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Maximal unilateral leg strength correlates with linear sprint and change of direction speed

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Preface

It is a constant problem for coaches, fitness coaches and strength and conditioning coaches to select exercises that are best suited for their sports. Earlier research on sports has examined specific qualities in general training and is now progressing towards more complex and sport specific qualities. When training for a specific sport, one of the main tasks is to analyze the specific sport in terms of movement patterns, intensity and which type of strength the sport require. More studies regarding sports specific training are still required. Sport coaches around the world suggest different advice for optimal training for a specific sport and it requires scientific research to confirm or reject the various proposals.

Unilateral (one leg) training is gaining popularity in sports. There are few scientific studies made in this field today and there is a need for evaluating different unilateral training, such as intervention studies and correlation studies, to assist sport coaches find exercises with a high transfer value to each sport. Intermittent sports require different activities such as change of direction, forward and backward running and lateral stepping ability. Intermittent sports are often performed unilaterally with the power and force development on one leg at the time, for example in running sports where one leg at the time is producing push-off acceleration force.

The authors of this study discovered that, despite the increased interest for sport specific training, research on unilateral resistance training is lacking. We therefore decided to investigate two major and different intermittent sports in Sweden, soccer and ice-hockey, and the transfer value between unilateral leg exercises to CODS and linear sprint.

This study have been inspiring and challenging for us and hopefully it will contribute to increased knowledge on unilateral training. Along the way, we have had good guidance and this we are grateful for. First of all we would like to thank our participants which made this study possible. We would also like to thank Jonas Enqvist for useful guidance, interesting discussions and the help with the testing equipment. Rolf Idegård at Friidrottens Hus for the great hospitality during the testing procedures. Finally we would like to thank our supervisor Phd. Jesper Augustsson for appreciated advice and review of the study.

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Best regards

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Abstract

Title (in English)	Maximal unilateral leg strength correlates with linear sprint and change of direction speed
Title (på svenska)	Maximal enbensstyrka korrelerar med linjär sprint och snabbhet i riktningsförändringar

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Summary:

Movement patterns in intermittent sports is influenced by change of direction speed (CODS) performance (i.e., acceleration and deceleration in short sprints). A cross-sectional study was used to examine if CODS (modified pro agility test) and linear sprint (5, 10 and 20 m) correlated with maximal (1RM) unilateral leg strength (unilateral Smith machine squat and unilateral leg press) and unilateral standing balance. Twenty youth male college athletes (soccer players n=10, ice-hockey players n=10, weight 76.8±6.6 kg, height 180.5±5.9 cm, age, 16.6±1.3 years) performed the tests. A significant ($P<0.005$) moderately strong correlation between CODS and normalized unilateral squat strength was found ($r = -0.606$). Furthermore, a significant ($P<0.003$) moderately strong correlation between CODS and normalized unilateral leg press strength were found ($r = -0.631$). A significant ($P<0.003$, $P<0.002$, respectively) moderately strong correlation between CODS and linear sprint (10, 20 m) were found ($r = -0.629$, $r = -0.641$, respectively). Normalized unilateral squat strength had a significant ($P<0.015$) moderately strong correlation to 10 m linear sprint ($r = -0.534$). Normalized unilateral leg press strength had a significant ($P<0.006$) moderately strong correlation to 10 m linear sprint ($r = -0.593$). Between normalized unilateral squat strength and 20 m linear sprint there was a significant ($P<0.027$) moderately low correlation ($r = -0.493$). The correlation between normalized unilateral leg press strength and 20 m linear sprint was significant ($P<0.020$) moderately strong ($r = -0.514$). The findings suggest that unilateral maximal strength testing is a good predictor for CODS and linear sprint for soccer players and ice-hockey players.

Sammanfattning:

Rörelsemönster i intermittenta idrotter är influerat av snabba riktningsförändringar (CODS) och består till stor del av acceleration, och deceleration under korta sprinter. En tvärsnittsstudie gjordes för att undersöka om CODS (modifierat pro agility test) och linjär sprint (5, 10 och 20 m) korrelerade med maximal (1RM) unilateral benstyrka (unilateral knäböj i Smith-maskin och unilateral benpress) och balans på ett ben. Tjugo manliga ungdomar på idrottsgymnasienivå (fotbollsspelare n=10 och ishockeyspelare n=10, vikt 76.8±6.6 kg, längd 180.5±5.9 cm, ålder, 16.6±1.3 år) utförde testerna. En signifikant ($P<0.005$) moderat stark korrelation mellan CODS och normaliserad unilateral styrka i knäböj i Smith-maskin hittades ($r = -0.606$). Vidare hittades en signifikant ($P<0.003$) moderat stark korrelation mellan CODS och normaliserad unilateral styrka i benpress ($r = -0.631$). En signifikant ($P<0.003$, $P<0.002$, respektive) moderat stark korrelation mellan CODS och linjär sprint (10, 20 m) hittades ($r = -0.629$, $r = -0.641$, respektive). Normaliserad unilateral styrka i knäböj hade en signifikant ($P<0.015$) moderat stark korrelation med linjär sprint (10 m), ($r = -0.534$). Normaliserad unilateral styrka i benpress hade en signifikant ($P<0.006$) moderat stark korrelation med 10 m linjär sprint ($r = -0.593$). Mellan normaliserad unilateral styrka i knäböj och 20 m linjär sprint fanns det en signifikant ($P<0.027$) moderat låg korrelation ($r = -0.493$). Korrelationen mellan normaliserad unilateral styrka i benpress och 20 m linjär sprint var signifikant ($P<0.020$) moderat stark ($r = -0.514$). Resultaten föreslår att testning av normaliserad unilateral maximal styrka är en bra förutsägning för CODS och linjär sprint för fotbollsspelare och ishockeyspelare.

Content

1. Introduction

Human locomotion needs biological energy production, and two mechanisms to contribute to produce energy are the aerobic and anaerobic energy systems. These two systems are the opposite of each other; the aerobic metabolism using oxygen for energy production, while the anaerobic do not require the presence of oxygen (Ratamess, 2008, Swank, 2008). An example of when the aerobic system is highly dominant is marathon or triathlon, with the anaerobic energy system contributing as little as 10-20 %, often using a cyclic movement during a long period of time. An example of the anaerobic energy systems extreme is Olympic weightlifting, high jumping or 100 m sprints, with the anaerobic energy system contributing as much as 80-100 % (Knuttgen, 2007). Intermittent sports such as tennis, basketball, soccer and ice-hockey is often a mixture of aerobic and anaerobic extremes. These sports have one thing in common; the presence of both energy systems but with different amount and it is important to construct a needs analysis for every specific sport (Baechle, Earle & Wathen 2008, Ratamess 2008, Swank, 2008).

Strength and conditioning coaches are thus struggling with specificity in training in intermittent sports that require both aerobic and anaerobic ability. Which exercises that contribute to the greatest transfer value, in sports like soccer, ice-hockey, tennis and basketball are still not clear. Intermittent sports are complex and involve energy contribution from both the aerobic and anaerobic systems, including activities such as deceleration, acceleration, linear sprint, changes of direction, backward running and lateral stepping. In these sports, training have traditionally been largely based on the game itself but new development in strength and speed training have proved to increase sport-related activities (Chelly et al. 2009, Jovanovic, Sporis, Omrcen & Fiorentini, 2011). As suggested by Knuttgen (2007) participation in a specific intermittent sport can contribute to improvements in strength and aerobic fitness, however most commonly improvement in aerobic fitness. A common misconception according to Knuttgen (2007) is that strength exercises improve aerobic performance or the opposite. To be able to challenge the aerobic and anaerobic systems, strength and conditioning coaches have to be aware of these two represent the opposite extremes of a muscular power continuum. Intermittent sports require both anaerobic and aerobic energy contribution and training programs must consider the challenge of the time availability for training to be effective.

Resistance training for sports involve three foundational principles: overload, progression and specificity for the training to be successful. It is important that progressively overload the muscles to gain increased strength and stimuli development (Baechle & Earle, 2008). Training adaptations are highly specific and in a higher level of a specific sport, specificity becomes even more important. The transfer value in training gains can differ greatly even in very similar exercises; the exercise selection is a main variable when designing training programs (Zatsiorsky & Kraemer, 2006). In intermittent sports the activities are complex and involve changes in speed, deceleration, acceleration, backward running and lateral stepping etc. Thus the exercise selections need to cover a lot of different abilities, and strength and conditioning coaches are struggling with and which exercise contributes to the greatest transfer value to the specific sport. The new development regarding the relationship between different strength variables and sport specific speed training could contribute to improvements in intermittent sports. To be able to train effectively it is important to understand different exercises and the transfer value to a sport-specific activity to be able to use the training time effectively.

1.1 Agility and sub-components

A central concept in intermittent sports is *agility*, which does not have any global definition but is often described simply as the ability to change direction rapidly (Sheppard & Young, 2006). Sheppard and Young (2006, p. 922) noted that the classic definition of agility does not cover overall agility performance and, as a consequence, proposed a new definition for agility as "a rapid whole-body movement with change of velocity or direction in response to a stimulus". According to Sheppard and Young´s model (2006), Figure 1, agility can be broken down into sub-components comprising of two main qualities, (1) perceptual and decision-making abilities (cognitive) and (2) change-of-direction speed (CODS) abilities (physical). Within these two main components (Figure. 1), sub-components exist such as visual scanning, leg strength and straight sprinting speed etc. For developing overall agility performance, strength and conditioning coaches can target improvements in agility by targeting the sub-components such as straight sprinting speed, leg muscle qualities, perceptual and decision-making factors, as well as train sport specific agility drills that include all sub-components.

The speed development in intermittent sports is undergoing a paradigm shift in the sport science community. Greater emphasizes is being placed not only on acceleration, maximum speed and speed endurance (Newman, Tarpenning & Marino, 2004) but also on agility (Chaouachi et al. 2009) performance because it is an important ability in intermittent sports. Agility performance depends on different factors whereas CODS is a main sub-component. For improving CODS performance practitioners can focus on technique, straight sprint speed or leg muscle qualities in training. The relationship between different variables to CODS performance are an important task to develop in intermittent sports, for an example if a strength exercise contribute to a sport specific drill.

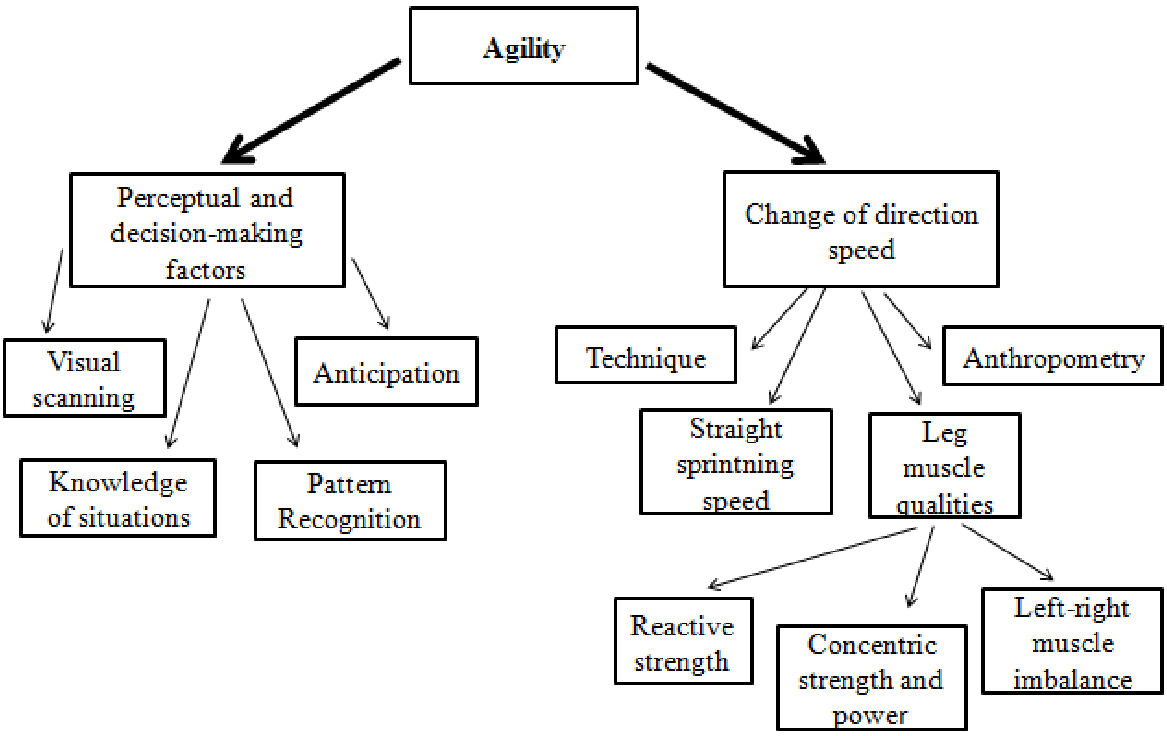

Figure 1. Agility and sub-components (Sheppard & Young, 2006). Agility could be described as a complex ability with two main variables; one cognitive factor (perceptual and decision-making factors), and one physical factor (change of direction speed).

