 70-80% of 1RM with the athlete trying or making a conscious effort to lift the weight as quickly as possible 5, Delecluse et al (5); Jones et al (9). The theory behind HWPT is that it allows for maximum recruitment of motor units, which results in a significant increase in maximum strength, Delecluse et al (5). In a study by Harris et al (7), HWPT resulted in marked maximum strength gains and in equal or superior power gains when compared to light weight power training (LWPT). Harris et al (7) also noted that there are two main ways that HWPT could increase the velocity and power of a movement. Firstly HWPT allowed for the recruitment of type II muscle fibers whose main role is the development of high force and power. For these fibers to be recruited and trained fully they require the stimulation of maximum or near maximum forces. Secondly the speed of the movement can be enhanced if the athlete performs the movement with the intention of moving as fast as possible. Jones et al (10) indicated that a major stimulus for the development of muscular power is that the athlete must make a conscious effort to attempt to produce fast, explosive contractions, regardless of the weight.

It has been well documented by Lyttle et al (11); Baker et al (2) in the literature that the optimum resistance for the development of peak power is in the range of 30-60% of 1 repetition maximum (1RM). The reason for this is that resistances in this weight range can be moved at speeds closer to those encountered in actual sporting situations. The term that is used to describe training at the level that maximizes power output is that of Maximum Power Training. This type of training is earned out at resistances in the range of 30-60% of 1RM in an attempt to maximize both velocity and force of movement, thus giving maximum power. This gives rise to the argument put forward by many researches that HWPT is not speed specific. To overcome the argument that HWPT is not speed specific, some researchers have combined HWPT with either LWPT or some type of plyometric exercises. Duthie et al (6) concluded from their study that contrast training is advantages for increasing power output but only for athletes with a relatively high strength base to begin with. A study by Young et al (15) revealed that stronger individuals might benefit from resistance training methods that utilize contrasting loads. While a study by Lyttle et al (11) showed that the combined use of HWPT and plyometric exercises produce better results than maximum power training. This may have been due in part to plyometric training being more dynamic and facilitating better neural adaptations to explosive movements.

## METHODS AND MATERIALS

Research for this paper involved the use of the National Sports Information Centre (NSIC) catalog and MEDLINE to locate articles and studies that address the issue of HWPT. The articles that were found contained information on both methods of power development and information relating to the velocity specific factor of power training, From the twelve articles that were deemed appropriate, their reference lists were searched for other relevant links and studies, From her another six studies were located at the NSIC that had relevance to the topic and as such were considered for the review. A total of four articles were excluded from the review, as the information that they contained was not appropriate.

## RESULTS

HWPT has been shown to result in large increases in power at or near the loads that were used in training. In a study by Moss et al (14) It was shown that the experimental group that completed nine weeks of strength training at 90% of 1RM, Improved their power output at 20, 40, 60, 80, and 90% of 1RM. Moss et al (14) also found that the velocity of movement increased at all testing loads, with the largest increases occurring at the testing load of 90% of 1RM. This study shows that performing HWPT, at 90% of 1RM, can result in an increase in both power output and movement velocity at the trained weight range. Smaller, but not as significant improvements occurred at testing loads further away from 90% of 1RM.

A study by Mayhew et al (12) which looked at the changes in upper body power following HWPT, showed that after training twice a week for twelve weeks there was an improvement in bench press power (BPP) and seated shot put (SSP) performance. Mayhew et al (12) found increases of an average 13.6% in BPP and an increase of 1.8% in SSP performance. The largest improvements for BPP occurred closest to the training levels. The loads used for training in this study varied from 74-88% of 1RM, with a 24% improvement in BBP being seen at 80% of 1RM when testing occurred. Jones et al (10) showed that after 10 weeks of training at loads of 70-90% of 1RM, baseball players were able to improve their power output in testing at both depth jumps and when tested at 30-50% 1RM squat jumps. Jones et al. (10) found increases of 347 watts in peak power output when testing depth jumps, while increases of 211 and 116 watts were evident in the 30% and 50% loaded squat jumps respectively. Following on from the previous study, Young et al. (1998) looked at the acute effects of HWPT on loaded counter movement jumps (LCMJ). Young et al (15) found that an LCMJ performance was improved by a significant 2.8% when preceded by squats with a load of 5RM.

McBride et al (13) showed that the subjects in their experiment who trained at 80% of 1RM had improvements in peak power output at testing loads of 30, 55, and 80% of 1RM. The largest increase in peak power output was recorded in the jump squat test at 80% of 1RM, with a significant increase of 14%. Peak velocity of the movement also increased at only the 55 and 80% testing loads, this may occur as a result of HWPT being very speed specific, thus no improvements at the fastest speed/lighter load occurred. A study by Delecluse et al (5) investigated the effect of HWPT on 100 meter sprinting performance. It was found that HWPT could have a positive and negative effect on sprinting performance. There was an improvement in the initial acceleration over the first ten meters of the race, while there was a decrease in the maximum speed that could be obtained.

In all the studies that were reviewed it was clear that HWPT lead to improvements in the values obtained for peak power and peak velocity. Significant improvements were also found in the maximum strength of the subjects, which lead to an increase in 1RM ability. What must be investigated from these studies are the reasons behind why the authors believe HWPT evokes the responses that were seen in their subjects.

## DISCUSSION

As outlined earlier power training, whether it is heavy or light weight, plays a major role in the performance of the athlete. HWPT has both advantages and disadvantages. Some researchers believe HWPT is advantageous while others feel it is not so practical and may hinder performance.

***Advantages-*** The rationale for HWPT revolves around the belief that attempting to lift heavy weights as explosively as possible allows for maximum strength. This theory of maximum motor unit recruitment is suggested to work only when attempting to lift heavy loads explosively, and that HWPT also enhances power and movement speed to greater extent than training with lighter loads, Delecluse et al (5). There have also been reports by Hams et al (7) that HWPT may be the most beneficial method when dealing with relatively inexperienced athletes. HWPT will allow for maximum gains in strength and power measures as a result of both hypertrophic and neural adaptations in inexperienced athletes Harris et al. (7). In a study by Jones et al (9) it was concluded that the intent to maximally accelerate concentrically with heavy loads might be better for improving strength and power than training heavy weights lifted slowly. Another improvement that results from the use of HWPT is that it allows for significant improvement in the force component of power, Dalziel et al (4). McBride et al (13) concluded from their research that HWPT is effective at increasing the initial acceleration while the movement velocity is slow. In their research McBride et al (13) also found that the experimental group, who had been performing HWPT, improved their time for the T-test agility ran. The relationship can be related back to the earlier point that HWPT improves acceleration at low velocity. As the T-test involves frequent stop start actions the overall velocity is low, thus the improvement in initial acceleration resulted in fastest times for the T-test. This may be an area of interest for coaches, particularly those involved in the team sport activities were acceleration is a vital component, whereby if HWPT is able to improve initial acceleration then this may result in improved team performances due to their increase in acceleration on the field. One last finding by Young et al (15) showed that loaded counter movement jump performance was improved by performing squats of 5RM immediately prior to the testing. The reason behind this is that high frequency stimulation of motoneurons associated with heavy squat set increased the probability of individual motor unit activation, Young et al (15).

