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Bilateral differences and relationship between rotational power and hand strength in young golf players

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Abstract

Background: Strength and power are important factors in many sports, and rotational power of the trunk and upper body are important components of golf performance. Trunk and pelvis cooperated in the rotation movement and strength in the muscles surrounding these segments is contributing to a successful and powerful rotation. Side-to-side asymmetry is often discussed in the field of injury prevention and it is suggested that bilateral imbalances affects the performance. Hand strength is a measure of diverse use when testing physical requirements in athletes. It has previously been concluded that hands strength correlates strongly with strength in both lower and upper extremity in youths, but the correlation among adults and athletes are unknown. In golf, hand strength has been stated to be one of the most important components for golf performance and it strongly correlates with golf specific variables such as ball speed and drivers distance. The relationship between hand strength and rotational power is unknown. ***Aim:*** The aim was to study rotational peak power and hand strength in young golf players to compare side-to-side differences and the relationship between rotational peak power and hand strength. ***Methods:*** Twenty-seven subjects, 22 men and 5 women, with a golf handicap of ≤5 participated in the study. The two tests performed was a hand strength test using a T.K.K handheld dynamometer and a rotational peak power test in Quantum. The tests were performed at the same session, first hand strength and then rotational peak power. In order to test the rotational peak power a 1RM test was performed. In order to study the relationship between hand strength and rotational power a Spearman´s range of correlation (r_s) was used. A Wilcoxon signed-ranked test was used to study the side-to-side differences between dominant and non-dominant hand strength and rotational power. ***Results:*** No statistical significant differences were found between dominant and non-dominant hand strength ($p = 0.28$) or between dominant and non-dominant rotational power ($p = 0.97$). A strong correlation between dominant hand strength and dominant rotational power was found ($r_s = 0.636$) and a moderate correlation between non-dominant hand strength and non-dominant rotational power ($r_s = 0.589$). ***Conclusion:*** There are no side-to-side differences in hand strength or rotational power in young healthy golf players. Dominant hand strength correlates strongly with dominant rotational power.

Introduction

Strength and power are important factors in many sports, and many sports require movement outside of the sagittal plane. Several sports require athletes to produce large power outputs where the athlete is expected to move his or her body or an external object very fast (Hamill & Knutzen, 2009). Rotational power of the trunk and upper body (henceforth referred to as rotational power) is considered an important component of performance for sports including swinging and throwing such as golf (Andre, Fry, Heyrman, Hudy, Holt, Roberts, Vardiman & Gallagher, 2012). Golf is a sport that has increased in popularity over the recent years, and with that the research for identifying physical requirements of the sport (Torres-Ronda, Sánchez-Medina & Gonzáles-Badillo, 2011). Strength around the hips and core and rotational power are essential factors contributing to an effective and successful golf swing, and previous studies suggest that side-to-side symmetrical strength among golf players is important for injury prevention (Lindsay & Vandervoort, 2014; Lindsay & Horton, 2006). The Swedish Olympic Committee (SOC) suggest that the term used when measuring the grip strength in athletes is hand strength, as opposed to handgrip strength which is the term often used in the literature. Henceforth the term hand strength will be used. As a measurement in athletes, hand strength is expressed with different views and opinions in the literature. In golf, hand strength correlates strongly with ball speed and drivers distance (Wells, Emli & Thomas, 2009). To the author´s knowledge no previous studies has examined the relationship between hand strength and rotational power and strength in any sport.

Background

Physical requirements in golf

Golf is a sport that requires power and precision to fulfil its purpose; to place a ball inside a small hole with the least amount of strikes as possible (Silva, Marta, Vaz, Fenrandes, Castri, & Pezerat-Correia, 2013). It is a demanding physical sport in terms of both precision and complexity and creation of explosive power though a wide range of motion (Wells, et al. 2009).

One of the most important factors of golf performance is the resulting combination of accuracy and driving distance. The most important factors influencing driving distance are skill, kinematics, shaft and club head characteristics, segmental sequence of action and reached power output (Torres- Ronda, et al., 2011). Development of strength and power has a positive influence on golf performance. Wells et al. (2009) investigated the correlation between total score and muscle performance in different vertical jumps, push- and pull-ups and grip strength and found significant correlation between all variables. The highest correlation to golf score was observed in grip strength, both in the dominant and non-dominant arm. Since golf is considered a rotational power sport, strength and power in the trunk and trunk rotation movement is important. Trunk rotation strength and power has been identified as the most significant factor in predicting swing speed (Torres- Ronda, et al., 2011). A strong trunk requires a strong core, and core strength (strength around the hips, pelvis and lower back) is essential to optimal performance in golf (Sell, Tsai, Smoliga, Myers & Lephart, 2007). To perform an effective golf swing the golfer needs to maintain a stable base (from lower extremities and pelvis) while rotating the mass of the torso, upper extremities and head. The higher rotational velocity of this mass, the greater strength of the core is required. Flexibility in shoulders, hips and torso along with balance are also characteristics essential to golf performance (Sell et al., 2007). Study results suggest that leg, hip and trunk power as well as grip strength are especially relevant to golf performance (Torres- Ronda et al., 2011).

Physiological variables and the kinematic sequence of the golf swing

The golf swing moves in a proximal to distal pattern where the motion starts in the heavier central body segments and then, as energy increases, the motion progresses outward to the smaller and faster segments. This sequence of motion is called the kinematic sequence, and is used to describe the transition- and downswing phase (Callaway, Glaws, Mitchell, Scerbo, Voight & Sells, 2012). The transition phase is the quick movement from backswing into downswing during which each body segment changes direction. The order of this change should, in a proper kinematic sequence, be; pelvis, thorax, lead arm and cub (Callaway et al., 2012). The power of the leg muscles rotates the pelvis forward, then the pelvis accelerates but quickly decelerates, and transfers energy to the thorax, which in turn accelerates and decelerates and transfers energy to the lead arm and ultimately the club. This order should continue throughout the downswing until the club impact with the ball (Callaway et al., 2012). The movement and power recruitment of the trunk therefore plays an important role in the golf swing. The trunk connects the lower extremity with the upper and affects the transfer of momentum from the legs to the arms (Okuda, Gribble, & Armstrong, 2010). Teaching professionals often seek to maximize rotation in upper torso during the downswing while minimizing rotation in the pelvis, creating a torso-pelvic separation (Myers, Lephart, Tsai, Sell, Smoliga, & Jolly, 2008). This separation demonstrates that rotation of the pelvis is not only a result of rotation in the torso, but also an involvement of the hips and the interaction between them are important for the torso-pelvic separation (Okuda et al., 2010). In golf the proximal to distal sequencing have been shown to play an important role in performance. Myers et al. (2008) found a moderate correlation between maximum torso and pelvic separation and ball velocity in golf players.