1.2 Understanding soccer and ice-hockey

Soccer and ice-hockey are intermittent sports which involve different activities, irregular movement patterns and complex load patterns. Elite soccer player cover a distance of 9-12 kilometer during a game (Mohr, Krustrup, & Bangsbo, 2003, Hoff & Helgerud, 2004) with approximately 1350 activities (Mohr et al. 2003) and perform about 50 powerful turns (Stolen, Chamari, Castagna & Wisloff, 2005). Soccer is mainly based on the energy contribution from the aerobic system (Hoff & Helgerud, 2004, Bangsbo, Mohr & Krustrup, 2006), however the anaerobic high intensity running and sprints are important factors for the outcome of the game. The importance of anaerobic training is shown in earlier studies, which concluded that professional soccer players perform more high-intensity running and sprints during a game than amateur level soccer players (Aziz, Mukherjee, Chia & Teh, 2008, Mohr et al. 2003, Abrantes, Macas & Sampaio, 2004). Linear sprint and high intensity CODS movements are thus important for soccer players. A high level of CODS performance in a game could be the difference between, for example, which player is fastest to the ball.

High intensity movements that require energy from the anaerobic system are essential for success in intermittent sports. Ice-hockey is a more anaerobic sport (Popadic Gacesa, Barak & Grujic, 2009) where the players go “all out” for approximately 30-80 seconds consisting of multiple short bursts of high intensity skating, continual starting and stopping, changing of directions and delivering and receiving body checks (Montgomery, 1988, Manners, 2004). This is followed by up to 4-5 minutes of passive recovery (Montgomery, 1988). These activities also require strength, balance and stability. In competition strength, balance and stability are central abilities for ice-hockey players.

Although ice-hockey is performed on ice, a lot of the training is conducted off-ice. Especially in the offseason, the training consists of a lot of off-ice training because the availability of ice time is reduced. It is important that the off-ice measures are capable of predicting specific on-ice performance for effective training (Farlinger, Kruisselbrink & Fowles, 2007). Studies have examined correlations between off-ice and on-ice variables (Behm, Wahl, Button, Power & Anderson, 2005, Potteiger, Smith, Maier & Foster, 2010, Farlinger, et al. 2007). Farlinger et al. (2007) examined 35 ice-hockey players and found a significant correlation between on-ice 35 m sprint and off-ice testing (30 m sprint, r = 0.78 and Edgren side shuffle, r = 0.55). Another study (Behm et al. 2005) on 30 junior hockey players also found a significant correlation between maximum skating speed and both 40 yard sprint (36.7 m, r = 0.51) and balance ability (wobble board test, r = 0.51). The authors concluded that off-ice testing could have some cross-over effects on skating speed and that balance is an important ability for ice-hockey players (Behm et al. 2005). With this in mind, it is important that off-ice training is effective and sport specific, making it a better predictor and thus a higher transfer value to specific on-ice performance. Off-ice training is a part of an ice-hockey player regular training and it is important that off-ice training contribute to ice-hockey specific movements and these studies (Behm et al. 2005, Potteiger et al. 2010, Farlinger et al. 2007) shows that there exists a relationship between off-ice training and on ice training.

1.3 The relationship between linear sprint and maximal strength

Studies have tested more complex strength exercises such as maximal back squat strength bilaterally (on two legs) and noted a strong relationship with linear sprints between different distances (Wisloff, Castagna, Helgerud, Jones & Hoff, 2004, Ronnestad, Kvamme, Sunde & Raastad, 2008, Chaouachi et al. 2009, McBride et al. 2009, Chelly et al. 2009, Chelly et al. 2010). McBride et al. (2009) examined 17 division 1-AA male football athletes and the relationship between maximal bilateral back squat strength (70° between femur and tibia) strength and linear sprint times and found a significant correlation between normalized back squat strength and 40 yard linear sprint times (r = -0,605) and 10 yard linear sprint times (r = 0.544). Wisloff et al. (2004) also reported a significant strong correlation between maximal bilateral half squat strength (90° between femur and tibia) and 10 m and 30 m linear sprint performance (r = 0.94, r = 0.71, respectively) when examining 17 elite soccer players.

1.4 The relationship between CODS and linear sprint

Studies have examined the relationship between CODS and different variables, for example linear sprint, strength and balance tests. Earlier studies have focused in particular on correlation between CODS and linear sprint, but it appears to have little or no influence on CODS (Sheppard & Young, 2006, Little & Williams, 2005, Chaouachi et al., 2009, Wisloff, Castagna, Helgerud, Jones & Hoff, 2004). Little & Williams (2005) examined the relationship between CODS (a zigzag test) and 10 m and 20 m linear sprint in 106 professional soccer players and found low correlations (CODS and 10 m, r = 0.35 and CODS and 20 m, r = 0.46 and 10 m and 20 m, r = 0.62). The authors concluded that acceleration and maximum speed and agility were unrelated and thus specific qualities. It therefore seems as if more specific training is required to develop CODS and that there is a need for more research on different physical variables (e.g. strength) and their transfer value to CODS performance.

1.5 The relationship between CODS and maximal leg strength

Leg strength is considered to be an important part of CODS performance (Young, James & Montgomery, 2002), however, recent studies have not been able to find a significant correlation between maximal leg strength and CODS performance (Markovic, Sekulie & Markovic, 2007, Markovic, 2007, Young et al. 2002, Kapidziv, Pojskic, Muratovic, Uzicanin & Bilalic, 2011). Young et al. (2002) examined the relationship between concentric leg muscle power and sprinting speed with changes of direction and found mostly low correlations between concentric leg muscle power and CODS, while CODS had a significant moderate correlation with reactive strength.

Markovic (2007) examined the relationship between leg extensor strength and power and CODS performance and found that leg extensor strength and power measures were poor predictors of agility, however the highest relationship with each of the agility tests were the one-leg rising test (r between -0.3 and -0.44) suggesting that a functional complex exercise performed unilaterally (on one leg) was a better predictor of CODS compared with other strength tests. As mentioned earlier, Wisloff et al. (2004) reported a significant correlation between maximal bilateral back squat strength and linear sprint but the relationship between maximal bilateral back squat strength and a CODS test (10 m shuttle run, r = 0.68) was lower, suggesting that other qualities effects CODS performance besides maximal bilateral leg strength.

Young et al. (2002) examined the relationship between isokinetic unilateral leg extensor power output and reactive strength with a drop jump. The results revealed that reactive strength between the right and left leg was correlated to CODS. The participants were significant slower in the weaker leg in a CODS sprint test.

1.6 The relationship between CODS and balance ability

Yaggie and Campbell (2006) examined the effects of a four week balance training program on functional exercises. 36 recreationally active participants attained the study and were randomly placed in an experimental and in a control group. The experimental group trained unilateral balance in different exercises on a BOSU ball. Pretest and posttest consisted of a CODS test (shuttle run) and functional tasks (time on ball-test performance and vertical jump height). The results revealed that the experimental group increased significant in the time on ball-test and CODS but not in vertical jump. Unilateral balance training could be used in a training program for increasing sports-related activities.

Table 1. Summary of recent research of correlation studies between CODS and different predictors.

Reference	Sample size	CODS test	Predictor	Results
Young et al. (2002)	15 (male soccer, tennis, basketball, Australian football players) strength in the same leg in DJ	8-m sprint with different changes of direction	bilateral and unilateral isokinetic squat and DJ	Participants who turned faster to one side tended to have greater leg
Thomas & Little (2005)	106 (professional soccer players)	Zigzag agility test	LS10m, LS20m	Significantly moderately low correlations between CODS and LS10m and LS20m ($r = 0.346$ and $r = 0.458$)
Markovic (2007)	76 (male physical education students)	lateral stepping, 20-yard shuttle run, slalom run	isoinertal squat, isometric squat, one-leg rising, squat jump, hopping power, standing long jump	highest relationship between one-leg rising and CODS ($r = 0.33$, 0.44 and 0.35)
Chaouachi et al. (2009)	14 (elite male basket-ball players)	T-test	bilateral 1 RM squat (free weights), LS5m, LS10m, LS30m, SJ, CMJ, Bench, 5JT	significant relationship between T-test and 5JT ($r= -0.61$)

LS5m = Linear Sprint 5 m, LS10m = Linear Sprint 10 m, LS30m = Linear Sprint 30 m, SJ = Squat Jump, CMJ= Counter Movement Jump, 5JT = 5 jumping test and DJ = Drop Jump

1.7 Limitations in earlier studies

CODS involve complex activities and the movements in intermittent sports are often performed on one leg at a time (Manners, 2004) and consequently unilateral lower limb training should be a good predictor of CODS. Brughelli, Cronin, Levin and Hansen (2008) concluded that resistance training and tests should mimic more closely to every specific sport to be a better predictor of change-of-direction speed (CODS). Most of the earlier studies examining the relationship between strength and CODS has reported a small sample group (Young et al. 2002, Chaouachi et al. 2009), lower body bilateral strength (Wisloff et al. 2004, Chaouachi et al. 2009) and no familiarization (Chaouachi et al. 2009, Wisloff et al. 2004). Altough intermittent sports often require unilateral leg strength during game performance, earlier studies have tested strength bilaterally (Wisloff et al. 2004, Chelly et al. 2009) The rationale for the present study is that we believe tests preferably be carried out on one leg at the time to mimic sports that demand unilateral leg strength more closely. As suggested by Markovic (2007) balance and complex unilateral lower limb strength training might be important abilities in CODS performance. Earlier studies (Markovic, 2007, Brughelli et al., 2008) suggested there is a need for more studies on specific exercises and tests that mimic performance of particular sports in a more realistic way.

1.8 Purpose

Since this research area is rather new, according to the authors, this is one of the first studies to examine the relationship between maximal unilateral leg strength and CODS, performed by youth male soccer and ice-hockey players. The purpose with the study was to examine the relationship between CODS to unilateral leg balance and maximal (1RM) unilateral leg strength and in normalized strength (mean strength for right and left leg divided with body mass) and linear sprint in youth soccer and ice-hockey players. Another purpose was to examine the relationship between linear sprint and maximal (1RM) unilateral leg strength and unilateral balance ability for youth male soccer and ice-hockey players. The same relationships were also tested when soccer and ice-hockey players were separated. Our research question was as following:

1. Examine the relationship between CODS to maximal (1RM) unilateral leg strength and normalized strength, unilateral leg balance ability and linear sprint for the total group.
2. Examine the relationship between linear sprint to maximal (1RM) unilateral leg strength and normalized strength and unilateral leg balance ability for the total group.
3. Examine the relationship between CODS to maximal (1RM) unilateral leg strength and normalized strength, unilateral leg balance ability and linear sprint for the soccer and ice-hockey groups separated.
4. Examine the relationship between linear sprints to maximal (1RM) unilateral leg strength and normalized strength and unilateral leg balance ability for the soccer and ice-hockey groups separated.

The expected findings of this study could contribute to the understanding of the importance of specificity in resistance training and testing soccer and ice-hockey players. The hypotheses were that maximal unilateral leg strength would correlate significant with CODS and linear sprint and that unilateral balance have a weak relationship with all the selected exercises. CODS and linear sprint was hypothesized to correlate poorly.