In summary the main points that result in HWPT being advantageous are that it allows for maximum motor unit recruitment, and it improves the maximum strength of the athlete or subject. HWPT has also been shown to improve the initial acceleration of movements undertaken at a slow velocity, and to improve the peak power, force and velocity of various movements. The main points that allow for the successful use of HWPT are that the athlete or subject must attempt to move the load as quickly as possible regardless of the weight.

***Disadvantages-*** From the articles that have been gathered for this review it is evident that there are numerous disadvantages associated with HWPT. The main downside of HWPT is that it does not make allowances for specificity. HWPT is not velocity specific to the movements that the athlete is training for. In the study by Mayhew et al (12) it was found that HWPT improved bench press power at all testing levels, but there were only minimal improvements in seated shot put performance. The authors explained that the lesser performance in the seated shot put was related to the lack of velocity specificity. The authors felt that neural adaptation and motor activation provide substantial explanation for the lack of improvement in the seated shot put despite the increases in strength and power in the bench press testing. There was speculation that the heavier loads used during training, 84-88% of IRM may have lead to better gains in strength than power, due to the load providing insufficient neuromuscular facilitation at the lower end of the power spectrum, Mayhew et al (12). However, there is also a lack of specificity in terms of the body position and movement action. A seated shot put is a very different exercise in comparison to a bench press in its body position, posture and movement in addition to the velocity of movement Also the neural mechanisms controlling peak muscular power may be related to the initial speed of contraction, which is then programmed and stored in the central nervous system. Mayhew et al (12) considered that HWPT failed to allow such programming to take place as the initial, or whole movement was not explosive in comparison to LWPT actions. They concluded that training with lighter loads at higher velocities could improve muscular and neural programming mechanisms, and allow for improved power output at sports specific velocities.

One of the major disadvantages of HWPT is that it doesn't allow for maximum power output, this is due to the tradeoff between force and speed. Although there may be high force the speed of the movement is slow thus bringing the overall power output down.

Many studies have shown that maximum power output occurs when training with loads in the range of 30-63% of IRM, Baker et al, (1); Lyttle et al (11). The reason for such a large range is that stronger athletes are able to generate their peak power output at the higher end of the scale, while weaker athletes show their peak power at lower weights. Baker et al (1) consider that weight heavier than 63% of IRM results in a greater proportional decrease in velocity than increase in mass, which consequently decreases power output. On the other end of the spectrum loads less than 30% of IRM leads to less power production due to large loss in mass. Baker et al (1) feel that as HWPT can result in significant improvements in maximal strength, but not necessarily significant improvements in power outputs at higher velocities, it still has a useful role in the training program. Their rationale is that if strength and power are closely related, then any drop in strength would result in a decrease in power output at any given load. Moss et al (13) has supported this relationship between strength and power and has proposed that there was a correlation between IRM and maximal power ($r = 0.93$, $P < 0.0001$), and between IRM and power at load 2.5 kg ($r = 0.73$, $P < 0.0001$). In conclusion, training with loads of 15% and 35% of IRM resulted in an increase in IRM. Although the increase in maximal power after training at 90% of 1RM showed some load specificity. It also increased maximal power at 15% of IRM. Training at loads near maximal power output would seem to increase power efficiently over a wide load range. The high correlation between IRM and maximal power at load 2.5 kg also would indicate that maximal strength is important for performance at light loads.

Other supporters of the velocity are Cronin et al (14). They feel that loads in the range of 30-60% of IRM are thought to offer the best compromise between force and velocity for the development of power, with loads greater than 70% of IRM allowing for the development of maximal strength. Jones et al. (9) showed that from their research, training is velocity specific, they indicated that low resistance and medium to high velocity improves high velocity peak power more than training with high resistances and low velocity. From their research Jones et al (9) concluded that the use of low resistance loads with the intention to maximally accelerate the load may increase peak power over a range of velocities, more so than the use of high resistance loads. It is evident that there is considerable disagreement between the proponents of the two methods of power training. The challenge for coaches who are unsure about which method to use is to determine the speed at which athletes will be performing. Once this is established, an appropriate program can be developed that allows for the athlete to train at a level where to maximize the expression of their power.

## SUMMARY

There is numerous views as to which method is best and how it should be approached. Each paper reviewed provided different results even when testing very similar characteristics, this shows that there is possibly a great deal of unreliability in the research, with researchers often divided on the issue of which method is best and what the outcomes of a certain method will be.

Harris et al (8) showed that power outputs and power loads are affected by technique, training experience, exercise specificity, and the method of which power is calculated. Additionally, similar maximum power outputs appear to occur over a greater range of load spectrums, than commonly perceived. Furthermore, many sports require the expression of functional power across a range of the power-load spectrum, so the predisposition of practitioners choosing 1 training load may be misplaced. Despite the confusion, the one thing that is clear is that power training, whether it is heavy or light weight, will evoke some type of positive performance response from the athlete. The challenge for coaches is to find which method will work best for the athletes with whom they work and for them to experiment with different or combination methods in an attempt to maximize the athlete's performance.

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*Importance Of Specific Shoulder Strengthening Exercises For Young Athletes In Rugby League And Rugby Union.*
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LEVEL 2 SUBMISSION

# IMPORTANCE OF SPECIFIC SHOULDER STRENGTHENING EXERCISES FOR YOUNG ATHLETES IN RUGBY LEAGUE AND RUGBY UNION

**David Heath**

## ABSTRACT

Rugby League and Rugby Union are sports which place a unique amount of stress on the shoulder joints. A fundamental skill in each sport is to tackle the opponent, or be tackled by an opponent. Both skills have the potential to place a certain amount of force on the shoulder joints in a variety of positions. These forces have the ability to cause injury to the shoulder joints, in particular the Glenohumeral Joint (one of the joints of the shoulder). Common injuries of this joint include subluxation (partial dislocation) and dislocation.