Rotational power and physiological variables

Strength and power

Strength is defined as the maximal force that a muscle or group of muscles can generate at a specific velocity (Beachle & Earl, 2008), and an athlete's capacity to produce high rate of fore development (RFD) is referred to as explosive strength, and is connected to the capability to acceleration (Cardinale, Newton, & Nosaka, 2010). Explosive strength is divided between two categories; dynamic and isometric. Dynamic explosive strength can result in high RFD and power outputs and isometric strength can result in an increased RFD and movement velocity (Cardinale, et al. 2010). Power is defined as *"'the time rate of doing work'", where work is the product of the force exerted on an object and the distance the object moves in the direction in which the force is exerted"* (Beachle & Earl, 2008, p.74). Power can be calculated as average power or instantaneous power, and is expressed as the product of force times velocity. The highest instantaneous value for power over a range of motion is peak power (PP) and the highest PP output that can be generated is expressed as maximal power (Cardinale, et al. 2010). Dynamic explosive strength and power are essential for athletes in several sports, and an athlete´s power output is most likely one of the most important factors for sport performance (Beachle & Earl, 2008). Power (Wells et al. 2009; Torres- Ronda et al. 2011), and especially rotational power (Doan et al., 2006; Sell et al. 2007) is an important factor in golf performance.

Rotational power

Sports that involve a swinging motion, such as golf, can be considered rotational power sports (Earp & Kramer, 2010). The rotational power is an important component in sports including rotation in the transverse plane, and rotational exercise is a sport- specific movement considering the velocity and range of motion used in the exercise (Andre et al., 2012), for example a medicine ball throw (Earp et al., 2010). It is vital for athletes in these sports to be able to create maximal angular velocity to successfully strike a ball (Earp et al., 2010).

The rotation movement and muscle activation

The rotation of the trunk is produced by muscle action on both sides of the vertebral column (Hamill & Knutzen, 2009). On the side to which the rotation occurs the multifudus muscles are active, as are the longissimus and iliocostalis on the other side. The abdominal muscles display a similar pattern where the internal oblique on the side of the rotation is active and the external oblique is active on the opposite side (Hamill & Knutzen, 2009). The pelvis and the trunk cooperate in movement, which is referred to as the lumbopelvic rhythm (Hamill & Knutzen, 2009). In rotation, the movement relationship between pelvis and trunk is equivocal since restriction in the movement may occur by the lower extremity. The pelvis rotates in the same direction as the trunk unless the lower extremity is forcing the pelvis to rotate in the opposite direction (Hamill & Knutzen, 2009). To create a stable base anterior stability is provided by rectus abdominis, internal oblique and transverse abdominis to aid in spinal stabilization, and posterior the ecrector spinae function to keep the upper body erect. The rotation is created and controlled by the external obliques along with the muscles of the hip and upper back (Shinkle, Nesser, Demchak, & McMannus, 2012).

During a swinging movement, such as the golf swing, the muscles triggers in a proximal to distal pattern. The order of the trunk muscles activation plays an important role in the organization of the proximal-distal sequence in order to transfer energy in explosive and precise motor tasks (Silva et al., 2013). In golf the kinematic sequence is of great interest, since the golf swing movement forces the pelvis to initially rotate in the opposite direction (Okuda, et al., 2010).

Side-to-side differences in rotation

The effects of bilateral strength imbalances are limited in the literature (Jones & Bampouras, 2010). Side-to-side differences among athletes are often discussed in terms of injury prevention. In the field of golf, Lindsay & Horton (2006) investigated the side-to-side differences in isokinetic rotational strength and endurance in control subjects, elite golfers without low back pain (LBP) and golfer with LBP. Although elite golfers without LBP tended to have greater axial rotation strength in the non-dominant rotation (left for right- handed players) compared with control subjects, they found no significant differences between dominant and non-dominant rotation within any group. The tendency for greater strength in the non-dominant rotation was even more apparent for players with LBP. In the rotational endurance test differences were found in non-dominant rotation between golfers with LBP and the two other groups, suggesting lack of endurance as a possible risk factors for LBP. In contrast to these results Bae, Kim, Seo, Kang and Hwang (2012) did find a significant side-to-side difference in isokinetic trunk rotation in fifty-one professional golfers, where the aiming side rotation was stronger. The difference between this study and the one by Lindsay et al. (2006) is in the degree/second the tests were performed. Lindsay et al. (2006) used 90deg/sec for the strength test and 180deg/sec for the endurance test while Bae, et al. (2012) used 30, 60 and 90deg/sec. This may contribute to the difference in result. Bae et al. (2012) also had a slightly larger group of test subjects than Lindsay et al. (2006) (51 vs. 33).

Sport specific demands may also result in development of side-to-side imbalance in muscle strength, as repeated asymmetrical movement increase the risk of overuse injury. In a study comparing spine motion in elite golfers with and without LBP, the golfers with LBP reported almost twice as much full swing practice and more rounds played per month than golfers without LBP (Lindsay & Horton, 2002), which may be another indicator that symmetrical training and strength is important in the practice of golf. Side-to-side differences should be prevented in rehabilitation programs, and golfers should be encouraged to practice swings in both directions (Lindsay & Vandervoort, 2014).

Symmetrical strength has been investigated in other rotational sports as well. Ellenbecker and Roetert (2004) found, when testing isokinetic trunk rotation strength in elite tennis players, that male players have symmetric trunk rotation strength. They suggest that symmetrical strength is an important factor in tennis and that conditioning programs for elite tennis players should include exercises to facilitate bilateral trunk rotation.

