Bachelor's programme in Exercise Biomedicine, 180 credits

BACHELOR THESIS

The relationship between power output in different squats and sprint performance in young male soccer players

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Bachelor thesis in Exercise Biomedicine, 15 credits

Halmstad 2015-05-15

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Acknowledgements

I would like to thank Jimmy Karlsson, Björn Frandsen, Halmstad University and Idrottscentrum Halmstad for all the help with scheduling, equipment’s and logistics during the testing sessions. Also, I would like to thank Christoffer Sundell and Patrik Svensson for a great collaboration across testing sessions and for a successful recruitment of subjects participating in this thesis. Finally, I would like to thank Oscar Horwath and my thesis supervisor Ann Bremander for all the feedback and advice.

Abstract

Background: Research has displayed a strong relationship between lower body strength and power, both in eccentric-concentric and concentric only exercises, in male soccer players. However the relationship between different types of squats and sprint performance has not been studied thoroughly in young male soccer players.

Aim: The aim of the study was to investigate the relationship between sprint performance and power output in different squat variations in young male soccer players.

Methods: Eleven young male soccer players, 17-19 years old, were tested in 1 repetition maximum (1RM) squat (S), 1RM concentric squat (CS) and in 5m, 10m, 15m and 30m sprint performance. Power testing in S and CS were performed at 30%, 50% and 70% of 1RM and registered as absolute power (W) and as power relative to body weight (W/kg). Results of the power output in S and CS were correlated with sprint performances. Correlations of $r_s \geq 0.6$ were considered to indicate a strong relationship.

Results: There were strong correlations (r_s = -0.61 to -0.68) between CS power output at 50% of 1RM, relative to body weight (W/kg), and all the sprint distances. S power output at 50% of 1RM, relative to body weight (W/kg), showed strong correlations (r_s = -0.64 to -0.67) to 5m, 10m and 15m sprint. The only absolute power output (W) value to strongly correlate (r_s = -0.62) with sprint performance was S at 50% of 1RM and 5m sprint.

Conclusion: Both S and CS performance showed strong correlations with sprint start performance in young male soccer players. In conflict with previous research, this study showed a stronger correlation between CS and 30m sprint performance than S did. The results support previous findings that strength and power divided by body weight are stronger associated with sprint performance than absolute measures are. Both S and CS should be performed in the general strength training program to improve maximal strength and power, and thereby enhance soccer performance.

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Introduction

In team sports such as soccer, sprinting and explosiveness are important components. The initial acceleration phase of the sprint (0-10m) is a factor of major importance and has been found to be connected to the outcome of the game (Sleivert & Taingahue, 2004). For soccer players, strength and power together with endurance are important qualities for success at top level (Wisløff, Castagna, Helgerud, Jones, & Hoff, 2004). In soccer, short sprint bouts occurs every 90 seconds and last for 2-4 seconds in average (Hoff, 2005; Comfort, Stewart, Bloom, & Clarkson, 2014). Elite soccer players perform more work at higher intensities in soccer games than players at lower level (Mohr, Krustrup & Bangsbo, 2003). The outcome of the game tends to be determined during the high intensity exercises when players making an interception, tackling or shooting (Comfort et al., 2014).

Lower body strength has been found to strongly correlate with a superior sprinting performance in both youth and adult male soccer players, both in linear sprinting and in change of direction sprint performance (Baker & Nance, 1999; Wisløff et al., 2004; Keiner, Sander, Wirth, Schmidtbleicher, 2014; Comfort et al., 2014).

Since the acceleration phase is of major importance to soccer players the aim of the study was to investigate the relationship between sprint performance and power output in different squat variations in young male soccer players

Background

The activity pattern of a professional soccer player differs in order to position, tactical role and standard of the league the player competes in. It is shown that soccer players in the English premier league perform 10-15% more high-intensity work than soccer players in the Swedish and Danish premier leagues, which are lower ranked leagues. In the English premier league, the average distance covered during a game is 10714m, 9% of these represent the high-intensity runs and 0.6% of the total distance is covered while sprinting. The average distance covered in high-intensity running is 2492m, central defenders perform least high-intensity runs and wide midfielders the greatest amount of high-intensity runs. The average distance covered while sprinting differs from 152m in central defenders whereas wide midfielders cover 346m in average. The duration of the sprints varies but 46% takes less than 2 s and only 10% takes longer than 10 s (O'Donoghue, 2002; Bradley, Sheldon, Wooster, Olsen, Boanas, & Krustrup, 2009).

Although the sprinting only represents a small percentage of the total distance covered, the outcome of the game tends to be determined during these parts, when players making an interception, shooting or tackling (Comfort et al., 2014). Lower body power is of major importance to perform these actions efficiently and thereby the development of muscular power is of interest to improve soccer performance (López-Segovia, Marques, van den Tillaar & González-Badillo, 2011).

Developing muscular power

Power is the product of force x velocity. The relationship between these two factors can be explained as when force production increases during a concentric muscle action, the velocity decreases, and when the velocity increases less force is possible to be generated. This phenomenon is called the force-velocity relationship and is characterized by an inverse relationship between force and velocity (Stone, O'Bryant, McCoy, Coglianese, Lehmkuhl & Schilling, 2003; Cormie, Mcguigan & Newton, 2011a).

A reported mechanism to increase the power production during a muscle action is the stretch-shortening cycle (SSC). The increased power output during SSC-movements is due to the storage and utilization of elastic energy. When a muscle-tendon unit is stretched, mechanical work is absorbed by the muscle-tendon unit and can be transferred to positive energy during the following concentric contraction. This is thought to enhance the maximal power production due to the increased force produced at the beginning of the concentric phase (Cormie et al., 2011).

It is shown that maximal strength is related to power production and that increases in maximal strength could lead to increases in maximal power output (Stone et al., 2003). Power production can be increased with resistance training in order to strengthen skeletal muscles and enhance neural adaptations (Behm, 1995; Stone et al., 2003; Cormie et al., 2011).

Muscle mechanics

Fibre type composition of the muscle has a great impact on the ability for a muscle to produce power. The fast twitch fibres (type IIa & type IIx) have a greater capacity to produce maximal power per unit cross sectional area (CSA) than the slow twitch fibres (type I). The fast twitch fibres have a greater ability to generate force in a short amount of time compared to slow twitch fibres. Muscles with high percentages of fast twitch fibres, especially type IIx, show superior power output performance compared to slow twitch dominant muscles. Power athletes tend to have predominately type II fibres and endurance athletes tend to have more type I fibres (McArdle, Katch & Katch, 2009; Cormie et al., 2011). Regardless of the fibre type, CSA of a muscle fibre is directly related to the ability to produce maximal force and therefore the ability to produce power is also dependent of the CSA. Increased power output by improved CSA is achieved, primarily, by heavy strength training and not by specific power training (Behm, 1995; Cormie et al., 2011).