The purpose of this paper is to provide background information on the biomechanics of the shoulder joints and to highlight how vulnerable the Glenohumeral Joint is to injury. The paper will then proceed to discuss how injury to this joint can be minimised through the implementation of specific shoulder strengthening exercises. Young athletes will be highlighted as being quite prone to subluxation and dislocation. Therefore the paper is directed at implementing specific shoulder strengthening programmes for young athletes that participate in either Rugby League or Rugby Union.

Young athletes that participate in these sports can more often than not have a view when they commence resistance training of wanting to ‘get big’. They normally want to concentrate on developing prime mover muscles. It can be difficult to implement some of the more specific strengthening exercises when young athletes cannot see the advantages. Therefore this paper aims to reinforce to the Strength & Conditioning coach the importance of educating your athletes on developing a well balanced athletic body, in particular developing strong shoulders as they are such a crucial joint to the Rugby League and Rugby Union player.

**KEY WORDS -** Glenohumeral Joint, Scapula, Rotator Cuff, Anterior Dislocation , Dynamic Stability

## THE SHOULDER STRUCTURE

The shoulder structure is composed of five joints: The Glenohumeral Joint, Acromioclavicular Joint, Sternoclavicular Joint, Scapulothoracic Joint and the Suprahumeral Joint. All of these joints have an important role to play in the functioning of a healthy, mobile shoulder. Likewise all can be injured while playing both Rugby League and Rugby Union. This paper will concentrate on the Glenohumeral Joint as it has been proven to be the “weak link” (4) of the shoulder. Due to its’ anatomy it is quite vulnerable to injuries in contact sports such as the Rugby codes. It is also vulnerable to injury in many other sports such as Baseball Swimming and Volleyball. Basically any sport where there is the chance of either direct or indirect forces on the shoulder or the chance of an overuse injury. While this paper will concentrate on the Rugby codes, many of the exercises mentioned can be implemented in any athletes programme.

## THE GLENOHUMERAL JOINT

The Glenohumeral Joint is a shallow ball and socket joint, as can be seen in Figure 1a. The ball and socket joint is formed by the head of the humerus being the ball (upper bone of the arm) and the glenoid surface of the scapula being the socket (shallow depression of the shoulder blade).


**Figure 1A - Glenohumeral Joint 'ball & socket'**

This joint allows for "remarkable ranges of motion" (6). This range of motion is at the expense of stability of the joint (6). This lack of stability is the main reason why, particularly in contact sports the joint is quite vulnerable to injury, especially subluxation or dislocation. These ranges of motion of the glenohumeral joint can normally be classified by three movement patterns; arm elevation, external and internal rotation and horizontal flexion and extension.

The reason why the joint has such mobility but lack of stability is due to the nature of the ball and socket joint itself. The 'socket' part to the joint (glenoid surface) is quite shallow in comparison to the size of the 'ball' (humeral head). The relationship between the two has been likened to a golf ball sitting on a tee (4). Where the golf ball is the humeral head and the tee is the glenoid surface. Due to the nature of this joint it must rely on the labrum, ligaments and muscles to ensure stability.

## GLENOID LABRUM

The glenoid surface (fossa) is a shallow depression in the scapula. "The glenoid labrum forms a rim that encircles the fossa and provides a greater surface area of contact for the humerus", (7) as can be seen in figure 1b. Due to the depression being so shallow the glenoid labrum provides a certain level of stability for the glenohumeral joint.


**Figure 1B - Glenoid Labrum**

Static stability is one of the glenoid labrums' priorities (6). Despite this labrum only one-third of the humeral head is in contact with the glenoid at any one time. Therefore ligaments and muscles must provide additional stability (1).

## GLENOHUMERAL LIGAMENTS

The Glenohumeral Ligaments reinforce the anterior capsule. Static shoulder stability, along with the Glenoid Labrum is enhanced by these ligaments (1). These ligaments consist of the Superior Glenohumeral Ligament (SGHL), Middle Glenohumeral Ligament (MGHL), Inferior Glenohumeral Ligament (IGHL) and the Coracohumeral Ligament. As can be seen in figure 1c.

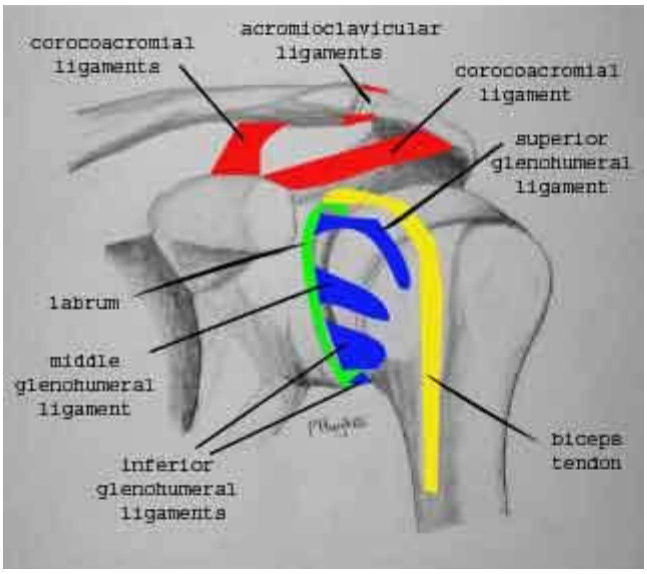


**Figure 1C - Glenohumeral Ligaments**

Along with static stability these ligaments also provide a certain amount of dynamic stability. For the purpose of this paper I do not need to detail how the different movement patterns affect each ligament. We do need to know that these ligaments play a very important role in the stability of the glenohumeral joint, especially static stability (1).

**SHOULDER MUSCULATURE**

The muscles required for dynamic stability (shoulder to remain stable through movement) of the shoulder can be broken into three major groups (2).

- Glenohumeral Protectors (Rotator Cuff): These include supraspinatus, infraspinatus, teres minor and subscapularis. View in Figure 1d.