Hand strength

Activity of the hands is necessary in a many daily tasks and sport activities, and is vital in that sense. Muscles in the hand and forearm are important to grip strength (Monoharan, Sundaram & Jason, 2015). The forces in a power grip (as opposed to a precision grip) are exerted by the proximal and distal phalanges on one side, and the thumb on the other side, and both flexor and extensor muscles in the forearm are active in a grip (Hoozemans & Dieën, 2004).

Hand strength as measurement

As a measure of physical effort and capacity, hand strength has diverse use in the literature and the opinions whether or not it is a suitable measure for overall strength in healthy subjects and athletes are varied. Wind et al. (2010) investigated hand strength as a predictor of total muscle strength in children and young adolescents and found a strong correlation. They suggests that hand strength measurements are not just a measure of the strength of the hand, but is also an adequate measurement for generalized muscle strength in adults as well, since they found that hand strength was also associated with arm, back and leg strength in youths. On the other hand, Bohannon (2009) suggest that hand strength measured with a dynamometer only correlates with strength in the limb that is tested (upper extremity). Bohannon (2008) also suggests that the use of a single measure, such as hand strength, should be used with caution when talking about overall strength in any kind of population. To the author's knowledge and according to Bohannon (2009) there is a lack of information in the literature whether or not hand strength is a proper measurement among athletes to characterize overall strength. A not yet published study however aims to investigate this particular question, which will aid future studies in the area (Filingeri, Palma & Boanco, 2013).

In sport, hand strength is often used as a measure of association to sport specific tasks. In golf Wells et al (2009) found a strong correlation among male subjects between hand strength (dominant and non- dominant hand) and driver ball speed, driver distance, 5- iron ball speed and 5- iron distance. Strong correlation has also been found between hand strength and swing speed, and hand strength seems to be of great relevance to golf performance (Torres- Ronda, et al., 2011).

Side- to side differences in hand strength

The significance of the difference in strength between dominant and non-dominant hand is not clear. A general rule states that the dominant hand is 10% stronger than the non-dominant hand (Petersen, Petrick, Connor & Conklin, 1989). However, studies present different results and differences in handedness between left-handed and right-handed subjects. In right-handed subjects the dominant hand was significantly stronger while the left-handed subjects showed

no difference between the sides in a study by Incel, Ceceli, Durukan, Erdem and Yorgancioglu (2002). The same result was found by Özcan, Tulum and Baskurt (2004). Both studies used healthy subjects with no criteria of being physical active. A recently published study investigating the difference in hand strength between left- and right-handed athletes also found similar results. There was no significant difference in strength between the sides in the left-handed males, while the right-handed males and females showed a significant greater strength in right-hand strength (Ziyagil, Gürsoy, Dane, Türkmen & Cebi, 2015).
The difference in hand strength among golf players is to the author's knowledge unknown.

The importance of rotational power in golf and the perception of side-to-side symmetry as a prevention of injury supports the research aim and question in this study. The unknown fact regarding the difference between dominant and non-dominant hand strength in golf players and the significance of this difference supports the aim further. Hand strength is presented as an adequate test when correlating with golf specific measures, but there is a lack of information regarding the association between rotational power and hand strength in golf players. To evaluate this a newly validated rotation test and a well-known measure for hand strength was used.

Aim

The aim of this thesis was to study rotational peak power and hand strength in professional golf players to compare side-to-side differences and the relationship between rotational peak power and hand strength.

Research questions

- Is there a difference in rotational peak power and hand strength between dominant and non-dominant side?
- Is there a relationship between rotational power and hand strength on both dominant and non-dominant side?

Methods

This is a cross-sectional study analysing data from two different bilateral tests; a trunk rotational test performed in the Quantum and a hand strength test performed using a digital grip dynamometer.

Subjects

Twenty-eight healthy golf players both men (*n* = 23) and women (*n* = 5) mean ages 19 (SD ±2) years were invited to participate in the study. The inclusion criterion for participation in the study was a golf handicap ≤5. They had to be free from injury and illness for the time of the test. One subject had a golf handicap of 15, whose data was excluded from the analysis, leaving 27 subjects in the study (men *n* = 22, women *n* = 5). The subjects were recruited from Aspero Idrottsgymnasium in Halmstad and the Scandinavian School of Golf in Halmstad. All subjects were right-handed and all but one was right-rotator. Descriptive data of test subjects are presented in table 1.

Table 1. Descriptive data test subjects (*n*= 27).

	Mean (±SD)
Age	19 (±2)
Weight (kg)	76.20 (±10.57)
Height (m)	1.79 (±0.08)

SD = Standard deviation

Procedures

Both the hand strength test and the rotational power test took place at the same session. The participants attended to the laboratory at Halmstad University four at a time. The sessions took place between 8 am and 12 pm. Before the test the subjects were measured and weighed. The subjects performed a five minute warm up on an ergonometric cycle at a self-selected pace and resistance prior to the tests (Algotsson, 2016).

Hand strength using a grip dynamometer

The hand strength was measured with a digital grip dynamometer (T.K.K. 5401 GRIP D, Takei Scientific Instruments Co., Ltd. Japan) (figure 1). The dynamometer examines the static flexor power of the forearm and displays the maximum measured values in kilograms of each forearm (Takei Scientific Instruments Co., Ltd. Japan). When comparing the T.K.K dynamometer with a Jamar and DynEx, España- Romero et al (2010) found that the T.K.K had the lowest systematic error (0.02) of the three devices.

Figure 1 T.K.K. 5401 GRIP D handheld dynamometer. (http://www.takei-si.co.jp/en/productinfo/detail/49.html Retrieved 2016-03-22)

Procedures hand strength

The test was performed according to the Swedish Olympic Committee test descriptions, *Fysprofilen* (Testbeskrivningar Fysprofilen, 2016). Before the test, the dynamometer was adjusted to the subject's hand size. In standing position the subjects held the dynamometer in one hand with a flexed elbow. Both dynamometer and arm was held slightly away from the body, since it cannot touch the rest of the body or the floor. When the dynamometer was at waist height, approximately 90° elbow flexion, the subject started to squeeze the hand. During the squeeze the arm was straightened out and stopped when the arm was fully extended. If the subject failed to perform the trial correctly they were given another try. Two trials on each hand were measured and recorded, with no rest in between. The highest value of each hand was registered as test result (Testbeskrivningar Fysprofilen, 2016).