2. Methods

This is a quantitative study with a cross-sectional–design, where the participants were selected through a mix of convenience sample groups, stratified and typical sampling.

2.1 Subjects

Twenty youth male soccer players (n=10, age: 17.6±1.0 years; body weight: 77.1±7.4 kg; height: 180.7±7.3 cm) and ice-hockey players (n=10, age: 15.6±0.5 years; body weight: 76.5±6.1 kg; height: 180.4±4.5 cm) volunteered to participate, after having signed an informed consent form and read information documents (Appendix 1 and 2) on the study. In the informed consent form the participant were promised their personal data would be handed with confidentiality, and the participant could choose to cancel the study at any time. The documents explained the background, risks, purpose and the procedure of the study**.** The inclusion criterions were the subjects had to be youth males between 15-19 years of age, active in ice-hockey or soccer at a sport school at college-level or an elite level sports team and have experience in resistance training. The participant was instructed not to conduct any strenuous leg training the day before the testing procedures. The exclusion criterions were absence of injuries or sickness during the tests. The goaltenders in neither of the sports were excluded because of the unique physiological demands of their position (Green, Pivarnik, Carrier, & Womack, 2006, Burr et al. 2008). Five elite sport organisations were contacted to be a part of the study. Of five organisations asked, two accepted.

2.2 Familiarization

The participant attended a familiarization session one week before the actual tests were performed, to eliminate learning effects. The order of the test battery during the familiarization session was in the same order the participant were going to conduct the tests one week later. During the familiarization sessions the test leaders were able to estimate approximately how strong each participant were in each strength exercise. By performing a familiarization session it was thought the numbers of 1RM trials during the actual strength tests to be reduced.

2.3 Testing Procedures

To evaluate the relationship between maximal (1RM) unilateral leg strength and unilateral leg balance ability with CODS and linear sprint, a battery of a total of five tests was chosen. The following tests were included: modified pro agility test (5-10-5 m), a modified SOLEC test (Standing One Leg Eyes Closed) performed on a balance disc, a maximal unilateral squat test performed in a standard Smith machine, a maximal unilateral leg press and a linear sprint test (5, 10 and 20 m). The first two sessions consisted of a familiarization session to eliminate learning effects, one for the soccer group and one for the ice-hockey group, respectively. After the two familiarization sessions the ice-hockey group and the soccer group was divided in two with five participants in each group, and had one test session each one week after the familiarization session. The testing area was located in an indoor running track and the test was completed with the subjects wearing training shorts, t-shirt and indoor shoes. All the test sessions were performed in the morning. The sequence of the tests according to Harman (2008) was as following; weight and height measurement, modified SOLEC on a balance disc, modified pro agility test (5-10-5 m), a unilateral Smith machine squat, a unilateral leg press and linear sprint (5, 10 and 20 m). The tests started with a 15 minutes warm-up, including running and dynamic stretching. During the tests no verbal encouragement was given to the subjects. A stop watch was used to ensure the right length of the rest periods depending on the test. Before the tests were performed, the participant were weighed and measured; only wearing shorts and t-shirts and no shoes.

2.3.1 SOLEC on a balance disc

The modified SOLEC test (Figure 2) was a balance test that required the subjects to stand on one leg on a BOSU-ball (Both Sides Up) (height 20 cm, width 62 cm). The other leg was held in 90° flexion of the knee joint and the arms of the participant were crossed, hands resting on the acromion. The aim for the participant was to stay in position on the ball as long as possible without breaking any of the above mentioned criterions. The participant was given two trials per leg, where the best time on each leg was documented using a stopwatch. The rest interval between each trial for each leg was at least two minutes.

Figure 2. Modified SOLEC-test (on BOSU ball). The participant was instructed to stand on one leg for as long as possible with eyes closed and the resting leg at a 90° knee flexion. The arms were crossed, with the hands resting on the acromion.

2.3.2 Change of direction speed performance test

A modified pro agility test, Figure 3, (Harman & Garhammer, 2008) was used to measure CODS performance. This test requires acceleration, deceleration and changing the direction of the participant by rotating the body 180° (Markovic, 2007). The test course started with a 5 m sprint in a straight line followed by a 180° turn, a 10 m sprint followed by a 180° turn and ended by a 5 m sprint. The test was conducted with a flying start, 50 cm behind the starting line. The 50 cm were marked with tape. A computerized system (MuscleLab, Ergotest Technology, Norway) was used to measure CODS performance. Timing gates were used at the starting/finish line and at every five m to record every participant performed the test correctly. The participant had two trials with a five minute rest period between the two trials. The best time was documented. The participant were instructed to run the course as fast as possible and in every 180° turn, face towards the same direction so both left and right leg performed a turn.

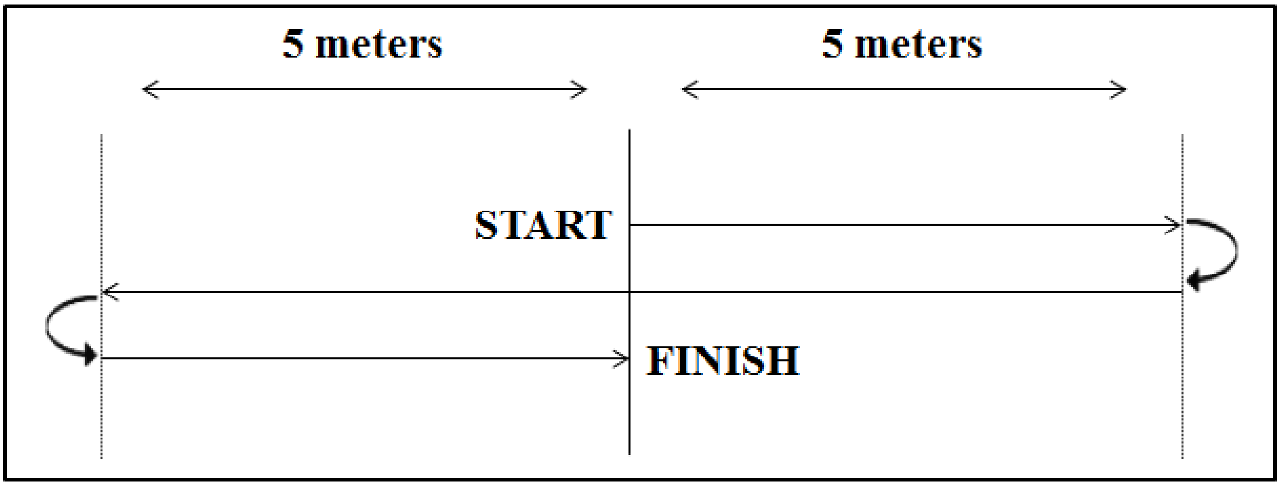

Figure 3. Modified pro agility test. The test started with a 5 m sprint, made a 180° turn and a 10 m sprint followed by a 180° turn and finished with a 5 m sprint. The participant was instructed to run the course as fast as possible and in every 180° turn, face towards the same direction so both left and right leg performed a turn.

2.3.3 Unilateral Smith machine squat

Maximal strength, one repetition maximum (1RM) was measured with a unilateral squat (Figure 4) in a standard Smith machine which has been validated by Tagesson and Kvist (2007). The unilateral squat was performed in a standard Smith machine (Nordic Gym, Bollnäs, Sweden), and the additional weights that were used were standard training discs (Eleiko, Halmstad, Sweden). A conventional Smith machine consists of a barbell that is fixed within steel rails, which only allow for vertical movement. When performing the unilateral squat, the participant stood erect and thereafter performed an eccentric movement to a required 90° angle of the knee joint (between femur and tibia, A in Figure 4) of the anterior leg. The participant then performed the concentric phase back to full extension of the knee joint. The squat depth of every trial was standardized with a goniometer and an elastic exercise band (Thera-band, Akron, USA). When reaching 90° angle in the knee joint, the participant had to touch an exercise band (B in Figure 4) with m. gluteus maximus before beginning the concentric phase. The exercise band was set parallel to the floor on the squat rack behind the participant, and its height was changed, depending on each individual's 90° knee angle. Both legs were tested, one leg at the time with three minute rest period before the next trial. The weights were increased with 2.5-10 kg until failure.

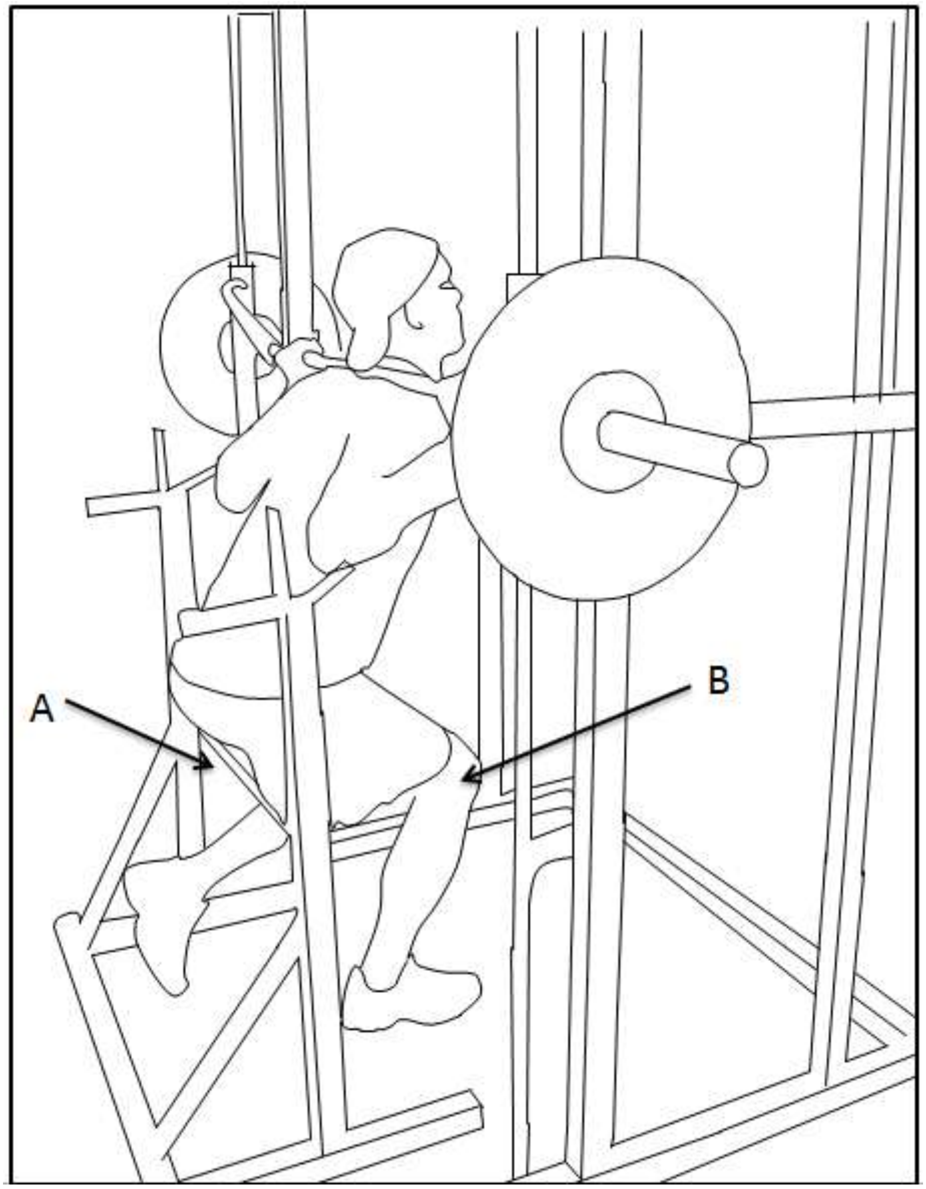

Figure 4. Unilateral Smith machine squat. When the anterior knee joint was at 90° as required (B) and m. gluteus maximus touched the exercise band (A), the participant was allowed to begin the concentric phase of the squat.

2.3.4 Unilateral leg press

Maximal strength of leg extensor muscles was measured by 1RM in a customized leg press performed unilaterally, as described by Baechle & Earle (2008). The participant was instructed to lower the machine foot platform in a controlled movement until the thighs were parallel with the machine foot platform, and on signal from the test leader the test person pushed the weight to full extension in the knee joint. Both legs were tested, one leg at the time followed by a three minute rest period before next trial. Since each participant had attended a familiarization session, the approximate value of 1RM was known in advance. It required no more than 4-5 lifts in order to assess 1RM. The weights were increased with 2.5-10 kg until failure.