Neural factors

The nervous system controls muscle activation through changes in motor unit recruitment, firing frequency, synchronization and inter-muscular coordination. To create training programs with an aim of maximizing power output, an understanding of these different mechanisms is necessary (Cormie et al., 2011).

Motor unit recruitment refers to the ability to add motor units to increase muscle force during muscle contraction. Motor units are recruited due to the demand of the situation, e.g. as the external load increases, the motor neurons are recruited with progressively larger axons. When the external load is lower, more type 1-muscle fibres (slow twitch) are recruited but as the load increases more type 2-muscle fibres (fast twitch) are activated. To generate maximal power the ability to rapidly recruit fast twitch-fibres are essential for the outcome. It has been hypothesized that resistance training leads to increased motor unit recruitment of fast twitch-fibres at lower external loads which would act to increase the activation of the agonist and consequently improve the power output (McArdle et al., 2009; Cormie et al., 2011).

Firing frequency of a motor unit can impact the muscle fibres force generating capacity in two different ways. Either by increasing the firing frequency to enhance the magnitude of force generated, or by the firing frequency impact the rate-of-force development (RFD). Therefore, motor unit firing frequency plays an important role in development of maximal power. It has been found that athletes in explosive sports have a greater firing frequency compared to untrained people and endurance athletes. Similar findings has been found in young adults compared to older adults, which supports the theory concerning a training induced enhancement of maximum motor unit firing frequency (Cormie et al., 2011; Kamen & Knight, 2004).

Motor unit synchronization and inter-muscular coordination are other neural mechanisms that may improve the ability to enhance maximal power. Synchronization is theorized to be the coincident timing of impulses from two or more motor units. Inter-muscular coordination refers to the activation of the agonist, synergist and antagonist through a movement. For an efficient movement the co-activation of the synergist should increase and the activation of the antagonist decrease. Resistance training can improve both motor unit synchronization and inter-muscular coordination (Behm, 1995; Cormie et al., 2011).

Lower body strength and sprint performance

Several studies have shown a strong relationship between maximal lower body strength and sprint performance (Young, McLean & Ardagna, 1995; Baker & Nance, 1999; Sleivert & Taingahue, 2004; Wisløff et al., 2004; McBride, Blow, Kirby, Haines, Dayne & Triplett 2009; Comfort et al., 2014). Wisløff et al., (2004) showed strong correlations between 1 repetition maximum (1RM) squat and sprint in elite male soccer players, where the shorter (10m) sprint showed a stronger relationship compared to the longer (30m) sprint. McBride et al. (2009) found a similar relationship between sprint and 1RM in squat, but not as strong as in the study by Wisløff et al (2004), but they also showed a difference between weak and strong subjects where the stronger subjects – in squats - performed better sprint times in 10 and 40 yard compared to the weaker group. More recently, Comfort et al. (2014) demonstrated that maximal absolute squat strength had a stronger relationship to 5m sprint than squat strength relative to body weight (bw) whereas relative strength was superior to absolute strength in 20m sprint performance. The findings by Comfort et al (2014) are somewhat conflicting because previous studies in the same area have shown stronger relationships between relative strength and sprint performance in varying distances, compared to absolute strength (Baker & Nance, 1999; Young et al., 1995; Cronin & Hansen, 2005). More studies are needed to better understand the relationship between strength and sprint performance at different sprint distances in young male soccer players.

A study performed by Young et al. (1995) concluded that absolute maximum strength was important for maximum speed. The study (Young et al., 1995) also found that the strongest correlations between 2.5m sprint were limited to concentric executed exercises and the authors suggested that SSC abilities are unimportant for starting performance in sprinting. This is supported by other studies who have shown that the initial part of the acceleration phase (0-10m) of the sprint is dominated by concentric muscle actions (Baker & Nance, 1999; Sleivert & Taingahue, 2004). Concentric split jump squats and concentric jump squats have been compared with sprint start performance and a correlation of -0.68 and -0.64 were found between the exercises and sprint start (0-5m), but there were no advantage of either the split squat or the squat technique compared to each other (Sleivert & Taingahue, 2004). Baker & Nance (1999) showed a stronger relationship between 10m sprint and power clean from the hang compared to squats. Baker & Nance discussed that the result wasn’t unexpected since the power clean from hang is a concentric exercise and the sprint start is dominated by concentric muscle actions.

Lower body power and sprint performance

Power has in previous studies been associated with sprint performance but the exercises examined and the results demonstrated have both been varying and inconsistent.

López-Segovia et al. (2011) investigated the relationship between power output, measured in both average power and peak power, in squats at different absolute loads and 30m sprint in young soccer players. The study found the strongest correlations with sprint performance at 10m, 20m and 30m when squats were performed with an external load of 70 kg. Average power showed a greater relationship with sprint performance compared to peak power. Baker & Nance (1999) found stronger correlations between 40m sprint performance and maximal power output in squats compared to maximal strength (r = -0.76 and -0.66 respectively). More recently, a study found a strong correlation (r = -0.70) between maximal average power- in squats- and 20m sprint performance but only weak correlations (r = -0.57) with 10m sprint performance (López-Segovia, Dellal, Chamari, & González-Badillo, 2014). Another interesting finding was that they found a difference between the subjects who produced most power and least power, where the most powerful subjects had better sprint times compared to the least powerful subjects (López-Segovia et al., 2014).

Jump performance has earlier been associated with sprint performance in soccer players, which supports the theory that the ability to produce lower body power can influence the sprint performance (Wisløff et al., 2004; López-Segovia et al., 2011; Comfort et al., 2014). Different jumps have been compared with sprint distances and relationship with both squat jump (SJ) and counter movement jump (CMJ) with sprint performance over 10m and 30m. SJ has been found to correlate stronger with 10m and CMJ stronger with 30m sprint (Smirniotou, Katsikas, Paradisis, Argeitaki, Zacharogiannis & Tziortzis, 2008).

These findings support the theory that concentric muscle action dominates the acceleration phase of the sprint and eccentric-concentric muscle action dominates the maximal velocity phase of the sprint but few studies have compared sprint performance with both squat and concentric squat performance in young male soccer players.