Rotational power test in 1080 Quantum

The rotational test was performed in a Quantum machine (1080Motion AB, Lidingö, Sweden). The Quantum is a cable machine made for testing and training with several different functions. It allows measures of force, speed and power. The adjustable arm in the machine can be locked in positions ranging from ground level up to 2.3 m and has a swivel pulley that rotates 360 degrees. The length of the cable is 5 m. In the concentric movement the load is adjustable from 0 - 50 kg and from 0 - 75 kg in the eccentric movement. The machine runs on a motor, which allows different resistance modes. With "normal weight" the machine acts like a normal cable cross machine which means that if the cable is pulled too fast a slack in the cable will result in the eccentric phase. With "no flying weight" the sense of inertia is the same in the concentric phase without slack in the cable at the turning point. The machine rewinds the cable very fast in the eccentric phase, which allows high speed and explosive movements without slack in the cable. The muscle tension is therefore the same in the concentric and eccentric phase (1080 motion AB, 2016). A 120 cm special made bar was used by the subjects to pull the cable (Algotsson, 2016).

Procedures rotational power

The rotation test in Quantum followed the procedures Algotsson (2016) used when validating the test. The Quantum power rotational (PRT) test showed a test-retest reliability of ICC 0.94 and Quantum 1RM rotation test (1RMRT) a reliability of ICC 0.98. PRT presented construct validity when correlated to medicine ball throw and sitting rotational test (r=0.8, r=0.52) as did 1RMRT (r=0.90, r=0.73) (Algotsson, 2016).

To standardize the execution of the movement a specific stance and grip are needed. Algotsson (2016) concluded in his study that the subjects´ height in centimetres divided by 3.3 is the optimal standardize stance width for this test, measured between the inner parts of the left and right heel. For testing of the right rotation the subject stands with the left side of the body towards the machine and vice versa. The bar was held with a straight arm at the end of the bar connected to the cable. The bar was placed horizontally under sternum and locked by the other arm by placing the lower part of humerus on the bar and with the hand of that arm grab the bar besides sternum. The subjects were instructed to keep their knees slightly bent and keep a straight vertical torso and then rotate as forcefully as they could until they pass the distal knee (figure 2). If needed, the heel of the foot closest to the Quantum was allowed to lift (Algotsson, 2016). If the subjects bent the arm, pulled from the hip or performed a golf swing movement the trial was not approved and they got another try after two minutes rest.

a) b)

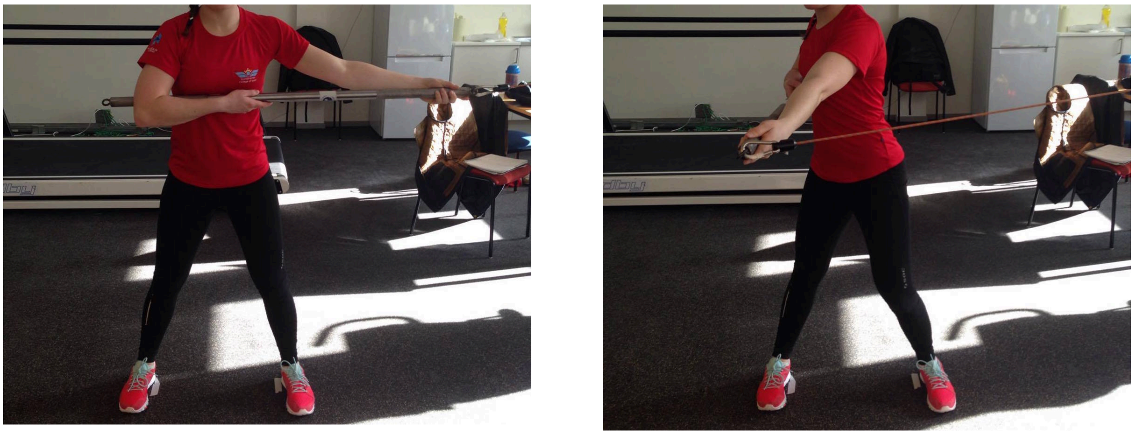

Figure 2. Start position with slightly bent knees, bar locked with humerus of one arm and the other arm straight (a), end movement when bar passed the opposite knee (b).

In order to test the average rotational power the one repetition maximum (1RM) must first be determined. Prior to the 1RM test a standardize warm-up was performed in the Quantum machine. First 10 rotations at 50% of estimated 1RM (in kilograms), to the right and left, followed by 8 at 60% 1RM, 4 at 80% 1RM and 1 at 90% 1RM (McBride, Haines & Kirby, 2011), with two minutes rest in between the sets. The estimated percentages were based on the participants' perceptions from the warm up session. This was followed by a five minute rest.

Rotational power 1RM

The subjects started with rotation at +1kg of the estimated 90% 1RM, in the same order as in the warm-up phase with two minutes rest in between the trials. Based on the subject's perception of the effort, the resistance were increased with 1 or 2 kg until they could not perform an approved attempt. If the subject failed due to poor technique, but still felt they could manage the weight they had one more attempt.

Rotational peak power test

The rotational peak power test was performed at 50% of the subjects´ 1RM. They were instructed to rotate as forcefully as they could. Three trials were made in each side with two minutes rest in between. Data from all three trials was recorded, but only the highest peak power value was selected for the analysis (Algotsson, 2016).

No order was set beforehand on which side the subjects started their rotations. If the subject started with a left rotation in the warm up session, all following sets started with a left rotation and vice versa.

Ethical considerations

Before participation each subject were given written information about the study and the tests. Each subject signed an informed consent (appendix 1) prior to their participation, in order to show their understanding of their involvement in the study. According to Datainspektionen (u.å) a person under 18 years of age (a minor) can give his or her consent as long as he or she is capable of understating the meaning of the consent. A person who has turned 15 years is generally able to have an opinion on the consent (Datainspektionen, u.å.). The coaches approved the subjects´ participation in the study.

