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A comparison of peak trunk rotational power and club head speed in elite golf players

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Abstract

Background: Golf is a sport with a growing focus on the physical aspect of the game and its relationship to performance. Studies have determined a correlation between club head speed and performance in golf. Rotational power has proven to be an important factor for the club head speed. By examining the relationship between club head speed and rotational power, researchers has found that rotation power on the golfers dominant side have a moderate to high correlation with club head speed. Previous research has mostly investigated the peak rotational power on the dominant side. Furthermore, additional research is needed to examine the bilateral strength and its relationship to club head speed. *Aim*: The aim of this study was to examine the correlation between peak trunk rotational power and club head speed in elite golfers, and also to study the impact of bilateral rotational strength on club head speed. *Methods:* The study included 27 elite golf players (21 males, 6 females) age 19±2 years. The subjects attended two sessions where the first session included a club head speed test and the second session a rotation power test in the Quantum machine. The rotational peak power ratio (dominant/non-dominant side) were ranged from 1-27 (the closer to 1, the higher order) to study a linier relationship with club head speed. Spearman's nonparametric rank correlations coefficient (r_s) was used since the data was not normally distributed. *Results:* There was a moderate correlation between peak trunk rotational power on the dominant side and club head speed (r_s=0.58, p=0.01). The correlation between the peak trunk rotational powers on the dominant and non- dominant side was high, r_s=0.82 (p=0.01). There were no significant correlation found between the ranged rotational peak power ratio and club head speed (r_s=0.30, p=0.1). *Conclusion:* The current study found a slightly lower correlation between peak trunk rotational power and club head speed than found in earlier studies. The golfers in this study had symmetric strength in the trunk, other studies have shown that the rotational strength in golfer´s dominant side were higher than of the non- dominant side. The result of this study indicates that balance between the sides not necessarily has a relationship with how high the golfer's club head speed is. Future research is needed to analyze the quadratic correlation between ratio and club head speed on a more advanced level. The results of this study can, if validated, be used for further researching and understanding of club head speed and golf performance.

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Background

Until the middle of the 90s, golf players focused on the mental, technical and tactical aspects of the game. Strength training were avoided due to the reasoning that it could counteract flexibility (Wells, Elmi, & Thomas, 2009). Elite golfers of today, like Annika Sörenstam and Tiger Woods, changed that reasoning and reached the top world ranking by focusing on, among other things, being physically prepared. To become physically prepared the golfers need to train their flexibility, posture, strength, power, balance and core stability (Doan, Newton, Kwon, & Kraemer, 2006; Gordon, Moir, Davis, Witmer, & Cummings, 2009; Wells et al., 2009).
Golfers use different golf clubs and swings, with varied power, to orientate the golf ball through the golf course, using as few strikes as possible. The golf swing is a complex movement which involves the whole body. The momentum that is created by the golf swing transfers to the ball and propel it in the desired direction and distance. To generate as much power as possible in that transfer, the golfer's movement pattern of the golf swing requires a coordinated sequence of muscle activity (McHardy, 2005). Different studies have investigated the significance of rotational power in golf and all findings indicate that rotational power is important for the golf swing (Andre et al., 2012; M. Burden, Grimshaw, & Wallace, 1998; Meister et al., 2011).

Rotational power

A rotational motion is defined as when parts of the body moves through the same angle, without the same linear displacement (Hamill & Knutzen, 2009).
Trunk rotation is a fundamental movement that is included in humans every day activities. Walking, running, and most sports require rotation in the trunk. There are not many activities that can be accomplished without rotating the trunk (Andre et al., 2012; Kumar, 2002; McGill, 2010). The core, also called the lumbopelvic-hip complex, comprises of a series of muscles in the trunk, hip and lower back who work together as a unit to stabilize the body. A stabilized core means an increased ability to maintain structural control and limit displacement in the lumbopelvic-hip complex (Willson, Dougherty, Ireland, & Davis, 2005), which has become of great importance in golf players physical training (Wells et al., 2009). These muscles also help the body generate and transfer energy from larger body parts to smaller (Kibler, Press, & Sciascia, 2006). It is the core that generates power to all limb movements (Kibler et al., 2006). The core is the connection between the upper and lower extremities that are essential for the transference of force through

stiffening (Winqvist, & Grenzdörfer, 2013). McGill, (2010) described the core as the lumbar spine, m. quadratus lumborum, m. latissimus dorsi, psoas, the gluteus muscles, the back extensors and the muscles of the abdominal wall combined.