Loads to maximize power output

There is a large discrepancy in the optimal load reported for maximizing power output in multijoint exercises ranging from 0 to 80% of 1RM. The highest mechanical power tends to be attained at higher percentages of 1RM compared to single joint exercises (Kawamori & Haff, 2004; Cormie, McGuigan & Newton, 2011b). Kawamori & Haff (2004) recommends that the optimal loads for each multijoint exercise shall be specifically determined.

Izquierdo et al. (2002) investigated at which load the maximal power output occurred in the half squat exercise in different athletes (weightlifting, handball, road cycling, middle-distance running, and control) and found that loads between 45-60%, depending on sport, of 1RM generated the highest power output. Cormie et al. (2007) found that maximal power was produced in the same spectra (56% of 1RM), when athletes from different sports performed squats at several submaximal loads. Another study, (Baker, Nance & Moore, 2001) investigated the jump squat exercise on power-trained athletes, and found that the highest power output was produced at loads of 55-59% of 1RM but also discussed that loads in the range between 48-63% of 1RM seemed to be equally effective to maximize power output in power-trained athletes. On the other hand, Cormie et al. (2007) concluded that 0% of 1RM in squats generated the highest power output in jump squats.

It has been observed that stronger athletes maximize their power output at higher relative loads (40% of 1RM) then weaker did (10% of 1RM) when performing squat jumps (Stone et al., 2003).

More studies are needed to investigate at which 1RM percentage young soccer players generate the highest power output and investigate if there is a relationship between concentric squats and sprint start performance in the same population. In addition, more research is warranted in order to establish if absolute strength or relative strength is the best predictor of sprint performance.

Aim

The aim of the study was to investigate the relationship between sprint performance and power output in different squat variations in young male soccer players.

Hypothesis

It was hypothesized that the concentric squat power output (CSP) would have a stronger correlation with the initial acceleration phase (0-10m) of the sprint compared to squat power output (SP) and that the SP would have a stronger correlation with the maximum sprinting velocity compared with CSP (30m). Also, it was hypothesized that 5m, 10m, 15m, & 30m sprint performance would have a stronger correlation with relative power output compared to absolute power output in young male soccer players. It was further hypothesized that the highest absolute power values would be produced at 30% of 1RM in both the squat and the concentric squat.

Methods

Subjects

Fifteen young male soccer players were asked to participate in this study. Inclusion criteria were that the subjects had to be familiar with the squat exercise, actively competing in soccer and were able to perform all parts of the study. Exclusion criterion was current injuries affecting the test situation.

Experimental design

All subjects participated in three seperate sessions; one sprint testing session and two strength/power testing sessions. All sessions were completed on seperate days with a minimum of one day and maximum of seven days between the testing sessions (Sleivert & Taingahue, 2004). Subsequently subjects performed a 1RM in the squat (S), 1RM in the concentric squat (CS), power testing in S and CS at different loads (30%, 50% and 70%) of 1RM and sprint testing.

Sprint testing

The sprint testing was performed in an indoor sports centre. All subjects performed a standardized warm-up protocol including 15 minutes of running at 60-70% (self-perceived) of maximal heart rate (Shalfawi et al., 2011). Then the subjects performed five accelerations over 40m (Shalfawi et al., 2011). After a five minute rest (Sleivert & Taingahue, 2004) the subjects performed two maximal 15m sprints and two maximal 30m sprints from a standing 3-point stance (Duthie, Pyne, Ross, Livingstone & Hooper, 2006; McBride et al., 2009) and the fastest 15m and 30m sprints were used for data analysis (López-Segovia et al., 2011). A minimum of three minutes rest was provided between each maximal sprint (Shalfawi et al., 2011). No comments on running or starting technique were given during the study and no verbal encouragement was given (McBride et al., 2009). Sprinting times of the 30m as well as the 5m, 10m, 15m, 20m and 25m were measured using timing gates (Musclelab, Ergotest, Norway) and the photocells were placed at 0m, 5m, 10m, 15m, 20m, 25m and 30m. The timing gates were activated when the subject passed the first photocell and times were then recorded when the subject passed each photocell.

Strength testing (1RM)

1RM was measured in both the S and the CS exercise. A standardized warm-up protocol was performed and an estimated 1RM was used to determine warm-up loads (McBride et al., 2010). The warm-up consisted of 10 repetitions at 50% of the estimated 1RM load, 2-4 repetitions at 70% of 1RM, and 1 repetition at 90% of 1RM (McBride et al., 2010). The subject then completed up to four attempts to achieve their 1RM and the rest between each attempt were three to five minutes (McBride et al., 2009). The heaviest, correctly performed, lift was set as 1RM and was recorded for data analysis (McBride et al., 2009).

Execution of the squat (S)

Feet were shoulder width apart and directly under the bar, the bar was held across the top of the shoulders and upper back (Sleivert & Taingahue, 2004). The subject descent until the top of the thigh was below parallel with the floor and then ascent to the start position (Baker & Nance, 1999). Proper depth was determined visually to assure that the squat was performed correctly.

Execution of the concentric squat (CS)

Feet were shoulder width apart and directly under the bar, the bar was held across the top of the shoulders and upper back (Sleivert & Taingahue, 2004). The subject descened until the top of the thigh was below parallel with the floor (Baker & Nance, 1999), and then a 1-second pause and then ascened to the start position (McBride et al., 2010). Eleiko Plyo Box, 30 cm (Eleiko, Halmstad, Sweden), and sufficient weight plates were used to determine the correct depth for each subject (see appendix 2).

Power testing

A standardized warm-up protocol was performed and consisted of five minutes cycling at a self-selected pace, two sets of five squats at 40% and 60% of 1RM followed by a maximal effort jump squat at 40% of 1RM. A minimum of three minutes rest was given for recovery between successive lifts. One lift at 30%, 50% and 70% of 1RM were performed, in a randomized order to eliminate an order effect, and measured in average power, watt (W), by Musclelab linear encoder (Ergotest, Langesund, Norway). To determine the lifting order, each subject picked a piece of paper- on which the different loads were written- before every single lift was performed. Data was measured in average power and analysed in both absolute (highest recorded W) and relative to body weigth (W/kg) values. The subjects were instructed to perform the concentric part of the lift as fast as possible (Sleivert & Taingahue, 2004).