At the time for the test the subjects received verbal information about the test and were offered to ask questions about the study and procedures, verbally or by email. All subjects had to have a golf handicap of ≤5 and to be free from illness or any injury that might inhibit the rotation movement or hand squeeze or influence the results due to reduced performance. Participation in this study meant no increased risk compared to their regular training. Participation in the study was optional and the subjects had the right to not complete their participation without any given reason.

Privacy and confidentiality of the subjects' results and personal information was upheld during the study. All analysis and results was performed and presented on a group level to ensure confidentiality.

Social considerations

The present study was based on current knowledge of upper body rotation, the mechanics behind a golf swing and hand strength. Due to the repetitive motion of upper body rotation in golf, the knowledge of side-to-side balance in rotational strength and power would be considered important for athletes and coaches to implement in both training and rehabilitation programs. The difference in strength between dominant and non-dominant hand in golf players has to the author´s knowledge not been investigated. This study will increase the knowledge about golf players' symmetrical strength in both rotation and hand strength.

Since not only professional golf players practice the sport this knowledge will possibly increase the health and training for not only professional players but recreational players as well.

Statistical analysis

In order to determine whether a parametrical or non-parametrical test should be used, a Shapiro-Wilks test was performed. The test demonstrated that the data did not fulfil the requirements for normal distribution (p >0.05) and non-parametrical tests were used. To examine the relationship between rotational power and handgrip strength a Spearman´s range of correlation (r_s) was used. The reference values for strength of the correlation was set to; low ± 0 to ± 0.4, moderate ± 0.4 to ± 0.6 and high ± 0.6 to ± 1.0 (Thomas, Nelson & Silverman, 2011). To analyse the differences between dominant and non- dominant upper body rotational power and hand strength a Wilcoxon signed- rank test was used. Statistical significance level was set to p = ≤0.05. The results are presented as range and median, but also mean and standard deviation (SD) in order to enhance the comparison with results from previous studies. SPSS Statistics 20 was used for the statistical analysis (IBM, Armonk New York, USA).

Results

27 subjects, 22 men and 5 women, completed the two bilateral tests in this study; a hand strength test and Quantum power rotational test.

The range in hand strength in dominant hand was 27.6- 64.5 kg and 29- 69.1 kg in non-dominant hand. The median value for both dominant and non-dominant hand were 47.3 kg. 1RM in dominant rotation ranged between 9- 25 kg and 9- 22 kg for non- dominant rotation. Median value was 15 kg in both directions. Maximum peak power in 1RM ranged between 152- 891 W with a median value of 233 W in dominant rotation and 90.1- 1043 W with median value of 262 W in non- dominant rotation. The peak power values ranged between 404- 1587 W with median value of 658 W in dominant rotation and between 432- 1422 W in non- dominant rotation with median value of 691 W. All results are presented in table 2.

Table 2. Descriptive values for hand strength in dominant, non- dominant hand, 1RM and 1RM peak power in dominant and non- dominant rotation and peak power in dominant and non- dominant rotation for all subjects (*n*= 27) presented as range between minimum and maximum, median, mean and standard deviation, and significance level (*p*) for Wilcoxon´s signed ranked test.

	Min- Max	Median	Mean (±SD)	*p*
Hand strength D, kg	27.6- 64.4	47.3	46.9 (±10.3)	0.28
Hand strength ND, kg	29- 69.1	47.3	46.4 (±10.2)	
1RM D, kg	9- 25	15	14.5 (±3.1)	
1RM ND, kg	9- 22	15	14.3 (±2.7)	
1RM peak power D, W	152- 891	233	354.2 (±225)	
1RM peak power ND, W	90,1 – 1043	262	371.8 (±265.7)	
Peak power D, W	404- 1587	658	750.1 (±284.3)	0.97
Peak power ND, W	432- 1422	691	754 (±287.2)	

D= dominant, ND= non-dominant, SD = standard deviation.

Side-to-side differences in rotational power and hand strength

To analyse the side differences in rotational power (expressed as peak power, W) and hand strength (kg) a dependent Wilcoxon´s signed-rank test was made. The difference in strength between dominant and non-dominant hand was not statistically significant (*p*= 0.28). The difference in peak power between dominant and non- dominant rotation was not significant (*p*= 0.97).

Relationship between rotational power and hand strength

Dominant hand strength had a strong positive relationship with rotational peak power in dominant direction (r_s= 0.636, *p*= 0.000). The linear relationship between dominant hand strength and dominant rotational peak power is shown in figure 2. Non-dominant hand strength had a moderate positive relationship with peak power in non- dominant direction (r_s= 0.589, p= 0.001). The linear relationship between non-dominant hand strength and non-dominant rotational peak power is shown in figure 3.

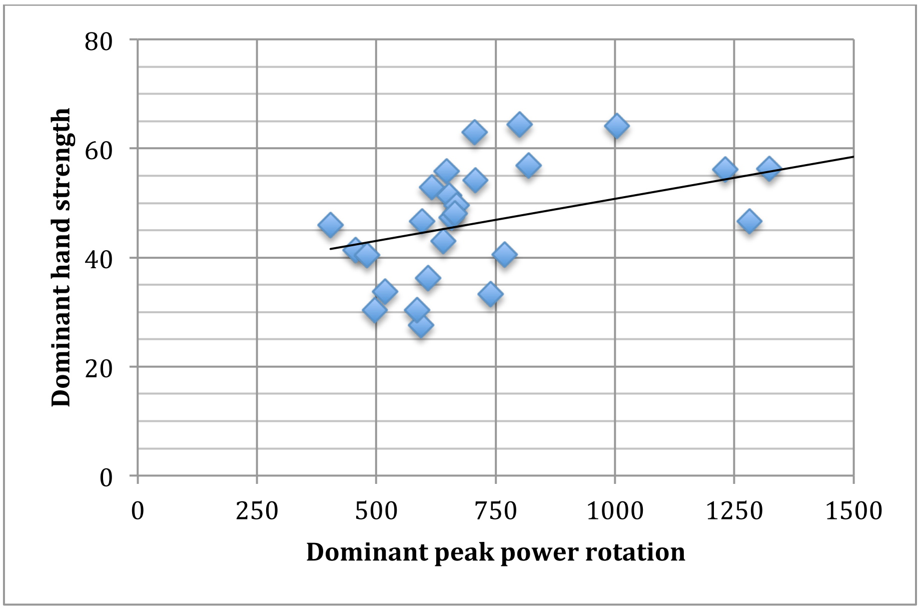

Figure 2. Linear relationship between dominant hand strength and dominant peak power rotation, r_s 0.636.