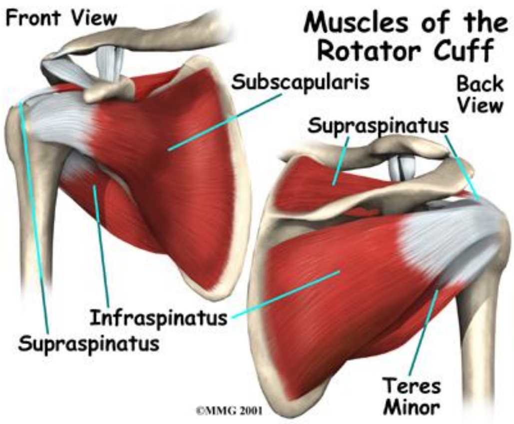


**Figure 1D - Glenohumeral Protectors ( Rotator Cuff)**

- Scapulohumeral Pivoters (Scapula Rotator Muscles): These include serratus anterior, levator scapulae, trapezius, rhomboids and pectoralis minor.

- Humeral Positioners: These include all parts of the deltoid, pectoralis major and latissimus dorsi.

What we have established is that the glenohumeral joint is very mobile yet quite unstable. Its' instability is due to the shallow nature of the joint itself. Stability is increased via the glenoid labrum, glenohumeral ligaments and a complex set of muscles. A further explanation as to how these muscles provide stability, particularly dynamic stability is now required as this papers' main purpose is to make the Strength and Conditioning coach aware of the complexities of the shoulder and how we can avoid injury through strengthening this group of muscles.

**DYNAMIC STABILITY OF THE GLENOHUMERAL JOINT**

Having an understanding of what gives the shoulder stability when it moves should have quite an impact on the way the Strength & Conditioning Coach writes their programmes for the young Rugby League and Rugby Union player. From the previous section we have learnt that there are a variety of muscles that give dynamic stability to the shoulder. The most important information being that the major muscle groups that are worked in most general strength programmes (deltoids, pectoralis major and latissmus dorsi) are only Humeral Positioners (2), their primary function is not stability for the joint. They simply position the humerus. There are two other groups of muscles that play much more key roles in the dynamic stability of the Glenohumeral Joint.

The Rotator Cuff muscles provide stability for the shoulder through a variety of movement patterns. The way these muscles provide this stability is through the "so-called centering phenomenon" (1). When the rotator cuff muscles contract through movement, a centering of the humeral head (ball) on the glenoid surface (socket) occurs. Due to the shallow nature of the glenoid surface it is quite important that these rotator cuff muscles provide the compression on the humeral head required for this centering to occur (1). This centering increases joint stability by maximising the contact area of the humeral on the glenoid surface. Simply, the rotator cuff muscles provide the glenohumeral joint with the stability to keep the large head of the humerus in the shallow glenoid surface through movement.

The Scapulohumeral Pivoters provide the shoulder the stability necessary for proper force transfer (4). The Rotator Cuff muscles rely on these Pivoters to function properly, particularly when the shoulder is required to absorb force (2). Due to the nature of the games of Rugby League and Rugby Union and the variety of forces placed on the shoulder joint, these Scapulohumeral Pivoters become very important when discussing stability of the Glenohumeral Joint. Proper force transfer allows the rotator cuff muscles to produce the "so-called centering phenomenom" (1) when the shoulder is required to absorb force, therefore providing the shoulder with added stability (4).

**WHY DO WE NEED STABILITY IN THE GLENOHUMERAL JOINT IN YOUNG ATHLETES?**

We need stability in our young athletes Glenohumeral Joint to avoid injury. Rugby League and Rugby Union, as has already been mentioned, places great strain and stress on the Glenohumeral Joint due to the very nature of the sports. Without optimal stability the joint is at greater risk of injury.

The Glenohumeral Joint is the most commonly dislocated joint in the body (8). This is due to the structure and mobility of the joint. The most common type of injury to the Glenohumeral Joint is the anterior dislocation or subluxation (7). The anterior shoulder dislocation represents approximately 97% of all shoulder dislocations (8).

Anterior dislocation is when the head of the humerus is displaced anteriorly (to the front) with respect to the glenoid surface. It normally requires medical help to relocate the head of the humerus. Anterior subluxation is when the humeral head moves greater than one half the width of the glenoid surface (7). This does not normally require medical help to relocate, it does it itself.

These injuries are normally caused by indirect forces (7). An outstretched arm that is forced into extension, abduction or external rotation can cause the Glenohumeral joint to dislocate indirectly (7). Dislocation can occur via direct impact upon the shoulder but common causes are indirect forces. Within the context of Rugby League and Rugby Union these indirect forced movements can occur frequently, causing dislocations.

When an athlete dislocates or subluxates their Glenohumeral joint various parts of the joint are damaged. The amount of damage will vary from individual to individual (8). Common types of damage will include, torn labrum, torn/strained rotator cuff muscles, ligament damage or chipped bone. Nerve damage can also be a byproduct of a dislocation (8). All injuries can vary in their severity. The major factor is that the joint stability has been compromised once there has been a dislocation or subluxation.

A number of studies have been done on both the anterior dislocation and subluxation and it has been found that once an athlete has had the injury, the recurrence rate is high, even after a rehabilitation programme has been adhered to. The damage caused by the initial dislocation or subluxation is difficult to repair without invasive surgical treatment (8).

The studies show that young athletes recurrence rates after a dislocation or subluxation are higher than the rest of the population (8). Studies vary in their results but the overwhelming fact is between 85-100% of young athletes (< 20yo) that have dislocated or subluxated their glenohumeral joint will repeat the injury unless surgery is performed on the damage (8). Studies do not reveal whether different parts of the Glenohumeral joint are major contributors or not.

With these facts about prevalence and recurrence of the dislocation and subluxation of the Glenohumeral joint, in particular for young athletes < 20yo, it becomes extremely important to ensure the programmes designed for shoulder strength in young athletes takes into consideration the lack of stability of the Glenohumeral joint and puts in place exercises that strengthen the muscles that control stability through movement of the joint (rotator cuff & scapulohumeral pivoters).

**PREVENTION OF THE ANTERIOR DISLOCATION AND SUBLUXATION**

The importance of prevention of these injuries in young athletes, I believe is highlighted by the very high recurrence rates (85-100%). As strength and conditioning coaches we must realise that recurrence of these injuries can cause major disruption to the career of the athlete or even premature retirement of the athlete.

Therefore with an understanding of the joint and its' predominant injury, as strength and conditioning coaches we must apply a Needs Analysis (5) on the sport you are preparing your athlete for. This requires thought on muscles used, energy systems involved and types of exercise required. This is essential in any preventative programme (5). Rugby League and Rugby Union places various types of stress on the Glenohumeral joint. Many indirect forces are applied to the shoulder. Therefore our strength programmes must be adjusted to prepare our athletes for the forces that they will be facing. Prevention or Prehabilitation exercises become just as important as general strength exercises.