Equipments

For the squat and concentric squat a power rack, Eleiko Olympic WL Traning Bars, and Eleiko Olympic WL Training Discs (Eleiko, Halmstad, Sweden) were used. The MuscleLab linear encoder (Ergotest, Langesund, Norway) was used to measure force, velocity and average power. The linear encoder was placed directly under the barbell- as vertical as possible- and to the right of the right foot. Studies have shown that the linear encoder is a reliable instrument to measure force, velocity and power in explosive lower body exercises (Hansen, Cronin & Newton, 2011; Ravier, 2011).

Ethical and social considerations

According to Swedish law, studies that include human beings should be in accordance with the Helsinki declaration (World Medical Association, 2013) and have to handle all personal data safely in order to protect the integrity of the individual. This means that data can't reach a third hand party and the person in mind must give clearance to use the data and the collected data must be relevant for the study (SFS 2010:1969). The informed consent is an important part of research studies that include human beings. The participant must be given information about the study before the consent is given and the information should be about the aim, a rough draft, methods, risks, the responsible researcher and that their participation is optional. If a person between 15-18 years of age participate in the study, it is the person in mind that should be given the information and give consent to participate, as long as he or she understands what participation in the study means (SFS 2003:460). In this study information was given to the participants both orally and written and an informed consent was collected (appendix 1) from all test subject before the study started.

This thesis can help us gain additional knowledge within the field of strength and conditioning in general, and more specific about how resistance exercise influences sprinting performance. It will also help strength coaches to make safe and efficient training programs for athletes and recreationally trained people both for increasing performance and improve general health (Kraemer, Ratamess, & French, 2002). In this thesis young adults and teenagers were recruited to participate which could lead to further strength training in the recruited group and thereby improve the subjects general health which ultimately can reduce future periods of sickness. This scenario will both favor the person in mind as well as the whole society, which describes the importance of physical activity and the importance of further research in this scientific field.

Statistics

According to the Shapiro-Wilk test, data was not normally distributed ($p < 0.05$) why non-parametric statistics were used. Spearman's two-tailed rank correlation coefficient (r_s) was used to measure associations between the tested variables. An $r_s < 0.6$ was considered as weak and an $r_s > 0.6$ was considered as strong due to the relatively big differences in the measured exercises (Thomas, Nelson & Silverman, 2011). Friedman's nonparametric test was used to analyze the differences between absolute power outputs at the different loads in both SP and CSP. If differences were found by the Friedman's test, Wilcoxon's test was performed to analyze differences between the variables. The results were analyzed in SPSS v.20.0 (SPSS Inc., Chicago, IL, USA).

Result

Fourteen subjects were willing to participate in the study and completed the 1RM test while 11 participants (17-19 years old; body weight 61-89 kg; height 169-190 cm) completed all three tests and the S 1RM ranged from 60-115kg and the CS 1RM ranged from 60-120kg. Subjects descriptive, results from 1RM squats test and the sprint results are presented in table 1.

Table 1. Descriptive statistics (n=11) and the result of squat (S) one repetition maximum (1RM), concentric squat (CS) 1RM and sprint over the different distances.

	Median	Minimum	Maximum
Height (cm)	181	169	190
Weight (kg)	73	61	89
Age (yr)	18	17	19
S 1RM (kg)	92	60	115
CS 1RM (kg)	92	60	120
5 m (s)	1.19	1.06	1.35
10 m (s)	1.95	1.85	2.18
15 m (s)	2.65	2.50	2.87
20 m (s)	3.37	3.08	3.66
25 m (s)	3.97	3.71	4.23
30 m (s)	4.58	4.32	4.89

Power output at different percentages of 1RM

In the S test, the power output did not statistically differ between the levels (30%, 50% and 70%) of 1RM ($p = 0.09$). In CSP, Friedman's test revealed a difference between the three levels of 1RM ($p = 0.02$). CSP at 50% of 1RM was statistically higher than CSP at 70% of 1RM, $p = 0.02$, while no differences were found between 50% and 30% of 1RM and between 30% and 70% of 1RM ($p = 0.86$ and 0.26 respectively) (table 2).

Table 2. Result of the power output (W) in squat (SP) and in concentric squat (CSP) at different percentages of 1RM, expressed as both absolute values and relative to body weight (W/kg). N=11.

	Median	Minimum	Maximum
SP (W) 30%	1062.0	501.2	1386.2
SP (W) 50%	1037.1	612.0	1263.5
SP (W) 70%	1017.2	568.8	1219.8
CSP (W) 30%	801.0	538.5	1068.7
CSP (W) 50%	873.5	437.2	1131.1
CSP (W) 70%	808.2	245.1	940.8
SP (W/kg) 30%	14.2	8.2	17.3
SP (W/kg) 50%	13.9	9.4	16.2
SP (W/kg) 70%	13.5	9.3	14.8
CSP (W/kg) 30%	11.1	8.1	13.6
CSP (W/kg) 50%	11.2	6.0	13.8
CSP (W/kg) 70%	10.6	3.4	12.5

Relationship between sprint performance and SP and CSP

The absolute SP and CSP all resulted in weak correlations (r_s = < 0.6) except for SP at 50% of 1RM and 5m sprint which resulted in an $r_s = -0.62$ ($r^2 = 0.38$) as shown in table 3.

The SP and CSP at 50% of 1RM- relative to body weight- had equally strong correlations to the initial acceleration phase. The 5m sprint resulted in an r_s of -0.64 ($r^2 = 0.41$) and -0.68($r^2 = 0.46$) respectively. The 10m resulted in an $r_s = -0.67$ ($r^2 = 0.45$) and -0.66 ($r^2 = 0.44$) in SP and CSP respectively, but at 30m sprint the CSP had a stronger correlation $r_s = -0.61$ ($r^2 = 0.37$) compared with the SP, $r_s = -0.51$ ($r^2 = 0.26$) as shown in table 4, figure 1 and figure 2.

Table 3. Correlations (rs) between power output (W), in absolute values, and sprint performance, n=11.

Sprint distances	SP 30%	SP 50%	SP 70%	CSP 30%	CSP 50%	CSP 70%
5 m sprint (s)	-0.42	**-0.62***	-0.55	-0.33	-0.56	-0.51
10 m sprint (s)	-0.37	-0.54	-0.45	-0.31	-0.48	-0.44
15 m sprint (s)	-0.27	-0.46	-0.34	-0.22	-0.44	-0.40
30 m sprint (s)	-039	-0.54	-0.49	-0.13	-0.57	-0.57

SP = Squat power output; CSP = Concentric squat power output; 30%, 50% & 70% = percentages of 1RM. *= p < 0.05

Table 4. Correlations ($r_{s)}$) between power output, relative to body weight (W/kg), and sprint performance, n=11.