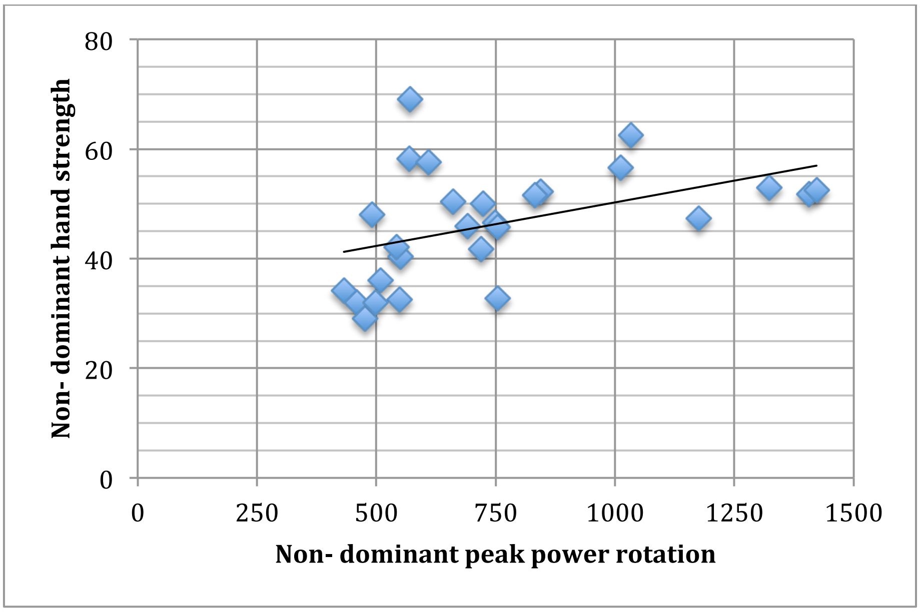

Figure 3. Linear relationship between non-dominant hand strength and non-dominant peak power rotation, r_s 0.589.

Discussion

The aim of this study was to investigate the side-to-side difference in hand strength and rotational power and the relationship between the two variables in young golfers. The findings reveal a similar bilateral strength in both hand strength and rotational power in the subjects. Dominant hand strength correlates strongly with dominant peak power rotation and a moderate correlation was found between non-dominant hand strength and non-dominant peak power rotation.

Result

Side-to-side differences in rotational peak power

Peak power rotation showed no significant difference between dominant and non-dominant side (p= 0.97), reflecting findings from previous studies. Lindsay et al. (2006) investigated the isokinetic rotational strength and endurance in professional golf players, with and without low back pain (LBP) and a control group of healthy non-golfers. They found no significant side-to-side differences in peak torque between dominant and non-dominant rotation within any of the groups (control: p = 0.59: control golfers: p = 0.26; golfers with LBP: p = 0.25). They did not find any differences between dominant and non-dominant rotation endurance either (control: p = 0.38; control golfers: p = 0.45; golfers with LBP: p = 0.66) (Lindsay et al., 2006). Even though the present study analysed the rotational peak power and not strength, strength and power are linked since strength is essential for power output (Cardinale, et al. 2010), and therefore the results may reflect each other.

It has earlier been hypothesized that the rotational peak power would be greater in dominant direction, since golf is a unilateral sport and the majority of rotation occurs in the dominant direction (Lindsay et al., 2006; Bae et al., 2012). Lindsay et al. (2006) found no statistically significance in side-to-side differences in either group, but does discuss a slightly trend in asymmetry among the golfers with and without LBP. They discuss their findings to be due to the possibility that the eccentric forces on the dominant side helps facilitate concentric strength development of the same muscles, since powerful eccentric contractions on the dominant side are also required to decelerate of the torso during the follow-through of a golf swing. Whether or not a trend may be detected in the present study is problematic to argue for, since the number of test subjects was fairly low. A larger group of test subjects may detect whether a trend in asymmetry exists or not.

Lindsay et al. (2014) suggest that side-to-side symmetry is preferable for injury prevention. All subjects in the present study were all free from injury and the results may therefore be considered positive from an injury prevention point of view. The subjects in the present study were also high level athletes, who perform varied training for the whole body on a weekly basis, which could contribute to the non-significant statistical difference in rotational power found in this study.

It can be discussed whether the difference is of clinical relevance or a type II error is at hand (Bhardwaj, Camacho, Derrow, Fleischer, Alan & Feldman, 2004). A larger group of subjects could result in greater side-to-side differences, as the case in Bae at al. (2012). They found a significant difference in isokinetic rotational strength between dominant and non-dominant direction, where the aiming side rotation was stronger. They used 51 professional golfers for their study. However, the subjects in Bae et al. (2012) were all Korean golfers. How the training for professional golfers differs between countries and cultures are to the author´s knowledge unknown.

Side-to-side differences in hand strength

The side-to-side difference in hand strength between dominant and non-dominant hand was not significant, which indicate a similar strength between the two hands among the subjects. When comparing the median and mean values between the dominant and non-dominant hand the findings are almost equal. Özcan et al. (2004) found a significant greater strength ($p<0.05$) in the dominant hand among the right-handed subjects, which is in conflict with the findings in this study. However, the subjects in the study by Özcan et al. was randomly selected and they did not record whether the subjects were physically active or not. The study of hand strength in athletes by Ziyagil et al. (2015) found, in common with Özcan et al., no difference between dominant and non-dominant hand in the left-handed group but a greater strength in the dominant hand in the right-handed group. However, Ziyagil et al. (2015) did not specify which sport was represented for each group, which could affect the results since handball and basketball players are known to have a great strength in their hands (Visnapuu & Jürimäe, 2007)). The left-handed group in the study was also smaller than the right-handed group (15 vs. 253 in females and 87 vs. 1147 in males), which might indicate a type II error in the study by Ziyagil et al. All subjects in the present study were right-handed and no comparison could be made between right- and left-handed subjects. Due to the low number of female subjects in the present study, no comparison between the sexes could be made. Another study, performed on 149 volunteers, also found greater strength in the dominant hand in the right-handed group and no significant difference in the left- handed group (Incel et al., 2002). They conclude that the "10% rule" (Petersen et al., 1989) cannot be used to generalize hand strength. The result from the present study further indicates that the 10% rule cannot be generally applied. The fact that the subjects in the present study all are high level athletes may contribute to the results in hand strength as well.