2.3.5 5, 10 and 20 m linear sprint

The participant conducted a 20 m linear sprint, where a computerized system (MuscleLab, Ergotest Technology, Norway) was used to document the time at 5, 10 and 20 m. Timing gates was used at the starting line, at 5 m, at 10 m and at 20 m which also was the finish line. The linear sprint test was conducted with a flying start 50 cm behind the starting line. The 50 cm line was marked with a stripe of tape. The participant performed two trials with a rest period of five minutes between each trial. The best time was documented. The participant was instructed to run the course as fast as possible.

2.4 Statistics

Statistical analysis was performed using SPSS software (version 20.0, SPSS, Inc, IL). The significance level was set at $P<0.05$. Pearson product moment coefficient of correlation was performed to examine the relationship between each selected variables. According to Thomas, Nelson & Silverman (2005) a correlation of 0.6 is acceptable and sometimes lower depending on the research. For this study a Pearson *r* of 0.0-0.25 was considered low, 0.25-0.50 was considered moderately low, 0.5-0.75 was considered moderately strong and >0,75 was considered strong.

In addition, the coefficient of determination (r^2) was used to examine the amount of explained variance between tests. The coefficient of determination indicates the part of the total variance in one measure that can be explained, or accounted for, by the variance in the other measure (Thomas et al. 2005).

The participants result on left and right leg on unilateral squat, unilateral leg press and modified SOLEC on a balance disc were documented and summed together. The total sum was divided by two to present the mean load (1RM mean) and mean time. 1RM mean was also divided with each participants body mass to get a ratio result for the normalized strength.

3. Results

Descriptive statistics (mean ±SD) for all selected variables are depicted in Table 2 including. The participant (n=20) performed five different unilateral leg tests to examine the relationship to CODS and linear sprint. The results of the selected tests showed that the mean maximal strength in unilateral squat was 125.0 ± 22.7 kg and the mean maximal strength in unilateral leg press was 119.2 ± 28.1 kg. The linear sprint tests mean time for 5 m linear sprint was 1.05 ± 0.05 sec, 10 m linear sprint was 1.78 ± 0.08 sec and for 20 m linear sprint 3.07 ± 0.13 sec. The mean time on the CODS tests was 4.94 ± 0.15 sec and the mean time for the unilateral leg balance test (SOLEC) was 14.51 ± 22.28 sec.

Table 2. Descriptive statistics (n=20) for maximal unilateral leg strength, speed, unilateral leg balance and anthropometric variables.

	Mean (±SD)	Range	Min.	Max.
Age	16.6 (± 1.3)	4	15	19
Weight (kg)	76.8 (± 6.6)	24.7	66.0	90.7
Length (cm)	180.5 (± 5.9)	24	174	198
CODS (sec)	4.94 (± 0.15)	0.58	4.71	5.29
SOLEC (sec)	14.51 (± 22.28)	88.54	2.72	91.26
US (kg)	125.0 (± 22.7)	77.5	87.5	165
ULP (kg)	119.2 (± 28.13)	92.5	80.0	172.5
LS5m (sec)	1.05 (± 0.05)	0.22	0.98	1.20
LS10m (sec)	1.78 (± 0.08)	0.32	1.65	1.97
LS20m (sec)	3.07 (± 0.13)	0.52	2.85	3.37

CODS = Change Of Direction Speed, SOLEC = modified Standing on One Leg Eyes Closed (on a BOSU ball), US = Unilateral Squat (in a Smith machine), ULP = Unilateral Leg Press, LS5m = Linear Sprint 5 m, LS10m = Linear Sprint 10 m and LS20m = Linear Sprint 20 m.

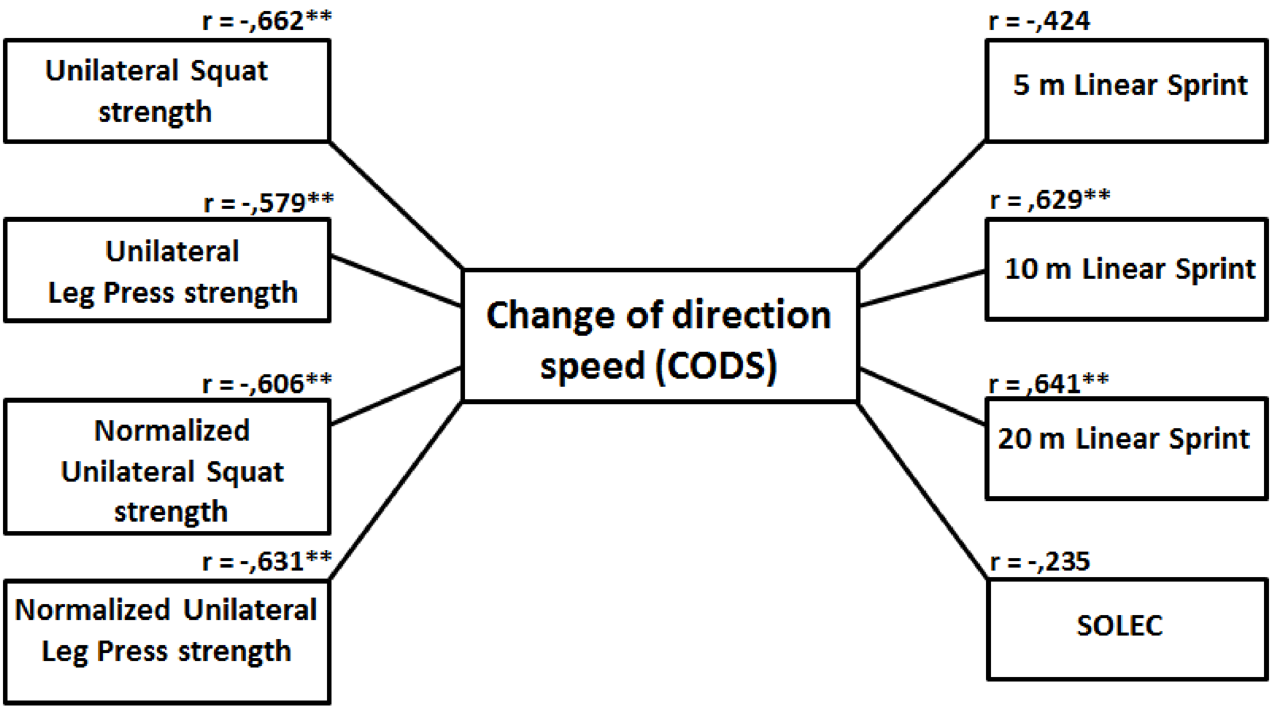

Figure 5. Model shows an overview of the relationship between Change Of Direction Speed (CODS) ability and unilateral balance ability (SOLEC), linear sprint (5, 10 and 20 m), maximal unilateral squat strength, maximal unilateral leg press strength and normalized strength (unilateral squat strength/BM, unilateral leg press strength/BM) for youth male soccer and ice-hockey players (n=20). ** Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2- tailed).

3.1 Correlations between CODS and maximal unilateral strength

The correlations between various tests are shown in Table 3 and Table 4. Figure 5 shows an illustration between the relationship between CODS and different tests for soccer and ice-hockey players (n=20). There were a significant moderately strong correlation between CODS and maximal strength (Figure 5) in both unilateral Smith machine squat and unilateral leg press (r = -0.662, P<0.001 and r = -0.579, P<0.007, respectively). When comparing CODS with the normalized strength variables, unilateral leg press strength was superior to unilateral squat strength (r = -0.631, P<0.003 and r = -0.606, P<0.006, respectively).

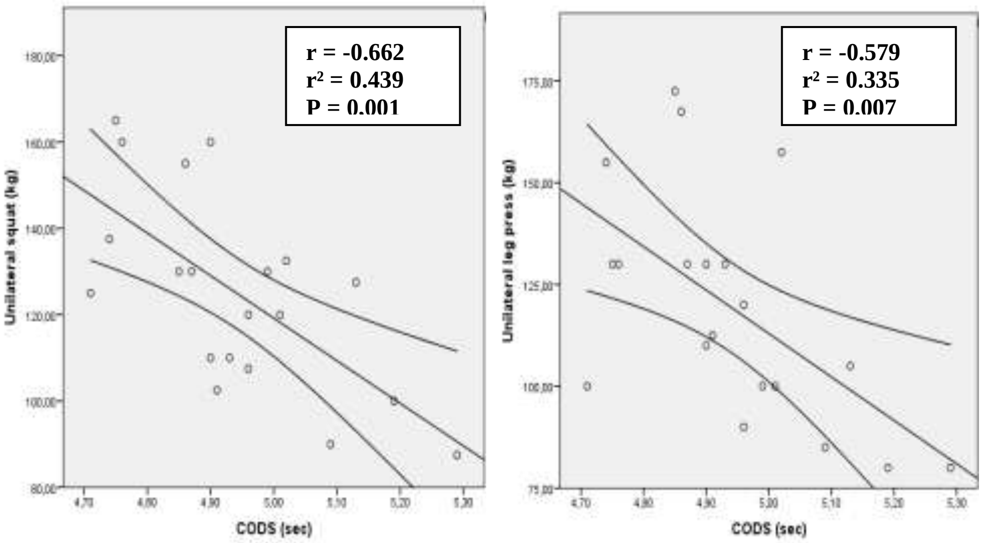

Figure 6. Correlation between maximal unilateral squat strength and maximal unilateral leg press strength respectively, and the test of CODS performance (modified pro agility test) in youth male soccer and ice-hockey players (n=20) with 95 % confidence interval.

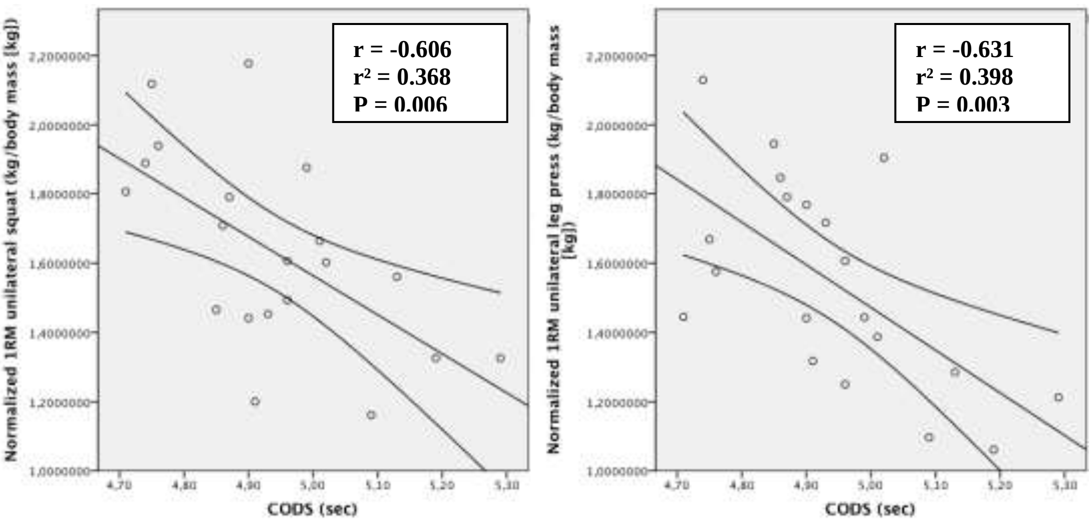

Figure 7. Correlation between maximal normalized unilateral squat strength and maximal normalized unilateral leg press strength, respectively, and the test of CODS performance (modified pro agility test) in youth male soccer and ice-hockey players (n = 20) with 95 % confidence interval.

3.2 Correlations between CODS and linear sprint

The relationship between linear sprint and CODS were different depending on distance measured. The correlation was significant between CODS and 20 m linear sprint and 10 m linear sprint ($r = 0.641$, $P<0.002$ and $r = 0.629$, $P<0.003$, respectively) but not between CODS and 5 m linear sprint.