According to Willson et al (2005) no muscle individually contributes >30 % of the stability of the lumbar spine. That leads to the conclusion that the stability of the lumbar spine comes from the activation off all core muscles together, rather than only a few particular muscles at a time. Additionally, those are the muscles necessary for rotating, and thus performing a golf swing Gordon et al., 2009.

The golf swing and rotational power

The golf swing generates force from the rotational power (Bae, Kim, Seo, Kang, & Hwang, 2012). A skilled golfer initiates the golf swing by rotating the upper torso, arms, wrists, hands and club simultaneously away from the address position followed by rotating the pelvic, creating a backswing. The downswing starts with the pelvic rotating back to the start position, followed by a rotation in the upper torso and the movement of the upper extremities and club (Myers et al., 2008). To generate increasing speed to the golf club in the down swing phase, the lower body´s weight have to be shifted. M. Latissimus dorsi, m. pectoralis major and the rotator cuff have to be activated (Bae et al., 2012). The mainly associated active muscles in the trunk in the down swing phase are external oblique of the aiming side and latissimus dorsi and internal oblique of the non-aiming side (Bae et al., 2012). Ligaments, muscles, discs and joints of the lumbar spine are the structures influenced by the forces, created by the golf swing (Bae et al., 2012).

Studies have shown a strong correlation between the rotational power of the core musculature and club head speed (Torres-Ronda, Sánchez-Medina, & González-Badillo, 2011). According to Jönsson & Söderström, (2014) rotation power and its correlation to club head speed is interesting to investigate due to its similarity to the golf swing, with its sport specific components. In previous studies rotation has been measured mostly on the dominant side, and information concerning bilateral strength and its importance for club head speed is lacking.

Physiological variables and golf performance

Two important physiological variables for golf players are strength and power. Strength and power can determine if an athlete will succeed or not (Cardinale, Newton, Nosaka, 2011, p. 349). Strength has been defined as the ability to produce force. Power can be defined as the product of force and velocity, and is the rate of doing work, and is measured in Watt (W) (Cardinale et al., 2011, p. 107). Strength is a term that designates an athlete's ability to exert maximal force on the environment. Force is explained as that which tends to change or changes the state of motion or rest in matter and is measured in Newtons (N) (Komi, 2008, p. 3). The force magnitude depends on both selected movements like arm flexions, but also on a numerous characteristics of the chosen motor task like movement velocity and body posture (Komi, 2008, p. 439). Power can be determined for both a single body movement, a series of movements and repeated movements. It can be determined instantly in a movement at any point. Power can also be averaged for any fragment of a movement or exercise (Komi, 2008, p. 3).

An athlete's explosive strength is linked with the ability to generate high rate of force developments (Cardinale et al., 2011, p. 349). Additionally, this is related to the athlete's acceleration capabilities (Cardinale et al., 2011, p. 349). Rate of force development reflects the neuromuscular systems ability to produce very steep increases in muscle force within parts of a second at the onset of contraction. This has important functional significance for the generating of power and force during forceful and rapid movements (Cardinale et al., 2011, p. 349).

Dynamic and isometric are the two types of explosive strengths. Dynamic explosive strength can result in high power production and high rate of force development. Isometric explosive strength can produce an increased movement velocity and rate of force (Cardinale et al., 2011, p. 349).

According to Jönsson & Söderström (2014) the athlete's ability to produce strength and power is highly correlated with the performance. Power can be calculated as instantaneous or average power. The highest instantaneous value for power found over a range of motion is expressed as the peak power (PP). When peak power is generated under perfect conditions, the highest power output can be expressed as the maximal power (Cardinale et al., 2011).

Strength and power are two important variables when measuring a golfer's club head speed. An increased physics lets the golfers rotate faster and more forcefully, which increase the club head speed (Turner, 2016; Fletcher et al., 2004). Several studies have examined the effects of strengths and power on club head speed (Doan et al., 2006). Doan et al. found that 11 weeks of physical conditioning increased club head speed. Additionally, the study by Fletcher et al. (2004) found that following an 8 week weight plyometric training intervention improved club head speed.