Our programmes must be specific to our sports and our age group (5). We now know that the Glenohumeral joint is highly mobile and we know what muscles affect the stability of the joint. Our programmes while building strength in prime movers must also concentrate on strengthening rotator cuff muscles and scapulohumeral pivoters, as they play such an important role in the stability of the Glenohumeral joint.

The preventative exercises that will be spoken about in this paper are general for the sports of Rugby League and Rugby Union. Individuals within your team or squad may require more specific training programmes as they have an injury or a muscular imbalance. These exercises should not substitute for your normal screening processes.

**EXAMPLE EXERCISES FOR GLENOHUMERAL JOINT STABILITY**

Preventative exercises for the Glenohumeral joint are required to ensure the stability muscles are strong. The joint's structure allows for movement but lacks stability. The joint is non-weight bearing, therefore our strength programmes must be specific in ensuring the joint develops well balanced strength of all stabilizing muscles (2).

The muscle groups that aid the movement of the shoulder can be split into three groups: Glenohumeral Protectors (Rotator Cuff), Scapulohumeral Pivoters and the Humeral Positioners. Therefore we will break our preventative exercises up into these three categories.

For all of the exercises correct technique is essential, weight should not be increased until technique is perfected. Only small weight increases should follow, particularly for the Rotator Cuff exercises. Increases of 0.5 – 1 kg are recommended.

The Glenohumeral Protectors (Rotator Cuff) are essential for effective, stable movement of the joint. The following exercises isolate this muscle group and allow the young athlete to specifically strengthen the group. As young athletes' priorities in the gym can be to lift heavy weight and work the primary movers, a suggestion is to place these exercises in the 'warm up' phase of the session. This places an emphasis on them and the young athlete begins to understand their importance.

The exercises revolve around internal and external rotation. Due to normal movements throughout development the muscles responsible for internal rotation are normally stronger. Therefore ensure that external rotator movement is emphasised. "Good balance between internal and external rotator strength is essential (3). I try to do two to three exercises per session, one internal and two external rotator movements. All of these exercises should be done with 3 sets and vary your reps from 8 – 15, depending on your periodization. For all of these exercises the Scapula should be in the correct position (pulled back toward the spine). If you do not have access to a cable system, bands or dumbbells can be used.

**Figure 2A - Internal Rotation with Cable**

**Figure 2B - Internal Rotation with Dumbbell**

**Figure 2C - External Rotation with Cable**

**Figure 2D - External Rotation with Dumbbell**

**Figure 2E - External Rotation 90 degree Abduction with Cable**

**Figure 2F - External Rotation 90 degree Abduction with Dumbbell**

Figure 2G - Internal Rotation 90 degree Abduction with Cable

Figure 2H - Internal Rotation 90 degree Abduction with Dumbbell

The Scapulohumeral Pivoters allow Rotator Cuff muscles to 'centre' (1) the humeral head as they help to transfer force through the shoulder (4). As we know Rugby League and Rugby Union places many varied forces on the Glenohumeral joint, whether they be direct or indirect. Therefore for the Rotator Cuff muscles to work effectively in keeping the head of the Humerus in the socket the Scapula Pivoters must be developed properly.

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A number of these exercises may already be within a standard strength programme. The only difference may be emphasis placed on particular movements (eg. Scapula pinch). A 'Scapula Pinch' places the emphasis on squeezing your scapula together. As a coach you can place your finger between the two Scapula and tell the athlete to squeeze your finger. This will allow the athlete to get the correct feeling. Sets and reps can vary according to your periodization.

Figure 3A - Wall Angel, 'Scapula pinch' and hold for 3-5sec

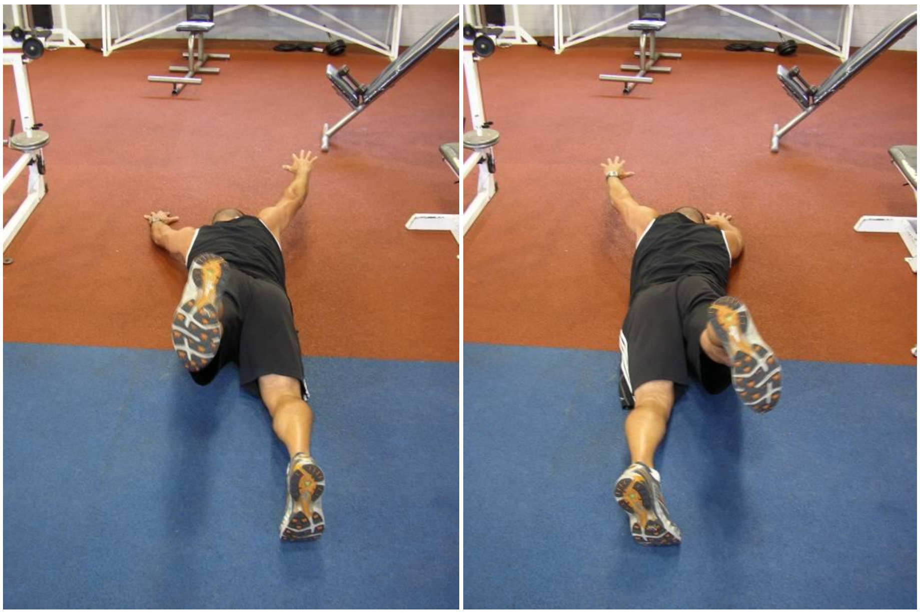

Figure 3B - Superman, hold for 3-5sec. Concentrate on controlling Scapula.