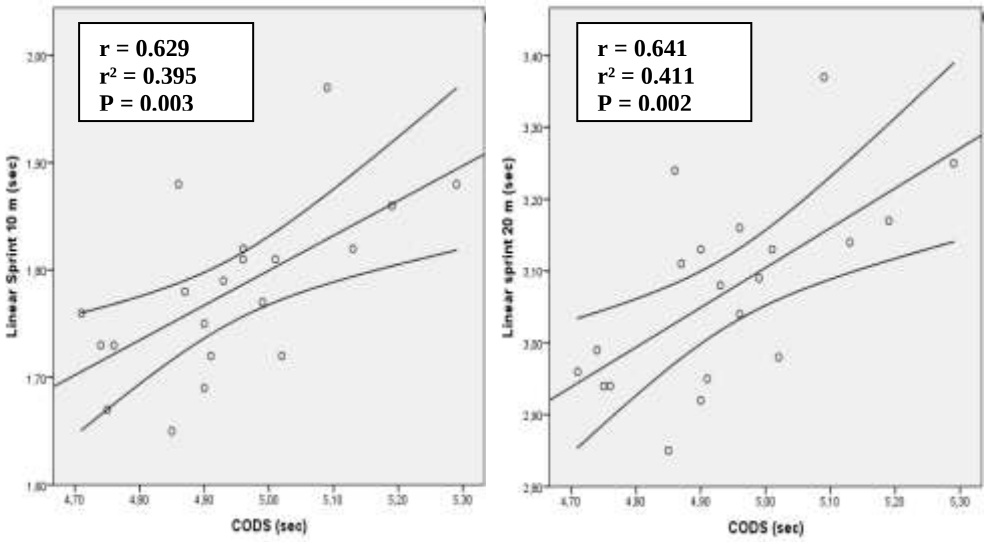

Figure 8. Correlation between 10 m linear sprint and 20 m linear sprint, respectively, and the test of CODS performance (modified pro agility test) in youth male soccer and ice-hockey players (n=20) with 95 % confidence interval.

3.3 Correlations between linear sprint and maximal unilateral leg strength

The relationship between linear sprint to maximal strength in unilateral squat and maximal unilateral leg press were different depending on distance measured. The correlation was significant between maximal unilateral squat strength and maximal unilateral leg press strength with 20 m linear sprint (r = -0.536, P<0.015 and r = -0.485, P<0.030, respectively) and 10 m linear sprint (r = -0.575, P<0.008 and r = -0.547, P<0.013, respectively**)** but not between maximal unilateral squat strength and unilateral leg press strength with 5 m linear sprint. In normalized strength, similar results were found and a significant relationship between 20 m linear sprint and maximal normalized unilateral squat strength and maximal normalized unilateral leg press strength (r = -0.493, P<0.027 and r = -0.514, P<0.020, respectively) and also to 10 m linear sprint (r = -0.534, P<0.015 and r = -0.593, P<0.006, respectively).

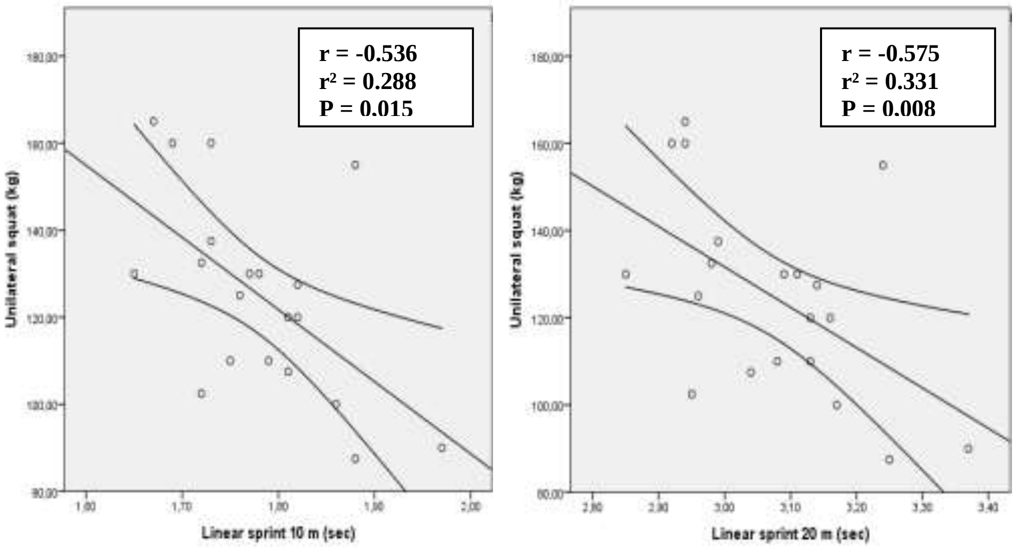

Figure 9. Correlation between maximal unilateral squat strength test and 10 m linear sprint and 20 m linear sprint, respectively, in youth male soccer and ice-hockey players (n=20) with 95 % confidence interval.

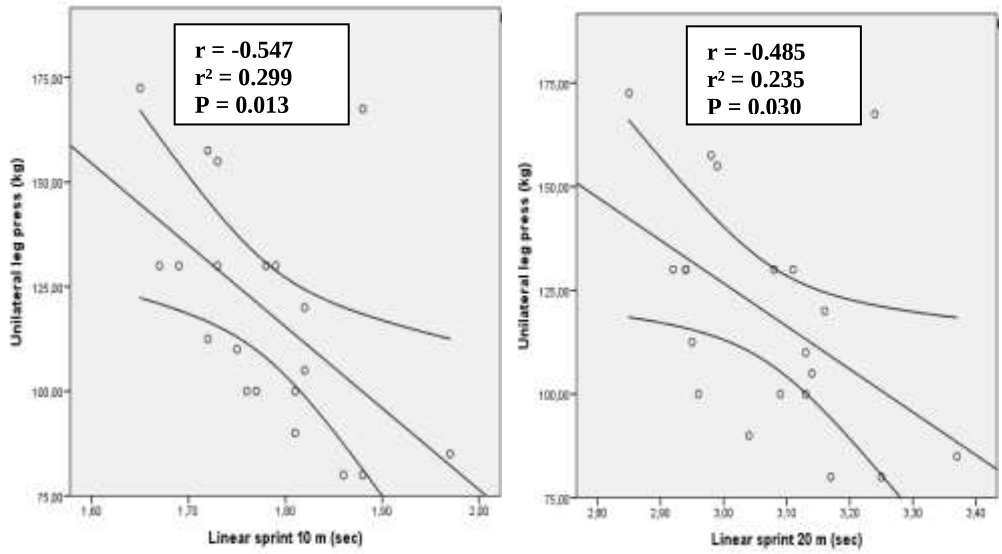

Figure 10. Correlation between maximal unilateral leg press strength test, and 10 m linear sprint and 20 m linear sprint, respectively, in youth male soccer and ice-hockey players (n=20) with 95 % confidence interval.

3.4 Comparing correlations between soccer and ice-hockey players

When comparing soccer and ice-hockey players, differences were found between correlations (Table 5, Table 6, Table 7 and Table 8). There were a statistical significant moderately strong relationship between CODS and 10 m linear sprint and 20 m linear sprint ($r = 0.646$, $P<0.043$ and $r = 0.712$, $P<0.021$, respectively) for soccer players but not between any other variables. For ice-hockey players the relationship were significance between CODS and maximal unilateral squat strength and maximal unilateral leg press strength with a moderately strong correlation ($r = -0.644$, $P<0.044$ and $r = -0.646$, $P<0.043$, respectively) but not when comparing in normalized strength.

The relationship between linear sprint and different variables also differed depending on the specific sport. For soccer players 10 m linear sprint correlated significant with CODS (r = 0.646, P<0.043) but also with the strength tests maximal unilateral squat strength and maximal unilateral leg press strength and maximal normalized unilateral leg press strength (r = -0.722, P<0.018 and r = -0.819, P< 0.004 and r = -0.784, P<0.007, respectively). For ice-hockey players 10 m linear sprint correlated significant with maximal normalized unilateral squat strength (r = -0.663, P<0.037). There were also a significant correlation for soccer players between 20 m linear sprint and CODS (r = 0.712, P<0.021) but also with maximal unilateral squat strength, maximal unilateral leg press and maximal normalized unilateral leg press strength (r = -0.663, P<0.037 and r = -0.703, P<0.023 and r = -0.666, P<0.035, respectively). For ice-hockey players 20 m linear sprint correlated significant with maximal normalized unilateral squat strength (r = -0.753, P<0.012).

Table 3. Correlation matrix (soccer and ice-hockey, n=20) for strength (mean), speed (mean) and anthropometric variables.

	Groups	Age	Weight	Height	CODS	SOLEC	US	ULP	LS5m	LS10m	LS20m
Groups	1										
Age	-0.781**	1									
Weight	-0.044	0.191	1								
Length	-0.026	0.104	0.596**	1							
CODS	-0.410	0.196	-0.216	-0.043	1						
SOLEC	-0.153	0.275	-0.299	-0.068	-0.235	1					
US	0.530*	-0.198	0.321	-0.084	-0.662**	0.116	1				
ULP	0.292	0.009	0.628**	0.142	-0.579**	-0.158	0.653**	1			
LS5m	-0.194	-0.121	-0.156	-0.223	0.424	-0.223	-0.432	-0.347	1		
LS10m	-0.215	-0.079	-0.196	-0.090	0.629**	-0.133	-0.575**	-0.547*	0.907**	1	
LS20m	-0.078	-0.174	-0.198	-0.086	0.641**	-0.283	-0.536*	-0.485*	0.876**	0.947**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2- tailed).

CODS = Change of Direction Speed, SOLEC= Standing One Leg Eyes Closed (on a BOSU ball), US = Unilateral Squat (in a Smith machine), ULP = Unilateral Leg Press, LS5m = Linear Sprint 5 m, LS10m = Linear Sprint 10 m and LS20m = Linear Sprint 20 m.

Table 4. Correlation matrix (soccer and ice-hockey, n=20) for normalized strength, speed (mean) and anthropometric variables.

	Groups	Age	Weight	Height	CODS	SOLEC	NUS	NULP	LS5m	LS10m	LS20m
NUS	0.567**	-0.288	-0.147	-0.356	-0.606**	0.282	1	0.550*	-0.403	-0.534*	-0.493*
NULP	0.392	-0.091	0.305	-0.078	-0.631**	-0.056	0.550*	1	-0.362	-0.593**	-0.514*

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2- tailed).

CODS = Change of Direction Speed, SOLEC = Standing One Leg Eyes Closed (on a BOSU ball), NUS = Normalized Unilateral Squat (in a Smith machine), NULP = Normalized Unilateral Leg Press, LS5m = Linear Sprint 5 m, LS10m = Linear Sprint 10 m and LS20m = Linear Sprint 20 m.

Table 5. Correlation matrix for soccer group (n=10) on strength (mean), speed (mean) and anthropometric variables.

	Age	Weight	Height	CODS	SOLEC	US	ULP	LS5m	LS10m	LS20m
Age	1									
Weight	0.278	1								
Length	0.265	0.604	1							
CODS	-0.177	-0.188	-0.073	1						
SOLEC	0.377	-0.374	-0.133	-0.387	1					
US	0.442	0.374	-0.084	-0.599	0.149	1				
ULP	0.469	0.673*	0.053	-0.483	-0.211	0.765**	1			
LS5m	-0.603	-0.513	-0.502	0.412	-0.222	-0.553	-0.571	1		
LS10m	-0.551	-0.542	-0.336	0.646*	-0.069	-0.722*	-0.819**	0.887**	1	
LS20m	-0.482	-0.474	-0.348	0.712*	-0.211	-0.663*	-0.703*	0.912**	0.970**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2- tailed).

CODS = Change of Direction Speed, SOLEC = Standing One Leg Eyes Closed (on a BOSU ball), US = Unilateral Squat (in a Smith machine), ULP= Unilateral Leg Press, LS5m = Linear Sprint 5 m, LS10m = Linear Sprint 10 m and LS20m = Linear Sprint 20 m.

Table 6. Correlation matrix for the soccer group (n=10) in normalized strength, speed (mean) and anthropometric variables.