Relationship between hand strength and rotational peak power

The relationship between dominant hand strength and dominant rotational peak power was strong. There are, to the authors´ knowledge, no previous studies made investigating this relationship in any sport. However, a study by Doymaz and Cavlak (2007), examined the relationship between handgrip strength and trunk muscle endurance (among other tests). They found weak correlations between handgrip strength and trunk muscle endurance in the female subjects (curl-up, r = 0.083; horizontal side bridge, r = 0.182) and positive good correlations in male subjects between handgrip strength and curl- up and side bridge (curl-up, r = 0.319; horizontal side bridge, r = 0.307). The authors did however not set any reference values for strong or weak correlations and the results should be observed with caution. A rotation is produced by muscles in the trunk (Hamill & Knutzen, 2009; Shinkle et al., 2012) and trunk muscle strength is an important factor for golf performance (Doan et al., 2006; Sell et al., 2007). Core strength and rotational power are interrelated. After an 11-week training program, including exercises for strengthening the core, Doan et al. (2006) found an increased rotational power in the subjects. The findings from Doymaz et al. (2007) may therefore be compared to the findings in the present study.

Hand strength is suggested to be (along with leg, hip and trunk power) especially relevant to golf performance (Torres-Ronda et al., 2011), and has been used as measurement in relationship with other golf related measures. Wells et al. (2009) found a good correlation among male subjects between handgrip strength (in both dominant and non-dominant hand) and driver ball speed (r = 0.65), driver distance (r = 0.64), 5- iron ball speed (r = 0.60), and 5-

iron distance (r = 0.60). These findings may be comparable with the results in the present study, since ball speed and driver distance are results of a golf swing, i.e. a rotation.

Method

Hand strength

Hand strength as measurement is a reliable test and easy to perform (Innes, 1999). The hand strength test used in this study is a well-known instrument in the field of strength testing in both athletes and non-athletes and the procedures in this study was performed according to the procedures used by The Swedish Olympic Committee (SOC). España- Romero et al. (2010) performed a validity and reliability test on three different handheld dynamometers; Jamar, DynEx and the T.K.K used in this analysis. They performed a criterion-related validity test (dynamometer vs. known weights) and a reliability test (repeated measurements) using known weights, ranging from 20- 70 kg, held with a rope from the centre of the handle of the dynamometer. The bias and limits of agreement for the T.K.K dynamometer was 0.49 ($p <$ 0.05) and 1.32 respectively for the validation. The reliability test showed a systematic bias of 0.02 ($p < 0.05$) and the limit of agreement was 1.57, leaving the T.K.K dynamometer with the lowest systematic error (0.02). España- Romero et al. (2010) also concluded that the most appropriate position of the elbow is in full extension when performing a hand strength test. Since the procedures in this study followed the guidelines made by SOC, and the subjects did move the elbow to full extension during the test, the procedures in this study should be considered appropriate.

Previous studied has found that activity-specific warm-ups, in form of submaximal grips, have resulted in increased hand strength (Innes et al., 1999). Such a warm-up was not performed in this study. Since it was not the magnitude of strength that was examined in this study it is unclear whether an activity-specific warm-up prior to the hand strength test would affect the results.

Rotation test in Quantum

The rotation test in Quantum is a recently validated test for upper body rotational power and strength (Algotsson, 2016). The test-retest reliability for both the Quantum rotational power test and Quantum 1RM rotational test was high (Algotsson, 2016) correspondingly to other rotational tests (Andre et al., 2012; Ikeda et al., 2009; Lindsay et al., 2006). The construct validity of the rotation tests in Quantum was tested against previously described but not validates tests, since there are no previous tests for rotational strength and power that has been investigated for validity (Algotsson, 2016). Algotsson suggests that the test should undertake further investigation for validity. According to the high values in both test-retest reliability and construct validity, and the fact that this is (to the author´s knowledge) the only standing rotational test for dynamic power and strength that has undertaken reliability and validity testing, the Quantum rotational test should be considered a suitable test for the present study.

There are limited studies that compare the effect of bilateral muscle strength imbalances in terms of performance (Jones & Bampouras, 2010). Bilateral strength imbalances have traditionally been investigated by isokinetic dynamometry, as is the case in Lindsay et al. (2006) and Bae et al. (2012). This is also a time-consuming method, which require specialized equipment and is considered impractical for coaches and physiotherapists (Jones et al., 2010). Isokinetic dynamometry excludes the universal impact of qualities such as power and skill performance (Jones et al., 2010). The Quantum rotational test could therefore be considered a more sport-specific test for rotational strength imbalances, since the test allows the subject to move several body parts in the rotation as is done in most sports, for example golf.

Wells et al. (2009) executed the physical tests (vertical jumps, pull-ups, push- ups, abdominal strength and hand strength) continuously with at least five minutes recovery between the tests to minimize fatigue, which was the case in this study as well. Yet, the order of the execution of the tests could possibly affect the results. In order to test the rotational power a 1RM test had to be made. Fatigue from the 1RM test could have affected the results in the rotational power test, even if the subjects did rest in between the tests. Due to logistic reasons there was no time to execute the tests on different occasions. Though avoidance of these factors could have enabled the subjects to produce higher values, it is unknown how this would affect the results. If higher values were produced on both sides, a non-significant statistical difference could still be the result. Higher values in rotational peak power could affect the correlation with hand strength. These aspects should be considered for similar studies in the future.

Prior to the test session it was discussed whether the hand strength test or the rotational tests would be performed first. The author and supervisor decided that execution of the hand strength test first was the most optimal order, since it was believed that the hand strength test would affect the rotational tests less than the other way around. The rotational tests naturally require activity in more muscles than those in the hand and arm, and therefor the current order of the test was decided as the most suitable.