Sprint distances	SP 30% (W/kg)	SP 50% (W/kg)	SP 70% (W/kg)	CSP 30% (W/kg)	CSP 50% (W/kg)	CSP 70% (W/kg)
5 m sprint (s)	-0.36	**-0.64***	-0.35	-0.12	**-0.68***	-0.39
10 m sprint (s)	-0.32	**-0.67***	-0.32	-0.12	**-0.66***	-0.38
15 m sprint (s)	-0.28	**-0.65***	-0.27	-0.10	**-0.68***	-0.37
30 m sprint (s)	-0.35	-0.51	-0.29	0.11	**-0.61***	-0.33

SP = Squat power output; CSP =Concentric squat power output; 30%, 50% & 70% = percentages of 1RM. *= p < 0.05

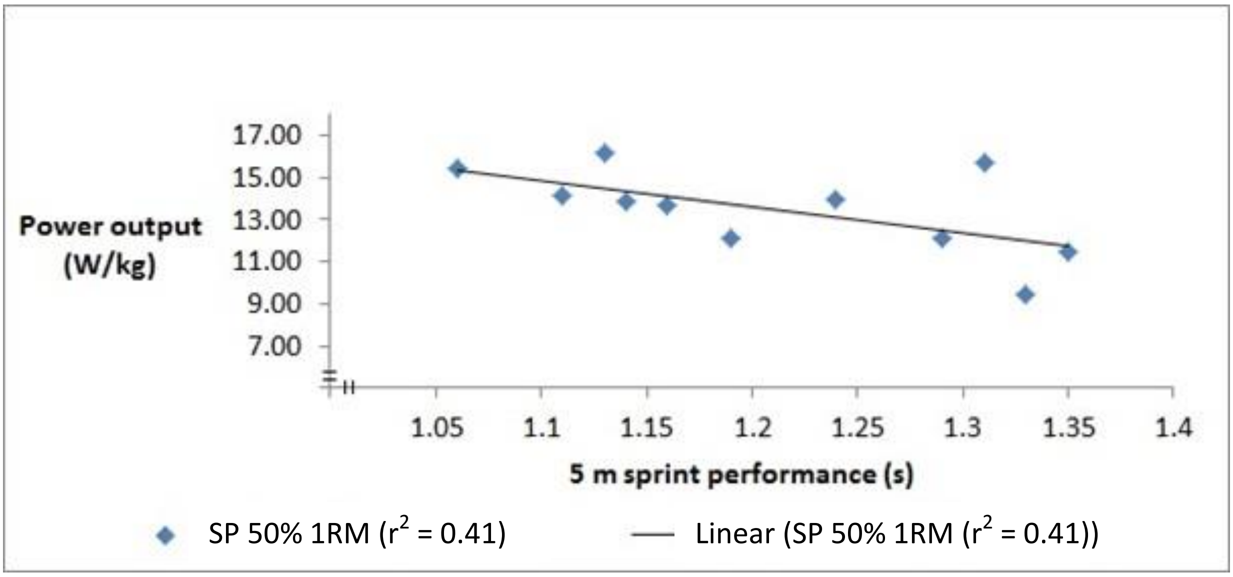

Figure 1. Relationship between relative squat power (SP) at 50% of 1 repetition maximum (1RM) and 5m sprint, $r_s = -0.64$ ($r^2 = 0.41$), n=11.

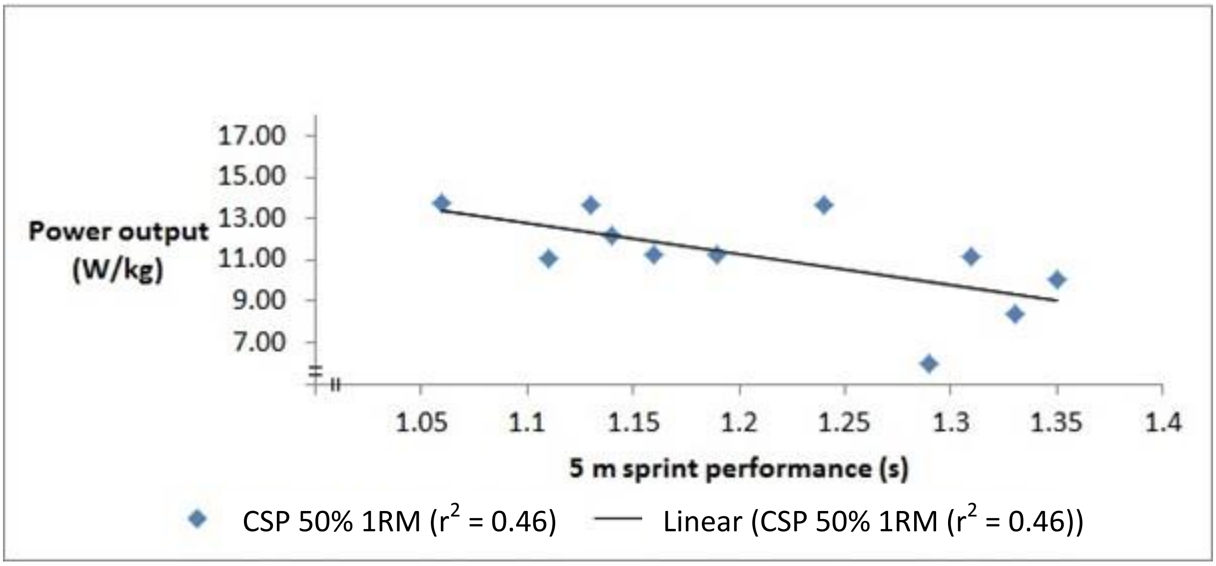

Figure 2. Relationship between relative concentric squat power (CSP) at 50% of 1 repetition maximum (1RM) and 5m sprint, r_s = -0.68 (r^2 = 0.46), n=11.

Absolute vs relative strength to predict sprint performance

As shown in table 3 and 4, the sprint performance had a stronger correlation with SP and CSP when expressed in relative values. The only sprint distance with a strong correlation to the absolute SP were 5m sprint and SP at 50% of 1RM, r_s = -0.62 (r^2 = 0.38). No absolute CSP reached a strong correlation with any sprint distance (table 3).