	Age	Weight	Height	CODS	SOLEC	NUS	NULP	LS5m	LS10m	LS20m
NUS	0.289	-0.244	-0.439	-0.557	0.424	1	0.573	-0.259	-0.423	-0.412
NULP	0.469	0.415	-0.169	-0.543	-0.103	0.573	1	-0.480	-0.784**	-0.666*

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2- tailed).

CODS = Change of Direction Speed, SOLEC = Standing One Leg Eyes Closed (on a BOSU ball), NUS = Normalized Unilateral Squat (in a Smith machine), NULP = Normalized Unilateral Leg Press, LS5m = Linear Sprint 5 m, LS10m = Linear Sprint 10 m and LS20m = Linear Sprint 20 m.

Table 7. Correlation matrix for ice-hockey group (n=10) on strength (mean), speed (mean) and anthropometric variables.

	Age	Weight	Height	CODS	SOLEC	US	ULP	LS5m	LS10m	LS20m
Age	1									
Weight	0.211	1								
Length	-0.306	0.595	1							
CODS	-0.366	-0.414	-0.020	1						
SOLEC	-0.285	-0.181	0.049	-0.127	1					
US	0.465	0.455	-0.093	-0.644*	0.449	1				
ULP	0.188	0.677*	0.410	-0.646*	0.157	0.496	1			
LS5m	0.112	0.534	0.516	0.308	-0.403	-0.244	0.354	1		
LS10m	0.020	0.370	0.468	0.515	-0.490	-0.415	0.134	0.951**	1	
LS20m	-0.083	0.269	0.519	0.573	-0.579	-0.547	-0.016	0.810**	0.925**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2- tailed).

CODS = Change of Direction Speed, SOLEC = Standing One Leg Eyes Closed (on a BOSU ball), US = Unilateral Squat (in a Smith machine), ULP = Unilateral Leg Press, LS5m = Linear Sprint 5 m, LS10m = Linear Sprint 10 m and LS20m = Linear Sprint 20 m.

Table 8. Correlation matrix for the ice-hockey group (n=10) in normalized strength, speed (mean) and anthropometric variables.

	Age	Weight	Height	CODS	SOLEC	NUS	NULP	LS5m	LS10m	LS20m
NUS	0.397	-0.051	-0.426	-0.480	0.617	1	0.284	-0.565	-0.663*	-0.753*
NULP	0.096	0.240	0.154	-0.614	0.335	0.284	1	0.089	-0.099	-0.230

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2- tailed).

CODS = Change of Direction Speed, SOLEC = Standing One Leg Eyes Closed (on a BOSU ball), NUS = Normalized Unilateral Squat (in a Smith machine), NULP = Normalized Unilateral Leg Press, LS5m = Linear Sprint 5 m, LS10m = Linear Sprint 10 m and LS20m = Linear Sprint 20 m.

4. Discussion

The purpose with this study was to examine the relationship between CODS and linear sprint to unilateral balance and unilateral maximal (1RM) leg strength in youth male college soccer and ice-hockey players. Another purpose was to compare if there were differences in correlations depending on the specific sport. The hypotheses were that maximal unilateral leg strength would correlate significant with CODS performance and linear sprint and that unilateral balance would have a weak relationship with all selected tests. CODS and linear sprint were hypothesized to correlate poorly.

The main results from the study showed that maximal unilateral strength (unilateral squat and unilateral leg press) correlated significantly with 10 and 20 m linear sprint and CODS, also when expressed as normalized strength (normalized unilateral squat and normalized unilateral leg press) for youth male soccer and ice-hockey players. There was a significant moderately strong relationship between CODS and linear sprint in 10 m and 20 m ($r = 0.629$, $P<0.003$ and $r = 0.641$, $P<0.002$, respectively) but not 5 m linear sprint. The unilateral standing balance test (SOLEC on a BOSU ball) did not correlate significantly with any of the selected variables.

When the soccer and ice-hockey groups were separated differences were found. For the soccer group (n=10) a significant moderately strong correlation between CODS and 10 m linear sprint and 20 m linear sprint ($r = 0.646$, $P<0.043$ and $r = 0.712$, $P<0.021$, respectively) was found. For the ice-hockey group (n=10) a moderately strong significant relationship were found between CODS and maximal unilateral squat strength and maximal unilateral leg press strength ($r = -0.644$, $P<0.044$ and $r = -0.646$, $P<0.043$, respectively).

For the soccer group 10 m linear sprint correlated significantly with maximal unilateral squat strength, maximal unilateral leg press strength and maximal normalized unilateral leg press strength ($r = -0.722$, $P<0.018$, and $r = -0.819$, $P<0.004$, and $r = -0.784$, $P<0.007$, respectively). 20 m linear sprint correlated significantly with maximal unilateral squat strength, maximal unilateral leg press strength and maximal normalized unilateral leg press strength ($r = -0.663$, $P<0.037$, and $r = -0.703$, $P<0.023$, and $r = -0.666$, $P<0.035$, respectively).

For the ice-hockey group 10 m linear sprint correlated significantly with maximal normalized unilateral squat strength ($r = -0.663$, $P<0.037$). 20 m linear sprint correlated significantly with maximal normalized unilateral squat strength ($r = -0.753$, $P<0.012$).

4.1 Correlation between linear sprint and maximal unilateral leg strength

The results of this study are presented in Table 3 and Table 4 and shows there is a moderately strong relationship between maximal strength in unilateral leg press and unilateral squat to linear sprint in 10 m linear sprint and 20 m linear sprint even when expressed as normalized strength. This confirms that maximal lower limb strength is an important factor for linear sprint, however recent studies have focused on bilateral leg strength (Wisloff et al. 2004, Ronnestad et al. 2008, Chaouachi et al. 2009, McBride et al. 2009, Chelly et al. 2009, Chelly et al. 2010). This study also shows that unilateral strength is important for linear sprint. Wisloff et al. (2004) reported a significant strong correlation between maximal (1RM) bilateral half squat (90˚ in knee flexion between femur and tibia) and 10 m linear sprint and 30 m linear sprint (r = 0.94 and r = 0.71, respectively) when testing 17 international male soccer players. Chaouachi et al. (2009) also tested maximal (1RM) bilateral half squat strength and found a significant relationship to linear sprint 5 m, 10 m and 30 m (r = -0.63 and r = -0.68 and r = -0.65, respectively) and the best correlation were found to linear 5 m sprint when examining 14 elite professional basketball players. Cronin and Hansen (2005) tested 26 part-time and full-time professional rugby league players and found no significant correlation between maximal (3RM) squat strength and 5 m, 10 m and 30 m sprint times. Rugby players usually are heavier than for example soccer players, which could explain the results. In this study we found no significant correlation between 5 m linear sprint and maximal (1RM) unilateral strength. This was unexpected because earlier studies have reported that maximal strength is important in the first 5 m, although we found no earlier studies tested the unilateral strength in maximal unilateral leg press and maximal unilateral Smith machine squat. The results could be affected by inexperience in sprinting technique or the fact that no power measures were used in the study.

This confirms that maximal lower limb strength is important for linear sprint in intermittent sports.

4.2 Correlation between CODS and linear sprint

A statistically significant correlation was also found between CODS and linear sprint in the distances 10 and 20 m linear sprint (r = 0.629, P<0.003 and r = 0.641, P<0.002, respectively) but not 5 m linear sprint. The results of our study are not in line with earlier studies (Little & Williams, 2005, Wisloff et al. 2004, Chaouachi et al. 2009), which has reported low correlations between CODS and linear sprints. Chaouachi et al. (2009) examined 14 professional elite male basketball players and the relationship between CODS (T-test) and linear sprint (5, 10 and 30 m) and found no significant correlation. Why we found a correlation between CODS and linear sprint could be due to the fact that different CODS tests used were T-test which consist of acceleration, deceleration, lateral stepping and backward running and is a more complex test than our modified pro agility test which does not include lateral stepping and backward running. The modified pro agility test is further similar to linear sprint compared with the T-test. There were also a difference in Chaouachi et al. (2009) study were less participant attended as well as a shorter rest period, two to three minutes between the trials compared with this study (five minutes). Fatigue may have influenced the test results.

Little and Williams (2005) examined a large sample consisting of 106 professional soccer players and the relationship between CODS (zigzag agility test) and 10 m sprint (acceleration) and flying 20 m sprint (maximum speed). The results showed that acceleration, maximum speed and CODS are specific qualities and thus unrelated. Although a Little & Williams

(2005) used a large sample only a significantly moderately low correlations were found. This could be due to the differences in selection of CODS test were zigzag agility test require acceleration and changes of direction speed, and the pro agility test require acceleration, deceleration and 180° turns.

The modified pro agility test is a relevant test for both soccer and ice-hockey which constantly requires high intensity acceleration, deceleration and 180˚ turns during game performance, which could explain the significant results. CODS are a complex activity and there are differences in CODS tasks depending on the sport.

Results on the relationship between CODS and linear sprint are not consistent. We found a correlation between CODS and linear sprint, however these correlations seems to depend on which type of CODS test and to the population tested.

4.3 Correlation between CODS and maximal unilateral strength

The study shows a significant relationship between CODS and maximal strength in unilateral leg press and unilateral squat and also in normalized strength. Earlier studies which tested the bilateral strength have failed to report a significant relationship to CODS (Chaouachi et al. 2009, Markovic, 2007, Markovic et al. 2007). In Markovic (2007), 76 physical education students performed three different CODS tests including 20 yard shuttle run and six leg extensor strength tests including maximal (1RM) bilateral back squat strength in a Smith machine but did not found any significance between strength and CODS. The best correlation was found between the functional test one-leg rising test ($r = 0.31$) and CODS. In the study by Markovic (2007) a large sample group of physical education students were used with backgrounds in both individual and team sports which could have affected the results because the lack of specificity in the tests to the population. In this study we used the modified pro agility test (also called 20 m shuttle run) which is very similar to the 20-yard shuttle run used in Markovic (2007) study and we found a significant relationship. This could be due to the specificity in selection of exercise to the tested population. Bilateral back squat in a Smith machine does not require a high degree of balance and stability and is not specific to intermittent CODS sports.

A study by Chaouachi et al. (2009) examined the relationship between maximal (1RM) bilateral back squat strength with free weights and a basketball relevant CODS test (T-test) in fourteen elite male professional basketball players. The results showed no significant correlation between 1RM back squat strength and the CODS test, although a CODS test relevant to basketball were used as well as back squat performed with free barbells. Despite performing bilateral back squat with free barbells which require more balance and stability no significant correlation was found. The results from this study prove there are differences between bilateral and unilateral leg strength exercises and the relationship to CODS and the findings of this study shows the importance of unilateral leg strength in intermittent sports.

According to the authors of this study the reason why this study found a significant relationship between maximal lower limb strength and CODS were due to the fact that most

CODS tasks is often performed and developing power on one leg at the time and strength should therefore be tested as such. Unilateral squat is a complex exercise to perform, which requires maximal lower limb strength, stability and balance which seems to be a good predictor for CODS performance. Unilateral leg press strength was also significant correlated (r = -0.579, P<0.007) to CODS although it is a less complex exercise but still require the participant to develop force on one leg.

The highest measured correlation with CODS was with maximal unilateral squat strength (r = -0.662, P<0.001, Figure 6). Significant correlations was also found between CODS and normalized strength (maximal unilateral squat and maximal unilateral leg press, r = -0.606, P<0.006, r = -0.631, P<0.003, respectively), in line with Newton's second law of motion the acceleration is affected by force and body mass (Figure 7). These results show the importance of complexity in exercise selection and unilateral normalized strength when testing for CODS.

4.4 Correlation between CODS and linear sprint to unilateral balance ability

As suggested by Markovic (2007) agility is a complex activity and balance could be a part that determines agility performance, and therefore we tested the modified SOLEC on a BOSU ball and the relationship to linear sprinting and CODS. During a standard SOLEC test, the participant standing on one leg and eyes closed on a flat surface. To increase the sensitivity of this test when it came to the young, healthy and well trained subjects in this study we choose to modify the level of difficulty by using a BOSU ball. The results revealed no significant results to any of the selected tests. The unilateral balance test (modified SOLEC on a BOSU ball) was not a good predictor for either CODS or linear sprint for youth male soccer and ice-hockey players. This was in line with our expectations; however balance is probably still an important ability in CODS which involve unilateral balance in changes in direction in high speed. Yaggie and Campbell (2006) four week unilateral standing balance study showed a significant improvement in a CODS test which suggest that unilateral balance have some transfer value to CODS. In the present study a more specific test for balance ability and a larger number of participants might show different results.