FIGURE 3C - Progression for Superman, hold for 3-5sec

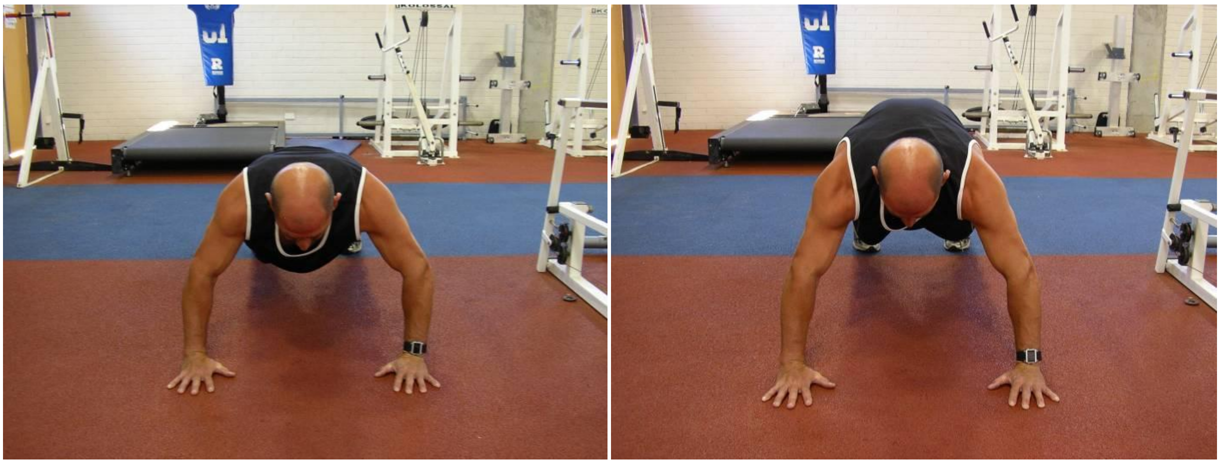

**Figure 3D - Push Pluses. Normal push up is completed, the plus is added (separate the scapula/ ‘angry cat position’)**

**FIGURE 3E - Seated Row. Ensure ‘Scapula Pinch’**

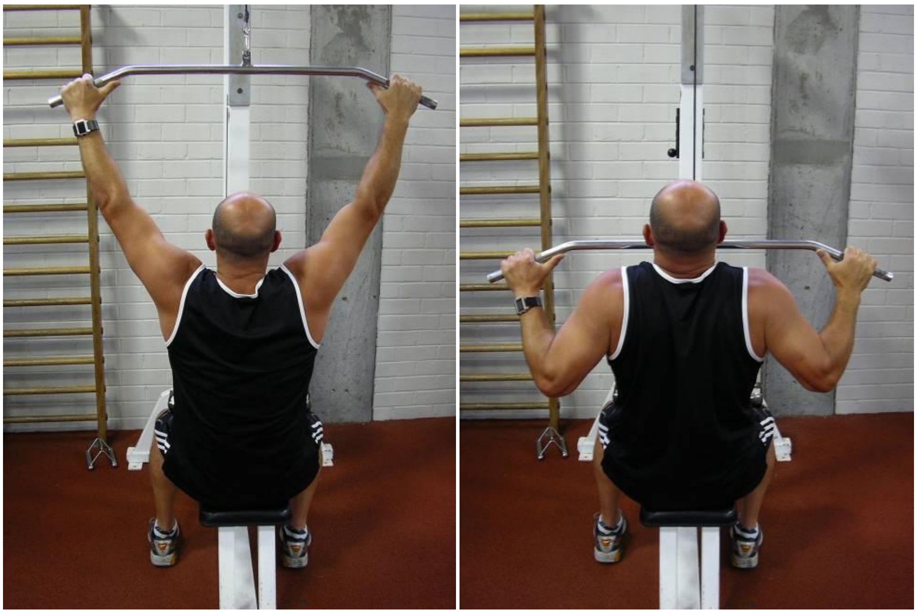

**FIGURE 3F - Lat Pull Down. Ensure ‘Scapula Pinch’**

Any row or pull exercise can be performed as long as the 'scapula pinch' is emphasised. Rowing itself with the 'scapula pinch' technique is a very effective exercise for scapula strength. The young athlete must also learn to concentrate on the eccentric phase of the movement. Too many young athletes allow the weight to 'fall' back to position. A count of 3 can give you a good time to allow the weight to go back to its' starting position. A slower, controlled eccentric phase will help the strength of the Scapula Pivoters.

The Humeral Positioners; deltoid, pectoral major and the latisimuss dorsi can be strengthened through a variety of general strength exercises that this paper will not outline. With young athletes the Strength & Conditioning Coach must ensure the correct technique is used and that there is an emphasis placed on the eccentric phase of the lift (3 count). For example with bench press the bar is lifted, as the bar returns to the chest it should take 3 seconds to reach the chest. Wide grip chin ups, the body is lifted, as it comes back to the starting position it should take 3 seconds.

Overloading the shoulder joint must be avoided as it can damage the joint structure (3). Therefore too heavier loads with high reps and repetitive exercises should be avoided (vary your exercises).

Also ensure that the programme is balanced as muscle imbalance can lead to poor posture and lack of flexibility (3). Ultimately it can lead to instability of the Glenohumeral joint. Programmes must have a balance of pulls and pushes.

We now must recognise that Rugby League and Rugby Union requires a certain amount of power movements through the shoulder. Therefore specific power activities for the shoulders must be introduced once the Rotator Cuff and Scapula Pivoters have been strengthened. When power exercises are introduced with young athletes they should not replace strength exercises, simply accompany them. Placement of power exercise into your programme will be dictated by your periodization.

Medicine Ball Plyometric Throws are a good start to power exercises as movement can be fast and technique is not totally critical as it is with an Olympic lift. All of these exercises take the shoulder through fast, powerful movement, exposing the Rotator Cuff and Scapula Pivoters to power movement. Something that will be required when playing their sports. Sets of 3-6 and reps of 4-6 should be used. Medicine Ball should only be 3-6kg.

Exercises include: Med ball throw overhead into wall, Med ball throw right/left side into wall, Med ball throw into roof, Med ball throw into ground & Woodchopper (see figure 4a).

**Figure 4A - Woodchopper. Slow Down, Fast Up. Alternate Sides.**

## CONCLUSION

This paper has highlighted how vulnerable the Glenohumeral joint is to injury due to its' highly mobile nature. The emphasis of the paper has been on the Young Athlete due to the fact that they are at high risk of recurrence if they initially injure the joint via dislocation or subluxation. This recurrence can most of the time only be corrected via surgery, which is quite invasive and takes time to recover from.

Prevention of this initial injury should be the goal for the Strength & Conditioning Coach. Rugby League and Rugby Union place great forces on this joint, therefore educating Young Athletes about the joint and implementing Specific Shoulder Strengthening exercises into your programmes is essential for a well balanced young athlete.