Discussion

The purpose of this thesis was to investigate the relationship between sprint performance and power output in S and CS in young male soccer players. The result showed strong correlations between all studied sprint distances and relative CSP output at 50% of 1RM. The relative SP output at 50% of 1RM resulted in strong correlations with sprint performance at 5m, 10m and 15m but not to 30m. The strongest correlations found in this thesis were between relative CSP at 50% of 1RM and 5m and 15m sprint performance, both with an r^2 of 0.46 meaning that 46% of the sprint performance can be explained by the muscular power output in the CS. The only absolute strength measure resulting in a strong correlation with sprint performance was SP at 50% of 1RM and 5m sprint. An interesting finding in this thesis was that only 50% of 1RM, in both relative and absolute values, showed strong correlations with sprint performance. A statistically significant difference was found in the CS where 50% of 1RM yielded a higher power output than 70% of 1RM.

Result discussion

The strong correlation reported between CSP at 50% of 1RM and 5m sprint in the current thesis was similar to the result (r = -0.64) Sleivert & Taingahue (2004) reported between concentric jump squats and 5m sprint, both reported in relative values. The theory from Baker & Nance (1999) indicates that the acceleration phase (0-10m) of the sprint is dominated of concentric muscle actions and that the maximal running speed (0-40m) is more strongly related to a SSC exercise. The findings by the current thesis and by Sleivert & Taingahue (2004) support the theory of Baker & Nance (1999), that concentric power production influence the sprint start performance. However, in conflict with the theory of Baker & Nance (1999), and in conflict with the hypothesis of this thesis and with previous studies (Wisløff et al., 2004; McBride et al., 2009; López-Segovia et al., 2011) no S measures were found to strongly correlate with 30m sprint. CSP at 50%, relative to body weight, was the only strength measure to strongly correlate with 30m sprint. Since previous research concerning the relationship between CS and 30m sprint performance are limited, future research should further investigate this relationship with a larger sample size.

Relative power output showed stronger correlations with sprint performance compared to absolute power output, which is in line with previous research (Young et al., 1995; Baker & Nance, 1999; Cronin & Hansen., 2005). The stronger relationship between relative strength and sprint performance, compared to absolute strength, seems logical since sprinting is an exercise where the body mass must be accelerated (Cronin & Sleivert, 2005). It would also have been interesting to evaluate the body composition of the subjects. Previous research has found a strong relationship with sprint performance and body composition, where the sprint time improved when the fat mass decreased in elite soccer players (Ostojic, 2003; Nikolaidis, Dellal, Torres-Luque, & Ingebrigtsen, 2015). The result of the current thesis showed a strong correlation between absolute power output in S at 50% of 1RM and 5m sprint time, which was the only absolute measure to strongly correlate with any sprint distance. Comfort et al. (2014) reported a similar (r = -0.60) relationship between maximal S strength and 5m sprint in young male soccer players. Although relative power output showed slightly stronger correlation than absolute power output in the current thesis, absolute strength might be of importance for young male soccer players to enhance sprint start performance.

It was hypothesized that S and CS at 30% of 1RM would generate the highest power output due to the relatively unexperienced test subjects when it comes to strength training in general and power training in particular (Stone et al., 2003). However, there were no statistical significant difference in power output between the different loads in the S. In CS on the other hand a difference was shown between 50% and 70% but not between 50% and 30% or between 30% and 70% of 1RM. Interestingly, the only submaximal load to strongly correlate with sprint performance was 50% of 1RM, in both S and CS also when expressed in both absolute and relative values. According to previous research (Baker et al., 2001; Izquierdo et al., 2002; Sleivert & Taingahue, 2004; Cormie et al., 2007) maximal power output has been produced between 40-60% of 1RM in S and this might have been the case in this investigation too, even though it wasn't statistically significant, and thereby it can be an possible explanation of the current results. Larger studies are needed to further investigate at which percentages of 1RM the highest power output are produced and determine which percentages of 1RM are best associated with sprint performance.

Method discussion

The correlation coefficient indicates the relationship between two variables, cause and effect is not indicated by the correlation. Changes in one variable will not automatically cause changes in the other variable. The coefficient of determination (r^2) is the value used to see how one variable can explain another. If muscular power and sprint are related at r = -0.60, it means 36% of muscular power and sprint comes from common factors, and that 64% comes from unknown factors (r^2 = 36) (Vincent & Weir, 2012).

Previous research in this scientific field, investigating the relationship with both S and CS and sprint performance, are scarce. Earlier studies have either compared absolute or relative strength/power with sprint performance or different types of concentric squats with sprint performance. Since this thesis only managed to recruit 11 subjects, future studies should try to repeat this method with a larger sample size and thereby be able to examine if a difference exists between S and CS and determine which exercise and which load that correlates best with each part of the sprint. A large sample size is important to be able to draw conclusions from studies and to avoid type II errors. If the sample size is small, it limits the opportunity to get a group that adequately represents the tested population and thereby limits the ability to present results which represent the actual relationship in the population tested (Thomas, Nelson & Silverman, 2011).

A potential method error is the 1RM-testing, since the subjects were relatively unexperienced with strength training in general and with 1RM-testing in particular, it can be questioned if the 1RM-results were valid. Some subjects performed better result in the CS than in the S which was unexpected since the pause in the CS should inhibit the benefits of the SSC and a decreased performance would be expected. A possible explanation can be that the test subjects were insecure with the strength testing and performed the eccentric phase of the S to slow and thereby couldn't manage to take advantage of the SSC (Cormie et al., 2011). Cronin & Hansen (2005) investigated the relationship between 3RM-testing and sprint performance, 5m, 10m and 30m, but found only weak correlations (r= -0.01 to -0.29). Comfort et al. (2014) performed a repetition maximum testing with a regression equation to estimate the 1RM and found strong correlations (r= -0.60 to -0.65) with 5m and 20m sprint, which could have been an option for this thesis instead of performing 1RM with unexperienced subjects. The full squat was chosen since one study found better training adaptations to the full squat compared to the quarter squat (Hartmann, Wirth, Klusemann, Dalice, Matuschek, & Schmidtbleicher, 2012). It would also have been preferable to perform the S 1RM and CS 1RM at separate days to eliminate a potential fatigue effect.

In this study the subjects performed one repetition each at each load in the power testing with the instruction to perform the concentric part as fast as possible, but if the effort can be considered valid as a maximal power performance is hard to determine. Stone et al (2003) let the subjects repeat their trial if the subject believed that the repetition didn’t represent maximal effort, a method future studies could mimic and evaluate. Jump squat was an opportunity but since the subjects were familiar with the S and not with the jump squat, the S was chosen in the current thesis.