4.5 Differences between soccer and ice-hockey

Even though both soccer and ice-hockey classifies as intermittent sports with lots of CODS activities, they are still requiring very different movements within each sport. The results indicate there are differences between the sports when comparing the relationship between CODS and the selected tests. For the soccer group (n=10) CODS correlated significantly (r = 0.646, P<0.043, r = 0.712, P<0.021, respectively) with 10 m linear sprint and 20 m linear sprint, whereas the ice-hockey group (n=10) showed a significant relationship between CODS and maximal unilateral squat strength and maximal unilateral leg press strength (r = -0.644, P<0.044, r = -0.646, P<0.043, respectively) but not when comparing in normalized strength. This could be explained by the large difference in the foundation of the specific sports where ice-hockey is performed on ice and soccer on grass and therefore the soccer players are more accustomed to the sprinting activities. Soccer naturally requires running activities while ice-hockey requires skating activities to perform different activities on a low friction foundation.

There were also differences between the sports and the relationship between linear sprint and the selected tests. For the soccer group 10 and 20 m linear sprint correlated significant with maximal unilateral squat strength, maximal unilateral leg press strength and in normalized strength. For the ice-hockey group 10 m linear sprint and 20 m linear sprint significantly correlated only with maximal unilateral squat in normalized strength. This could probably be explained by the low sample consisting of only ten participants in each group. A limitation in the comparison between soccer and ice-hockey is that the results only reveal a difference in correlation but not if it is significant, therefore it is not possible to make any conclusions. The results could be observed as differences between correlations but cannot compare the results due to the fact that random may have influenced.

4.6 Limitations

The results are in line with Sheppard & Young's (2006) universal model of agility which suggests that CODS performance depends on straight sprinting speed, technique, leg muscle qualities and anthropometrics. Our results confirm a significant relationship between CODS and linear sprint in 10 and 20 m and maximal unilateral leg strength and normalized strength. The results confirm the theory that intermittent sports require strength performed unilaterally, however it still require more studies to confirm the relationship. These results are based on youth male soccer and ice-hockey players, it still require more studies to confirm this results and if the same relationship exists in other intermittent sports.

A limitation of this study is the small sample size. The sample size consisted of twenty soccer and ice-hockey players to see if correlations were found between maximal unilateral strength exercises to CODS and linear sprint. When separating soccer and ice-hockey in to two different groups there were less significant results suggesting that a larger sample size is needed. In the present study it was not possible to see if there existed a statistically significant difference between the groups. The results shows a difference and future studies should be performed with a larger sample size to confirm our findings and allow for more predictor variables to be included in the analysis and to examine differences in intermittent sports.

The standardization of the tests are an important aspect of studies and the selection of strength tests were based on the assumption that specificity is important when examining sports and that intermittent sports often require to develop force and power unilaterally. The unilateral squat performed with free weights is an advanced exercise with a higher risk of injury, and to further increase the reliability we chose to conduct the test in a Smith machine. To standardize the testing procedures the depth of the squat were 90° in knee flexion (between femur and tibia). To ensure the right depth an elastic exercise band was attached to a rack (Figure 4) behind the participant. The unilateral leg press were standardized in a different knee angle where the participant were instructed to lower the weights until the thigh were parallel with the foot platform. The reason was to ensure the reliability because there were easier to make sure the participants attained the same depth.

The linear sprint test consisted of 20 m where timing gates were placed on 5 m, 10 m and 20 m to minimize the effects of fatigue. A flying start of 50 cm was used to eliminate the reaction time and unexpected initiation of the timing. The testing procedures consisted of five different tests on the same day and to minimize the effects fatigue the resting periods of five minutes between the different tests were used.

The reason only youth male athletes were included in the study was because the results could be applicable to the largest population possible. Another reason why only youth male athletes were chosen was due to limited population of active youth female ice-hockey players.

As no standardised protocol for testing strength of either soccer or ice-hockey players exists, as well as the test unilateral Smith machine squat have not been used in this particular research question, it is difficult to compare the results among different studies. In our view, intermittent sports are complex and require different activities in its nature and logically the testing procedure should mimic and try to capture the complexity of the movements. Isokinetic tests and strength test performed bilaterally do not test the sport specific strength in sports like soccer and ice-hockey which often develop force on one leg at a time, and therefore testing unilateral strength should be a better predictor of CODS.

5. Conclusion

It is a challenge for strength and conditioning coaches to find exercises which has a high transfer value to a given sport. There is often a time limit where strength and conditioning coaches have to prioritize exercises that contribute to the specific sport, and due to the limited amount of time available for strength training, the strength and conditioning coaches have to be able to choose the training exercise with the most transfer value to the sport. For training to be effective exercise selection should have a high transfer value to sport specific activities, and knowledge on unilateral and sport specific training needs to be further examined.

The results of this study suggest that maximal unilateral multi-joint leg strength is important and a good predictor in linear sprint in 10 and 20 m and CODS performance in youth male soccer and ice-hockey players.

Earlier studies have found a significant relationship between maximal bilateral squat strength and linear sprint but not to CODS. In the present study we found a significant relationship between maximal unilateral strength and linear sprint and CODS suggesting CODS is a more complex activity and require strength development unilaterally.

Earlier studies have struggled to find a significant relationship between maximal leg strength and CODS performance and it appears as a more functional and specific approach should be used. Unilateral squat represents a complex functional strength test that requires producing power and force in one leg at a time and seems to be a good predictor of CODS performance in soccer and ice-hockey players. Even maximal unilateral leg press strength were a good predictor of CODS even though it represent a lesser complex task but still require to produce unilateral leg strength.

Strength and conditioning coaches and sport scientists who work with intermittent sports should be aware of the fact that maximal unilateral squat strength and maximal unilateral leg press strength are good predictors of CODS and linear sprint performance. Unilateral resistance training could be a method for increasing linear sprint and CODS performance for soccer and ice-hockey players.

Future studies should examine the relationship between CODS and unilateral strength to different CODS tests and sports to increase the reliability. Intervention studies examining the difference between bilateral and unilateral strength training to CODS performance are needed.

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Appendix

Informed consent form 1(1)

Informerat dokumenterat samtycke

Syftet med studien är att se eventuella samband mellan maximal styrka i benmuskulaturen utfört på ett ben, balans och enbensknäböj i Smith-maskin, med Change of direction speed (snabbhet i riktningsförändringar) och linjär sprint (5 m, 10 m, 20 m).

Det som förväntas av dig som testperson är att genomföra ett familijäriseringstillfälle och ett testtillfälle. Dessa tillfällen består av mätningar bestående av vikt, längd, balanstest och agilitytest. Efter dessa test utförs två styrketest på ett ben bestående av maxstyrketest i benpress i en ben press och enbensknäböj i en Smith-maskin.

Familijäriseringstillfället tar totalt ca 60-90 minuter och testtillfället tar totalt ca 60-120 minuter. Testerna och familijäriseringen kommer att äga rum i Friidrottens hus, Göteborg. Samtliga tester instrueras och övervakas noggrant av tre testledare.

Inklusionskriterierna för deltagande i studien är att vara aktiv inom alltingen ishockey eller fotboll de senaste fem åren och styrketräningserfarenhet gällande sin sport. Deltagarna skall vara inom åldrarna 15-19 år. Deltagarna får inte ha någon nuvarande skada eller lida av någon pågående infektionssjukdom som kan påverka testresultaten.

Deltagarnas personuppgifter och resultat kommer att behandlas helt anonymt och endast användas i studien.

Deltagande i denna studie är helt frivilligt och kan avbrytas när man så behagar. Deltagande i denna studie möjliggör ny forskning som kan leda till nya träningsmetoder och en modern utveckling av deltagarens idrott.

Jag intygar att jag har tagit del av vad undersökningen går ut på och accepterar att frivilligt ställa upp som testperson. Jag säkerställer här med också att jag inte har någon nuvarande skada eller lider av någon pågående infektions sjukdom som kan påverka testresultaten.

Datum och underskrift_________________________Namnförtydligande_________________________

Tack för ditt deltagande!

Anton Arin, Daniel Jansson och Kristian Skarphagen

Idrottsvetenskap - Sport Coaching med inriktning fysiologi, Göteborgs Universitet

Information till deltagare i studien:

Maximal styrka på ett ben korrelerar med linjär sprint och snabbhet i riktningsförändringar

Bakgrund

Tidigare forskning har hittat ett samband mellan styrka i benmuskulaturen och linjär sprint på distanser mellan 0-20 m. Man har även försökt hitta ett samband mellan agility och styrka i benmuskulaturen, men misslyckats. Tidigare forskning har framförallt fokuserat på två ben, i isokinetiska maskiner och oftast isolerade övningar. Lite forskning har utförts på styrka på korrelationer mellan styrka på ett ben, agility och linjär sprint. Med tanke på att de flesta lagidrotter utförs i huvudsak på ett ben i taget är det intressant att se korrelationer till agility och linjär sprint.

Syfte

Syftet med studien är att se eventuella samband mellan maximal styrka i benmuskulaturen och balans utfört på ett ben med agility (snabbhet i riktningsförändringar) och linjär sprint (5, 10 och 20 m).

Projektets upplägg

Testningen sker under ledning av tre idrottsvetenskapsstudenter med erfarenhet av styrketräning och styrkemätning, som skriver sin kandidatuppsats. Du som deltar i projektet kommer genomgå test av maximal styrka i liggande benpress utfört på ett ben, enbensknäböj i Smith-maskin, ett balanstest på BOSU-boll, sprinttester på upp till 20 m samt ett agility-test. Under testerna kommer vi mäta testpersonernas sprint- och agility tider med hjälp av fotoceller och dataprogrammet MuscleLab, samt den maximala kraftutvecklingen i ett ben. Studien sker vid Friidrottens Hus, Göteborg.

Betydelse

Resultaten av denna studie ska ligga till grund för ökad kunskap om träningsmetoder för idrottsspecifika rörelsemönster.

Vad innebär medverkan i projektet?

All testning är kostnadsfri. Du kommer att kallas till sammanlagt två testtillfällen (beräknad tidsåtgång är ungefär 60-120 minuter per tillfälle). Tag med träningskläder (shorts och t-shirt) och gymnastikskor. Du kommer att få tillfälle att genomföra tester som är väldigt relevanta inom din idrott, med en högteknologisk och exklusiv testutrustning.

Du får inte genomföra någon ansträngande fysisk träning som involverar benmuskulaturen dagen innan testtillfället.

Lokal

Friidrottens Hus, Mikael Ljungbergs Väg 10, 414 76 Göteborg.

Fördelar och risker med att delta i studien

Risker

Att delta i studien kräver lite tid och uppmärksamhet från din sida, det krävs att du är tillgänglig vid två tillfällen. Testprotokollet som genomförs är maximala tester som kan medföra muskelsmärta (träningsvärk) dagarna efteråt. Testerna kan också uppfattas som ansträngande.

Fördelar

Du har möjlighet att delta i ett spännande och nytänkande forskningsprojekt som kan utmynna i ny kunskap om idrottsspecifik träning. Som deltagare har du möjlighet att ta del av information samt praktiskt utöva de senaste inom forskningen angående styrketräningsmetoder med hjälp av högteknologisk utrustning som annars skulle vara väldigt kostsamma att genomföra. Alla som deltar i studien kommer att vara anonyma i arbetet. Alla som deltar i studien kommer vid projektets slut få resultat av studien presenterat i form av ett utskrivet exemplar av examensarbetet. Dessutom är man välkommen att lyssna på vår presentation av projektet.

Rätten att avbryta medverkan i projektet

Deltagandet i projektet är helt frivilligt.

Om Du undrar över något är Du välkommen att ringa någon av oss i projektgruppen.