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*A Review Of The Squat Exercise And The Effect Of Different Techniques On Muscle Activation. J. Aust. Strength Cond. 18(2)64-70. 2010 © ASCA*

LEVEL 2 SUBMISSION

# A REVIEW OF THE SQUAT EXERCISE AND THE EFFECT OF DIFFERENT TECHNIQUES ON MUSCLE ACTIVATION

**Richard J Lynch**

**ABSTRACT**

The squat is an integral component of many athletic weight training programs and is one of the most widely used movements in the gym. Despite its popularity, continuing speculation exists as to the effect of certain squatting techniques on muscle activation. Text books, anecdotal reports and journal articles appear to display conflicting standpoints as to the effect of such changes. This review seeks to investigate the effect of different squatting techniques (back, front, wide, narrow, partial and full) on muscle electromyography (EMG) activity. Research indicates that only small changes are seen in muscle EMG activity during different techniques, with the most significant of these being the gluteus maximus muscle. This muscle has been shown to have a strong relationship with an increase in squatting depth and stance width. To a lesser extent the hip adductor and vastus medialis activity can be increased by performing wide and half squats respectively. Athletes should be free to choose their own squatting techniques as little changes are seen when varying bar position, foot width or squatting depth. Front squats should be preferentially used over back squats in order to decrease compressive knee forces.

**KEY WORDS -** Squat, Muscle Activation, Technique

## INTRODUCTION

The squat exercise is an essential part of many athletic strength and conditioning programs. It forms an important component of weightlifting exercises and helps generate lower body power in several sports such as sprinting, football and basketball. There is strong evidence to suggest that increase in squatting strengths improves athletic performance and sprinting velocity, (4, 5, 9) due to an increase in ground reaction force. As the squat is a closed kinetic chain exercise, it provides a useful tool in the rehabilitation of lower body injuries such as from a ruptured cruciate ligament of the knee (4).

Several technique variations exist when performing a squat. These include the back (the most widely used squatting technique) and front, narrow and wide and half and full squat. These variations are said to alter the emphasis of muscle activation and change the amount of weight a subject can lift (8). The concentric and eccentric motions of each technique are largely the same with only minor differences seen in back, hip, knee and foot positions. Conjecture remains as to whether technique variations significantly alter muscle EMG activation. Several textbooks and anecdotal reports believe muscle activation can be considerably altered with the use of different squatting techniques. Conversely, most research suggests that except for the gluteus maximus muscle, there is little to no change in muscle EMG activity with altered techniques.

## SQUAT

The squat is a multifaceted movement requiring strength, flexibility and core stability. The starting point of the lift involves setting the feet shoulder width apart, slightly pointed out. The descent is initiated after deeply inhaling to enhance intraabdominal pressure and reduce spinal compression (3, 11). The subject then flexes both their hips and knees until the thighs are parallel to the floor, while maintaining a flat back, chest out and heels on the floor (1, 3). The subsequent upward phase involves extending the hips and knees until reaching the start position, while again maintaining the same back, chest and foot position (1). During this stage it is important to align the hips directly under the bar. Athletes who have a more upright position are able to generate added power and lift a heavier weight, compared to athletes who position their trunk with more of a forward lean (11). The major muscles involved include the quadriceps, gluteus maximus and hamstrings, spinal erectors and to a lesser extent the abdominals and hip adductors (1, 3, 8).

**COMMON TECHNIQUE ERRORS**

The squatting technique is a complex movement involving almost all areas of the body. The movement is an excellent method of highlighting biomechanical weaknesses in an individual's strengths, power, coordination and flexibility characteristics. For this reason many technical errors are seen when performing the squat, these include (6):

*Inadequate Bar Position* - Positioning the bar unevenly across the back resulting in an irregular distribution of weight across the bar. Placing the bar too high or low across the back is also common.

*Heel Lift* - Normally a result of excessive forward lean caused by lack of overall strength around the hips and lower back. Adopting a wider stance with weight on the heels often corrects the problem.

*Excessive Forward Lean*- Occurs when the bar is positioned forward of the normal balance point during the ascent phase of the lift. This often arises when an athlete is attempting to lift excessive weight beyond their ability.

*Knee Alignment*- Lateral or medial movement of the knee outside its normal alignment with the hips. This is more commonly seen in woman as they have a greater Q angle than men.

**Figure 1 - Uneven Bar Position**

**Figure 2 - Heel Lift**

**Figure 3 - Excessive forward lean**

**Figure 4 - Medial knee alignment**

**MUSCLE CONTRIBUTION**

Muscle EMG activity during a full back squat displays both a distinct concentric and eccentric phase. A recent study by Robertson et al (13) demonstrates the role of 8 different leg muscles during a full back squat. The study showed initial knee flexion during the eccentric phase is instigated by the gastrocnemius, semitendonosus and bicep femoris muscles. The vastas lateralis, and increasingly towards the lower end of the squat the rectus femoris control the majority of eccentric work. The role of the gluteus maximus in controlling hip flexion peaks midway through the descent phase at around 25% of maximum voluntary contraction (MVC), and reduces in the latter third of the descent.

During the ascent phase the majority of the initial work comes from the gluteus maximus. Knee extensor's contribution is also high throughout this period, but unlike the gluteus maximus it does not begin to reduce its activation till the final third of the movement. However, the rectus femoris must be excluded from this. As it is a biarticular muscle it virtually contracts isometrically to stabilize the hip joint. The antagonist muscle of the hamstring and gastrognemius are predominantly recruited eccentrically during the midway point of the ascent. This assists the lifter by pulling the knee joint backward into extension. The gluteus maximus is responsible for the majority of hip flexion and its highest contribution is seen in the initial two thirds of the squat.

It is important to note that while EMG data provides some insightful information on muscle contribution, its results are not always exact. It is wrong to assume that EMG readings give an accurate quantification of overall muscle activation. Surface electrodes only detect a signal from a portion of a working muscle. Additionally common errors caused by factors such as electrode contact with the skin, electrode location, conductivity of the tissue and crosstalk must be taken into consideration (8). Their results can provide some interesting data but should be used with caution, especially for actions involving fast movements.

**BACK AND FRONT SQUAT**

The back squat involves placing a bar in the low (across the posterior deltoid and on the middle trapezius) or high (above the posterior deltoid at the base of the neck) position across the individual's upper back (1). The front squat follows the same fundamental technique apart from placing the bar across the anterior deltoid in the parallel (pronated grip with elbows parallel to the floor) or cross arm (elbow flexed across the bar with hands resting on top of the bar) position (1). The movement requires the individual to squat with a straighter back and a more neutral position (3).

Contrary to popular belief, it has been found that there is no significant difference in muscle activation between front and back squats (Table 1) (8, 14). Muscle activation remains the same for both exercises, although an individual has greater capacity to lift a heavier load during a back squat.

As a result of the additional weight lifted during a back squat, larger compression forces on the knee are experienced (8). For this reason it has been suggested the same workout can be achieved by performing a front squat while eliminating excessive forces on the knee (8). This may also prove advantageous for people with knee ligament and cartilage tears.