Baker & Nance (1999) and Wisløff et al. (2004) mentioned that the nature of the testing can influence the sprint result, since the 15m and 30m sprint were recorded for analysis it is conceivable that the athletes adopted a sprinting strategy that would favour the 15m and 30m times and thereby perform weaker results in the split times, 5m, 10m, 20m and 25m. It would have been preferable to perform each measured distance separately to exclude this potential error. Comfort et al. (2014) performed the sprint testing on the actual training field which would have been preferable to make the test more sport specific and, possibly, more valid.

Conclusion

The findings of this thesis support previous research regarding the strong correlation between CS performance and sprint start performance in male soccer players. S performance showed similar correlation to sprint start performance as the CS did. However, in conflict with previous findings, the present thesis showed a stronger relationship between CS performance and 30m sprint than S performance did. Also, the results support previous findings that strength and power divided by body weight have stronger associations with sprint performance than absolute measures have. The small sample size in this thesis may limit the reliability of the results and larger studies are needed to provide further knowledge about how the different squats can improve different phases of the sprint of soccer players. However, concerning the results of this thesis and previous research, both squats and concentric squats should be performed in the general strength training program to improve maximal strength and power, and thereby enhance soccer performance.

References

Baker, D., & Nance, S. (1999). The Relation Between Running Speed and Measures of Strength and Power in Professional Rugby League Players. *Journal of Strength and Conditioning Research*, *13*(3), 230–235.

Baker, D., Nance, S., & Moore, M. (2001). The load that maximizes the average mechanical power output during jump squats in power-trained athletes. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association*, *15*(1), 92–97.

Behm, D. (1995). Neuromuscular implications and applications of resistance training. *Journal of Strength and Conditioning Research*, *9*(4), 264–274.

Bradley, P. S., Sheldon, W., Wooster, B., Olsen, P., Boanas, P., & Krustrup, P. (2009). High-intensity running in English FA Premier League soccer matches. *Journal of Sports Sciences*, *27*(2), 159–168.

Comfort, P., Stewart, A., Bloom, L., & Clarkson, B. (2014). Relationships between strength, sprint and jump performance in well-trained youth soccer players. *Journal of Strength and Conditioning Research*, *28*(1), 173–177.

Cormie, P., Mccaulley, G. O., Triplett, N. T., & Mcbride, J. M. (2007). Optimal loading for maximal power output during lower-body resistance exercises. *Medicine and Science in Sports and Exercise*, *39*(2), 340–349.

Cormie, P., Mcguigan, M. R., & Newton, R. U. (2011a). Developing Maximal Neuromuscular. *Sports Medicine*, *41*(1), 17–38.

Cormie, P., Mcguigan, M. R., & Newton, R. U. (2011b). Developing Maximal Neuromuscular. *Sports Medicine*, *41*(2), 125–146.

Cronin, J. B., & Hansen, K. T. (2005). *Strength and power predictors of sports speed. Journal of strength and conditioning research / National Strength & Conditioning Association* (Vol. 19).

Cronin, J., & Sleivert, G. (2005). Challenges in understanding the influence of maximal power training on improving athletic performance. *Sports Medicine*, *35*(3), 213–234.

Duthie, G. ., Pyne, D. ., Ross, A. ., Livingstone, S. ., & Hooper, S. . (2006). The reliability of ten-meter sprint time using different starting techniques. *Journal of Strength and Conditioning Research*, *20*(2), 246–251.

Hansen, K. T., Cronin, J. B., & Newton, M. J. (2011). The reliability of linear position transducer, force plate and combined measurement of explosive power-time variables during a loaded jump squat in elite athletes. *Journal of Strength and Conditioning Research*, *25*(5), 1447–1456.

Hartmann, H., Wirth, K., Klusemann, M., Dalice, J., Matuschek, C., & Schmidtbleicher, D. (2012). Influence of squatting depth on jumping performance. *Journal of Strength and Conditioning Research*, *26*(12), 3243–3261.

Hoff, J. (2005). Training and testing physical capacities for elite soccer players. *Journal of Sports Sciences*, *23*(6), 573–582.

Izquierdo, M., Häkkinen, K., Gonzalez-Badillo, J. J., Ibáñez, J., & Gorostiaga, E. M. (2002). Effects of long-term training specificity on maximal strength and power of the upper and lower extremities in athletes from different sports. *European Journal of Applied Physiology*, *87*, 264–271.

Kamen, G., & Knight, C. a. (2004). Training-related adaptations in motor unit discharge rate in young and older adults. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *59*(12), 1334–1338.

Kawamori, N., & Haff, G. G. (2004). The optimal training load for the development of muscular power. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association*, *18*(3), 675–684.

Keiner, M., Sander, A., Wirth, K., & Schmidtbleicher, D. (2014). Long-term strength training effects on cahange-of-direction sprint performance. *Journal of Strength and Conditioning Research*, *28*(1), 223–231.

Kraemer, W. J., Ratamess, N. a, & French, D. N. (2002). Resistance training for health and performance. *Current Sports Medicine Reports*, *1*, 165–171.

López-Segovia, M., Dellal, A., Chamari, K., & González-Badillo, J. J. (2014). Importance of muscle power variables in repeated and single sprint performance in soccer players. *Journal of Human Kinetics*, *40*, 201–11.

López-Segovia, M., Marques, M. C., van den Tillaar, R., & González-Badillo, J. J. (2011). Relationships Between Vertical Jump and Full Squat Power Outputs With Sprint Times in U21 Soccer Players. *Journal of Human Kinetics*, *30*, 135–144.

McArdle, W., Katch, F.,& Katch, V. (2009). *Exercise Physiology: Nutrition, Energy and Human Performance (7 ed.).* Lippincott Williams and Wilkins.

McBride, J., Blow, D., Kirby, J. T., Haines, L. T., Dayne, M. A., & Triplett, N. T. (2009). Relationship between maximal squat strength and five, ten, and forty yard sprint times. *Journal of Strength and Conditioning Research*, *23*(6), 1633–1636.

McBride, J., Skinner, J., Schafer, P., Haines, T., & Kirby, T. (2010). Comparison of kinetic variables and muscle activity during a squat vs. a box squat. *Journal of Strength and Conditioning Research*, *24*(12), 3195–3199.

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences*, *21*(7), 519–528

Nikolaidis, P. T., Dellal, a., Torres-Luque, G., & Ingebrigtsen, J. (2015). Determinants of acceleration and maximum speed phase of repeated sprint ability in soccer players: A cross-sectional study. *Science & Sports*, *30*(1), e7–e16.

O'Donoghue, P, G. (2002). Time -motion analysis of work-rate in English FA Premier League soccer. *International Journal of Performance Analysis in Sport*, *2*(1), 36–43.