Idrottsvetenskapsstudent

Kristian Skarphagen, tel: 073-3447495

Idrottsvetenskapsstudent

Daniel Jansson, tel: 073-0568128

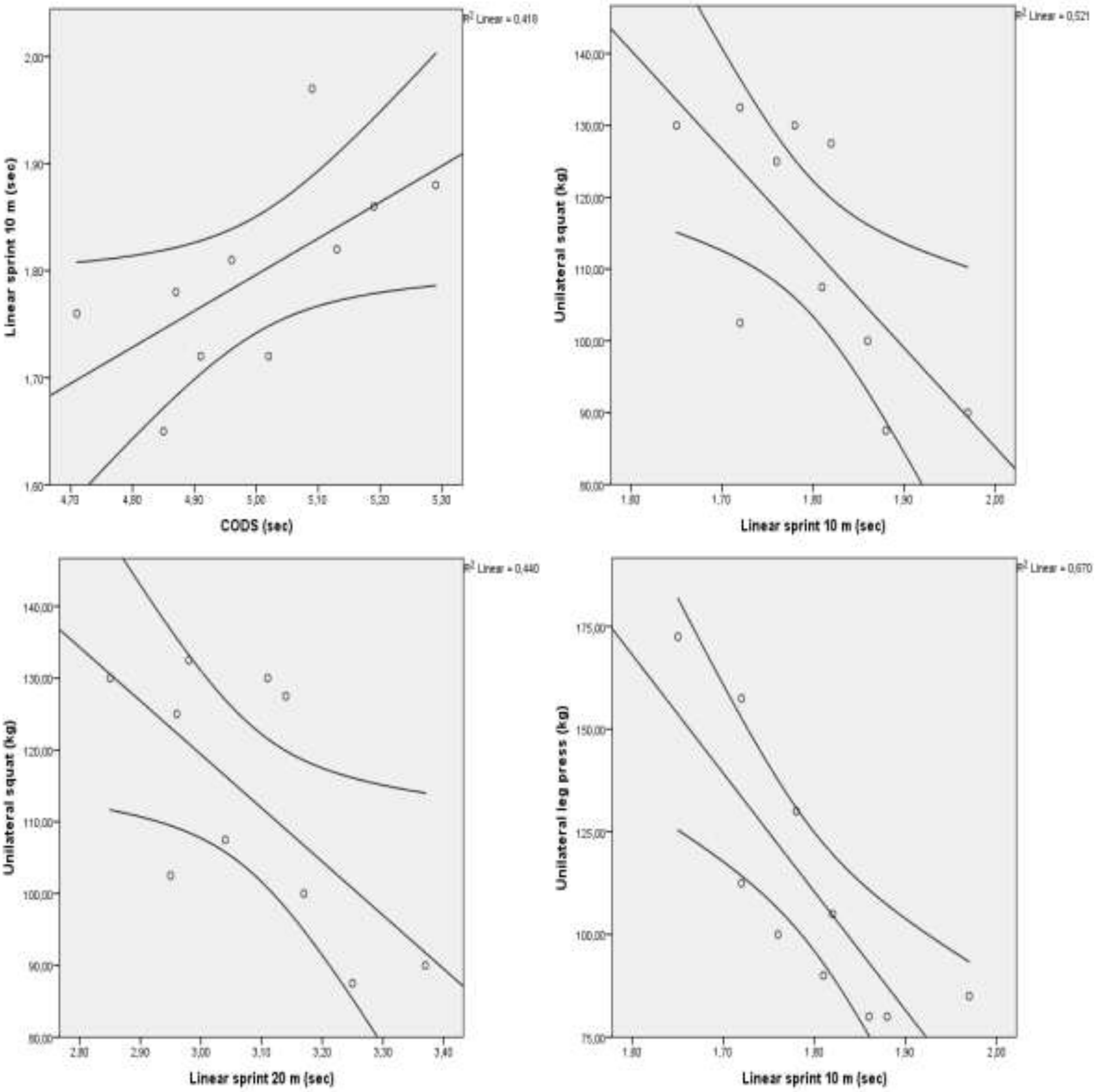
Idrottsvetenskapsstudent

Anton Arin, tel: 073-6728226

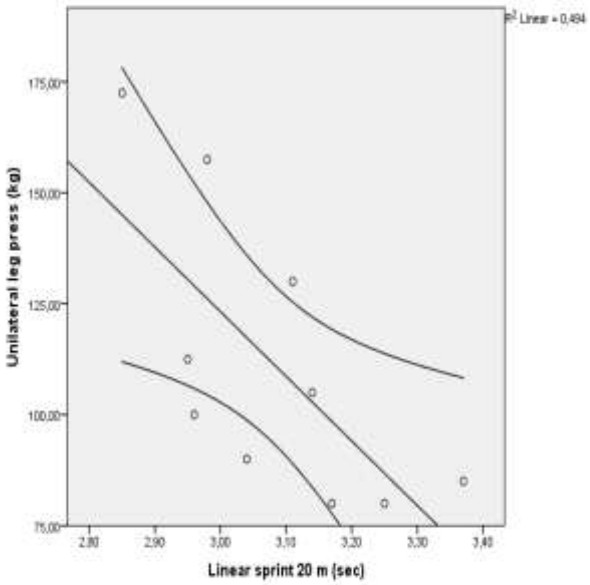
Leg. Sjukgymnast, med dr, handledare

Jesper Augustsson, tel: 031-7862237

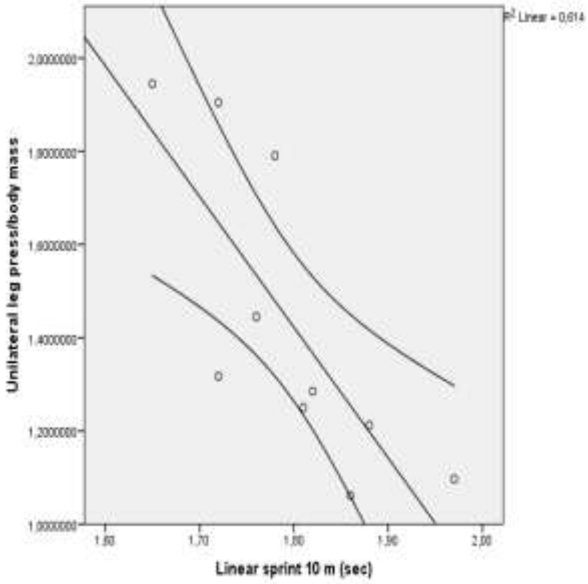
Figures for the soccer group, n=10 (absolute strength):

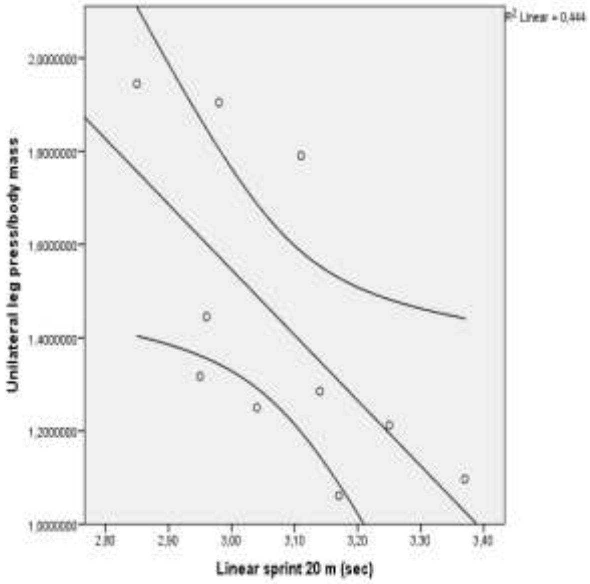


Figures 2(4)

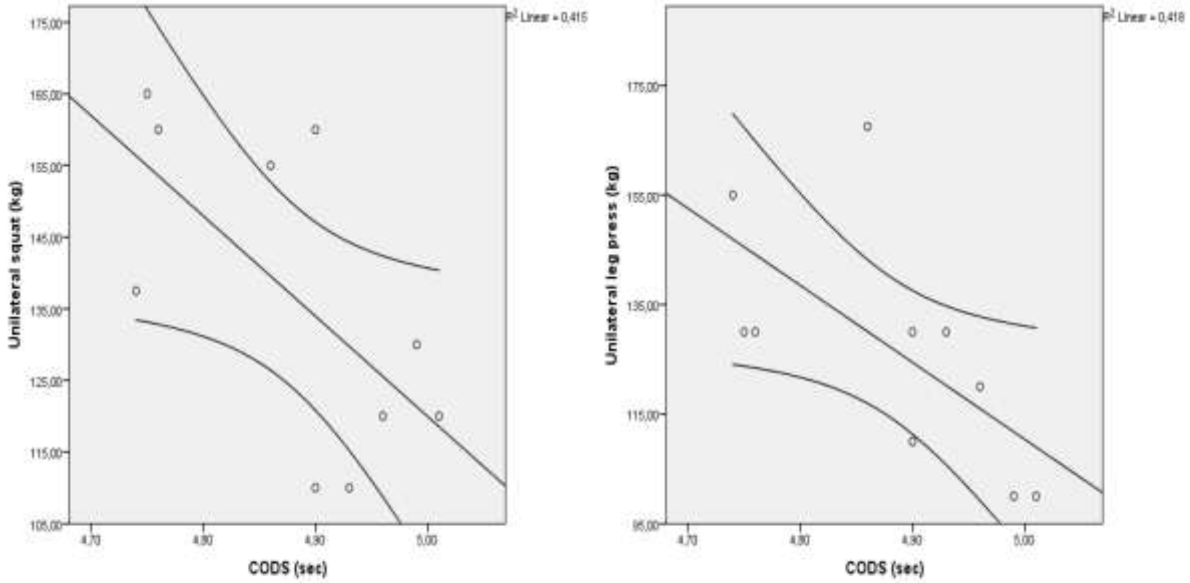


Figures for the soccer group, n=10 (normalized strength):

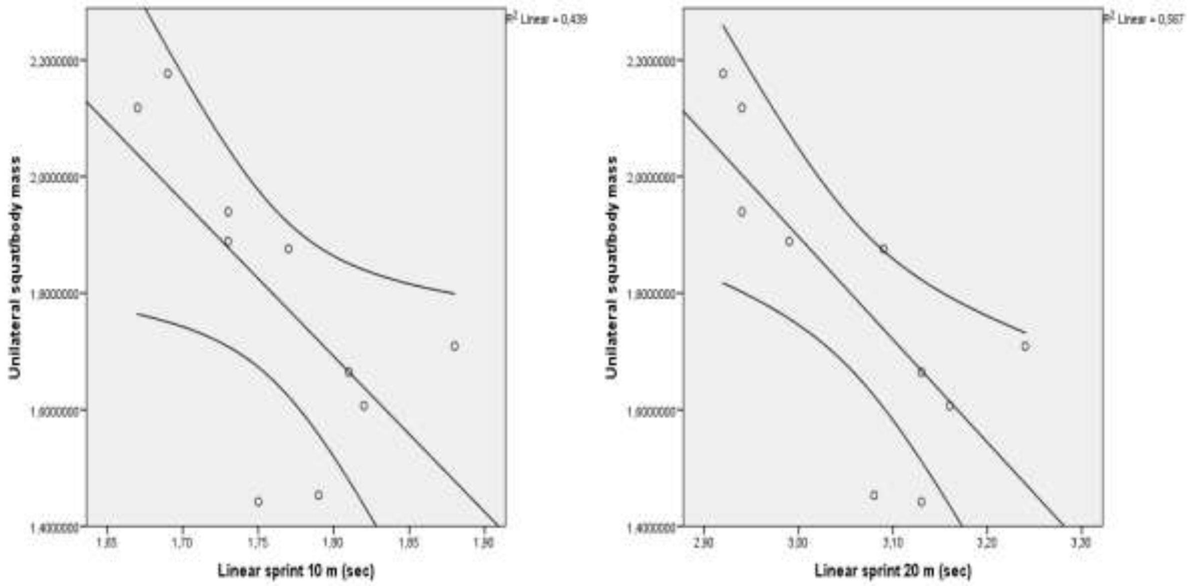




Figures for the ice-hockey group, n=10 (absolute strength):



Figures for the ice-hockey group, n=10 (normalized strength):



Figures for soccer and ice-hockey players, n=20 (normalized strength):