Even though it was asked of the subjects not to perform any hard training the day before the test session, it was unavoidable for some subjects since they had their ordinary golf training scheduled. This should also be accounted for when interpreting the results of the present study. Since the test sessions had to be set in the morning, due to opening hours of the laboratory, it was not possible to execute the tests during any other time of the day. The sessions had to be synchronized with the subjects´ attendance to the Halmstad Univerity facilities, which in all cases was in the morning.

In the present study a Spearman´s correlation coefficient was used to examine the relationship between hand strength and rotational power in dominant and non-dominant side. The coefficient of determination (r^2) could have been used to explain shared variance between the two variables. If calculating r^2 for the relationship between dominant hand strength and dominant rotational power, a shared variance of 40% ($r^2 = 0.40$) is detected. If calculation the r^2 for the non-dominant variables a shared variance of 35% ($r^2 = 0.35$) is shown. With this in mind, the reference values set for correlations in this study might have been set to low. When investigating correlations in such as small group (*n*=27) a shared variance higher than 40% would have been more satisfying for a strong relationship. However, if a higher reference value was set the correlation may not have been strong. It is a question all researchers have to contemplate when designing a study and depends on the aim and the correlating variables at hand. For example, when examining the affect of a new type of medicine high reference values ($r \geq 0.9$) are required.

Conclusion

The conclusion of this study was that no statistical significant differences exist between dominant and non-dominant hand strength and between dominant and non-dominant rotational power in young healthy golf players. The study also concludes that there is a strong correlation between dominant hand strength and domain rotational power in the same group. This study will aid further knowledge to the research in bilateral imbalances among athletes and to the research regarding the application of hand strength test among athletes. Future research should include a larger subject size in order to confirm or reject eventual type IIerrors. Investigation of the possible differences between men and women should be done as well. The tests should also be made in other rotational sports as well, in order to detect any differences in hand strength and rotational power between different sports.

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Appendix

Letter of consent

Information till deltagare i studien ”Bålrotationskraft och handstyrka” samt ”Bålrotationskraft och Club Head Speed”

Hej,

Vi heter Lina Fleetwood och Sebastian Frennessen och läser sista terminen på Biomedicin - inriktning fysisk träning vid Högskolan i Halmstad. Vi skriver nu vår kandidatuppsats och undrar om du vill vara med i våra studier där vi testar rotationskraft i bålen, handstyrka och club head speed.

Syftet med studierna är att testa rotationskraft i överkroppen, på både höger och vänster sida, med hjälp av en ny träningsmaskin som heter Quantum. Eftersom rotationer i överkroppen är ett frekvent förekommande rörelsemoment i golf finner vi det intressant att testa detta på golfspelare. I Linas studie är syftet att testa handstyrkan för att se om det finns något samband mellan handstyrkan och rotationskraften, och i Sebastians sambandet mellan rotationskraften och club head speed.

Förfrågan om deltagande

Du tillfrågas eftersom du är golfspelare med handikapp ≤4 och studerar på Halmstad Högskola eller Aspero Idrottsgymnasium. För deltagande i studien är det önskvärt att du är skadefri och frisk, då detta kan komma att påverka resultatet. Önskvärt är även att du har avhållit dig från hårdare fysisk aktivitet 24h innan testerna utförs.

Tillvägagångssätt

Rotationstesterna och handstyrkan kommer utföras på Högskolan i Halmstad och kommer ta cirka 3 timmar i anspråk. Under testtillfället kommer du till att börja med få bekanta dig med utrustningen och utföra en generell uppvärmning på cykel. Därefter kommer ett maximalt styrketest i rotation utföras följt av tre försök/sida på 50% av din maximala styrka. Handstyrka kommer mätas på både höger och vänster hand. Club head speed kommer testas i Idrottshallen i samband med din vanliga träning.

Ditt deltagande i studien medför inga risker utöver din vanliga träning.

Frivilligt deltagande

Ditt deltagande i studien är helt frivillig och du kan när som helst avbryta ditt deltagande utan vidare motivering.

Sekretess

Största möjliga konfidentialitet eftersträvas i studien och ingen obehörig får ta del av materialet. Materialet förvaras så att endast vi som undersökningsledare har tillgång till det. All insamlad data kommer lagras på ett USB- minne och förvaras på Högskolan i Halmstad. Resultatet presenteras i två kandidatuppsatser vid Halmstad Högskola och då all data rapporteras på gruppnivå kan resultatet inte kopplas till någon enskild individ. Huvudman för studien är Högskolan i Halmstad. Du har möjlighet att ta del av resultatet om så önskas, kontakta då Lina Fleetwood eller Sebastian Frennessen (se kontaktuppgifter nedan)

Har du ytterligare frågor om studien så hör gärna av dig till oss, Lina eller Sebastian, enligt kontaktuppgifter nedan.

Vänligen,
Lina Fleetwood & Sebastian Frennessen

Ansvariga för studien är:

Lina Fleetwood
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Handledare:
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Samtycke till deltagande i forskningsstudien ”Bålrotationskraft och handstyrka” samt ”Bålrotationskraft och Club Head Speed”

Du ger nedan ditt samtycke till att delta studierna som ämnar undersöka rotationskraft i överkroppen, sambandet mellan detta och handstyrka samt club head speed. Läs igenom informationen noga och ge ditt medgivande genom att signera ditt namn nedan.

Jag medgiver att jag:

- Tagit del av informationen kring studien och förstår vad den innebär.
- Har fått ställa de frågor jag önskar och vet vem som är ansvarig huvudman om jag har ytterligare frågor.
- Deltar frivilligt i studien och förstår varför jag blivit tillfrågad
- Vet att jag när som helst kan avbryta mitt deltagande utan att ange orsak.

Jag intygar att jag läst den informerade samtycket samt tagit del av informationen kring studien. Jag förstår vad deltagande i studien innebär och jag ställer upp frivilligt.

Ort och datum____

Namn____

Underskrift____

I started my studies at Halmstad University fall of 2013. This is my final work in the program, and I am looking forward to practice all my knowledge in professional life.

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