Ostojic, S. (2003). Seasonal alterations in body composition and sprint performance of elite soccer players. *Journal of Exercise Physiology*, *6*(3), 24–27.

Ravier, G. (2011). Reliability and reproducibility of two different inertial dynamometers for determining muscular profile. *Computer Methods in Biomechanics and Biomedical Engineering*, *14*(1), 211–213.

SFS 2003:460. *Lag om etikprövning av forskning som avser människor.* Stockholm: Utbildningsdepartementet.

SFS 2012:1969. *Personuppgiftslagen.* Stockholm: Justitiedepartementet.

Shalfawi, S., Sabbah, A., Kailani, G., Tønnessen, E., & Enoksen, E. (2011). The relationship between running speed and measures of vertical jump in professional basketball players: A field-test approach. *Journal of Strength and Conditioning Research*, *25*(11), 3088–3092.

Sleivert, G., & Taingahue, M. (2004). The relationship between maximal jump-squat power and sprint acceleration in athletes. *European Journal of Applied Physiology*, *91*(1), 46–52.

Smirniotou, A., Katsikas, C., Paradisis, G., Argeitaki, P., Zacharogiannis, E., & Tziortzis, S. (2008). Strength-power parameters as predictors of sprinting performance. *Journal of Sports Medicine and Physical Fitness*, *48*(4), 447–454.

Stone, M. H., O'Bryant, H. S., McCoy, L., Coglianese, R., Lehmkuhl, M., & Schilling, B. (2003). Power and maximum strength relationships during performance of dynamic and static weighted jumps. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association*, *17*(1), 140–147.

Thomas, J., Nelson, J., & Silverman, S. (2011). *Research methods in physical activity.* Human kinetics.

Vincent, W., Weir, J. (2012). *Statistics in Kinesiology (4 ed.).* Human kinetics.

World Medical Association. (2013). World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *The Journal of the American Medical Association*, 310(20), 2191-2194.

Wisløff, U., Castagna, C., Helgerud J, Jones, R., & Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine*, *38*(3), 285–288.

Young, W., McLean, B., & Ardagna, J. (1995). Relationship between strength qualities and sprinting performance. *Journal of Sports Medicine and Physical Fitness*, *35*(1), 13–19.

Appendix 1

Vill Du delta i en studie om fotbollsspelares sprintförmåga?

Vi är tre studenter från Biomedicin inriktning fysisk träning på högskolan i Halmstad som ska genomföra en studie som examensarbete inför kommande kandidatexamen. Vi vill studera eventuella samband mellan hopp, sprint och knäböj och resultaten från studien kommer att presenteras i tre olika kandidatuppsatser.

Vi vänder oss till Dig som är aktiv fotbollsspelare med vana av fysträning.

Om du kan tänka dig att delta i vår studie innebär det att du behöver komma till labbet på Halmstad Högskola vid 4 tillfällen.

Testerna som kommer att utföras är två olika typer av knäböj, 2 olika typer av hopp samt korta sprinter. Resultaten av studien kan hjälpa oss att veta vad och hur vi ska träna för att förbättra olika delar av en sprint. Huvudman för studien är Högskolan i Halmstad och ansvariga för utförandet av studien är Eric Emanuelsson, Christoffer Sundell & Patrik Svensson.

Genomförande

Studien kommer genomföras under 4 tillfällen, varav det första tillfället är till för att visa övningar som kommer genomföras i studien samt att varje deltagare kommer få pröva på utförande i respektive övning. Andra tillfället ska vi se vad du har för 1RM i de två olika knäböjen, alltså se vilken som är den maximala vikten du klarar i de två lyften. Vid det tredje tillfället, kommer knäböj vid olika belastningar (30, 50, 70 & 90 % av 1RM) mätas. Vid det avslutande testtillfället kommer 3 stycken 30-meters sprinter och hopptester att utföras. Testtillfällena kommer vara placerade inom 1-2 veckor från varandra.

Förberedelse

Om du vill delta ber vi dig avstå från fysisk träning och koffein de närmsta 24 timmarna innan varje testtillfälle.

Ditt Medverkande är helt frivilligt och kan när som helst avbrytas utan angiven anledning. Vid avbrytande av studien kommer din information raderas och inte räknas med i studiens resultat. All data kommer behandlas konfidentiellt och alla resultat redovisas endast på gruppnivå och identifikationer av individerna kommer inte att vara möjligt. Får att få tillgång till Dina egna resultat eller till kandidatuppsatserna, eller om Du har några frågor, är du välkommen att kontakta någon av oss tre testledare enligt nedanstående kontaktuppgifter. All personlig data kommer att raderas efter avslutat arbete.

Tack för din medverkan!

Kontaktuppgifter

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Informerat samtycke

Nedan ger Du ditt samtycke till att delta i en studie om fotbollsspelares sprintförmåga.

- Jag har tagit del av och förstår innebörden av ovanstående information.
- Jag har fått chans att ställa frågor om studien och jag vet vart jag ska vända mig för att kunna ställa ytterligare frågor angående studien
- Jag deltar i denna studie frivilligt och vet att jag när som helst under studiens gång kan avbryta mitt deltagande utan att behöva förklara varför/ange någon orsak.
- Jag ger mitt medgivande till Högskolan i Halmstad att lagra och bearbeta den information som samlas in under studiens gång

……………………… …………………………… ….…………………………..

Datum Namnteckning Namnförtydligande

……………………………………… ………………………………………..

Under 18 år, målsmans namnteckning Namnförtydligande

Undertecknad person har gått igenom och förklarat studiens syfte för ovanstående deltagare samt erhållit deltagarens samtycke. Deltagaren har även fått en kopia av informationen.

………………… ..……………………………. ………………………………….

Datum Namnteckning (Testledare) Namnförtydligande

Appendix 2

The execution of the concentric squats is presented in the pictures below. The starting position is presented in picture 1, with feet shoulder width apart and directly under the bar, the bar was held across the top of the shoulders and upper back. The subject then descended until the top of the thigh was below parallel with the floor and then a 1-second pause was performed before the ascent back to the starting position, see picture 2. A 30 cm high box and sufficient weight plates were used to determine the correct depth for each subject.

Picture 1. Starting position of the concentric squat.

Picture 2. Bottom position of the concentric squat where the 1-second pause was performed before the ascent back to the starting position.

Eric completed his Bachelor's degree in Exercise Biomedicine at the University of Halmstad 2015. NSCA-Certified Personal Trainer since 2014. The main subject of interest is improving athletic performance.

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