Again it is important to recognize the restrictions of EMG measurements. There is most likely a small amount of change in muscle activation that EMG is unable to detect. Consequently these results should be viewed objectively.

**Table 1 - Muscle activation during the ascent phase of a front and back squat (%MVIC) (8)**

| | Front | Back |
|---|---|---|
| Biceps Femoris | 17.2 | 19.4 |
| Rectus Femoris | 52.9 | 66.8 |
| Vastus Medialis | 61.0 | 64.1 |
| Vastus Lateralis | 79.4 | 79.7 |

**Figure 5 - Back Squat**

**Figure 6 - Front Squat**

## WIDE AND NARROW STANCE

A traditional starting stance for the squat requires the subject to stand with feet shoulder width apart, knees slightly flexed with toes angled outwards (1, 3). A subject opting to perform a squat with a wide stance will have their feet positioned around 140% of their normal shoulder width while a narrow stance would be performed using a stance of approximately 75% of shoulder width (10).

Varying stance width has been shown to be an effective method in changing muscle activation during a squat. Significant changes in muscle activation have been noted with the gluteus maximus muscle and to a lesser extent the hip adductors. However, no changes have been seen in knee extensor activation (10, 12).

Quadriceps activity is not significantly changed with the use of a different stance width. This is contrary to the belief that vastus medialis and lateralis activation can be increased by having a wide and short stance respectively. It is suggested that as the vastus medialis and lateralis are uniarticular muscles (only crossing the knee joint), their length is not changed through the use of different stance widths. This results in no change in muscle recruitment or activation (10). A small, insignificant increase in rectus femoris activation is noted for the wide squat.

Conflicting results exist when comparing the wide stance squat on hip adductor activation. It is generally thought that hip adductor activation is increased (especially adductor longus) when performing a wide stance squat. Mccaw & Melrose (10) agreed with this theory. Their study (table 2) concluded that adductor longus activation (to a small extent) was increased with the wide squat, (particularly in the ascent phase to prevent excessive thigh abduction). However a more recent study by Paloi et al. (12) suggests otherwise. These differing results are most likely due in part to the disparity between stance protocols, 1RM determination and surface electrode location in the studies. Nonetheless, adductor longus activation in all probability is slightly increased with a wide stance squat. The need to measure knee ligament stress remains, as increased pressure is placed on the knee joint.

The gluteus maximus has significantly more motor unit recruitment during a wide squat because of increased muscle length (10, 12). Mccaw & Melrose (10) conclude that because of the muscles insertion point at the tuberosity of the femur, its length / tension relationship is compromised due to increased hip abduction and lateral rotation. To counterbalance the reduced force capacity, EMG activity is increased, as more motor units must be recruited and at a higher frequency.

**Table 2 - Muscle activation during the ascent phase of a squat (75% 1RM) with a narrow, normal and wide stance (μV) (10)**

| | Narrow | Normal | Wide |
|---|---|---|---|
| Abductor Longus | 4 | 4.1 | 4.5 |
| Rectus Femoirs | 14.9 | 15.0 | 15.7 |
| Gluteus Maximus | 8.3 | 8.8 | 9.4 |
| Biceps Femoris | 4.8 | 4.0 | 4.3 |
| Vastus Medialis | 23.6 | 23.2 | 23.2 |

**Figure 7 - Wide stance squat**

**Figure 8 - Narrow Stance Squat**

## PARTIAL, PARALLEL AND FULL SQUATS

Performing squats to different depths has also been demonstrated to alter muscle activation. Three distinct squat depths are frequently used. These include a partial squat (half way between standing and a parallel squat or an angle of 135º between the femur and tibia), parallel squat (thighs lower to a point parallel to the ground or a femur and tibia angle of 90º) and a full squat (thighs travel below the parallel position or a femur tibia angle of 45º) (2).

The gluteus maximus has been shown to have the most varied input during the three different squat depths (Table 3). Caterisano (2) established that the contribution of the gluteus maximus muscle increased along with an increase in squat depth. Mean percent gluteus maximus EMG activity ranges from 16.92% ±8.7 with the partial squat up to 35.47% ±1.45 with a full squat. Therefore gluteus maximus activation is predominantly controlled by squat depth.

The vastus medialis (VMO) is the only remaining muscle to have significantly changed activation during varied squatting depths. The VMO contributes 30.88% of total EMG activity during a partial squat, but only 18.85% and 20.23% during a parallel and full squat respectively (2). This result supports the theory that the VMO controls the last few degrees of knee flexion.

Only minor muscle activation changes are seen in the hamstrings or remaining quadriceps muscles (2, 15).

**Table 3 - Percent muscle contribution during the concentric phase of a partial, parallel and full squat (2)**

| | Partial | Parallel | Full |
|---|---|---|---|
| Biceps Femoris | 13.3 | 15.4 | 15.0 |
| Gluteus Maximus | 16.9 | 28.0 | 35.5 |
| Vastus Medialis | 30.9 | 18.9 | 20.2 |
| Vastus Lateralis | 38.8 | 37.8 | 29.3 |

**Figure 9 - Partial Squat**

**Figure 10 - Parallel Squat**

**Figure 11 - Full Squat**

## PRACTICAL IMPLICATIONS

In general, a change in squatting technique does not considerably affect muscle activation. Lifters should be free to choose their preferred stance, bar position and squatting depth as only limited muscle activation changes are seen with the use of an altered technique. The greatest change in muscle activation can be seen in the gluteus maximus muscle. Considerable increases in muscle contribution are noted during both a deep and wide squats. To a lesser extent, the hip abductor and vastus medialis muscle contributions can be increased during wide and partial squats respectively.

The front squat appears to be an excellent alternative to the back squat. It has virtually identical muscle activation plus significantly less compressive knee forces (8). However, novice lifter should be gradually introduced to the technique as they commonly find it difficult to breath and position their wrist and elbows in the correct location. Furthermore, proper lifting technique must be enforced during a front squat, as range of motion can be limited due to lack of flexibility and hips strength.

Coaches who wish to target the muscles mentioned above are advised to use the relevant techniques. However, if there is no such concern it would be advantageous for an athlete to choose their most suited position to aid in adherence and ensuring correct technique.

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# CONFERENCE INFORMATION UPDATE!

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Presented By

## Vern Gambetta

Friday 12th November – 9am to 12pm

**Places are limited and will be accepted on a first-in first-served basis**

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