Club Head Speed

Club head speed has been defined as the body's ability to develop and transfer speed to the golf club head, and making it travel through contact with the ball (Fradkin, Sherman, & Finch, 2004; Hume, Keogh, & Reid, 2005; Turner, 2016). Club head speed is a common method to measure performance and has been proven to be an essential factor to the balls displacement during a golf swing (Fletcher & Hartwell, 2004; Fradkin et al., 2004). The golf drive is the swing which produces the highest power and acceleration (Hume et al., 2005; Lindsay, Horton, & Paley, 2002; Turner, 2016). An important variable for increasing club head speed is muscle power. To adapt a greater muscle strength, and thus higher club head speed, strength and plyometric training programs can be used (Fradkin et al., 2004). Previous studies have shown a strong correlation between handicap in golf and both muscle strength and club head speed, a lower handicap correlates with higher velocity (Fradkin et al., 2004; Hellström, Hälsoakademin, & Örebro, 2009; Jönsson & Söderström 2014). An increased club head speed can lead to a higher initial ball speed, longer striking distance and lower scores which are connected to better performance in golf (Wells et al., 2009). As previously stated, a players club head speed correlates with rotational power (Torres-Ronda et al., 2011). There are some different variables for increasing club head speed, and one important variable is muscle power. If the golfer wants to increase his club head speed to further increase the performance, he should therefore focus on increasing his mucle power. The knowledge about club head speed and its correlation to performance made it interesting to further investigate what is needed to develop a higher club head speed. It rasies the thoughts of wheather higher muscle power in both the dominant and non.dominant side leads to a better club head speed than golfers who only have trained muscles on their dominant side.

How to measure rotational power

Several studies have measured rotational power in the trunk. Studies who investigated the relationship between rotational power in the trunk and club head speed has found the correlation to be high. Until recently, the medicine ball side throw (MBST) has been the standard test when measuring rotational power in the trunk and upper body (Gordon et al., 2009); Winqvist & Grenzdörfer., 2013). In recent studies, researchers have used MBST and other measuring methods such as seated cable torso rotation (SCTR) and Medicine ball rotational throw (MBRT) to examine rotational powers correlation to golf performance (Winqvist & Grenzdörfer, 2013;

Jönsson & Söderström, 2014; Read, Lloyd, De Ste Croix, & Oliver, 2013). In a study by Winqvist & Grenzdörfer (2013) a standing medicine ball side throw and a seated cable torso rotation was used to measure correlations between rotational power and the golf swing. Their study showed a high correlation between club head speed and both MBST on the dominant side and SCTR on both dominant and non-dominant side. It also reported a high correlation between ball speed and both MBST and SCTR on the dominant side and on the non-dominant side. Jönsson & Söderström (2014) measured the correlation between club head speed and rotational power, measured with a medicine ball rotational throw (MBRT) on elite golf women. They found a high correlation between club head speed and MBRT. Additionally, Read et al (2013) measured the correlation between club head speed and MBRT and also found a high correlation. In a recent methodological study, Algotsson (2016) tested a new standing rotational power test using a Quantum machine and found it to be valid and reliable. The quantum rotational power test validated by Algotsson (2016) is a new test that has not been used for studying the relationship between rotation and club head speed. Ellenbrecker & Roetert (2004) tested the trunk rotation strength on elite tennis players with an isokinetic testing profile and found that elite level male tennis players did not have any large differences in trunk power. Bae et al (2012) measured the trunk rotation strength of Korean male professional golf players and found that the aiming side rotation strength of the golfer was higher than that of non-aiming side. Winqvist & Grenzdörfer (2013) measured golfer's rotational peak power on both dominant and non-dominant side and found that the sides are almost equally strong. Bae et al (2012) concluded that further studies were needed to investigate if strengthening of the trunk muscles (especially on the aiming side) could improve performance. No study known to the author of this paper have investigated the rotational peak power ratio between the dominant and non- dominant side on elite golfers and correlated it with club head speed. This could be interesting to further examine due to the fact that bilateral strength has been linked with enhanced performance in other sports, like tennis (Ellenbrecker & Roetert, 2004).

Aim

The aim of this study was to examine the correlation between peak trunk rotational power and club head speed in elite golfers, and also to study the impact of bilateral rotational power on club head speed.

Research questions

1. What is the correlation between peak trunk rotational power on the dominant side and club head speed in elite golfers?
2. What is the relationship between the bilateral peak trunk rotational power and club head speed?

Methods

A correlation study design was used, which consisted of a one-time measure on a single-group. The design was used to examine the rotation power and the club head speed in elite golf players, which were measured using a Quantum-machine and a TrackMan radar 3e.

Subjects

27 healthy subjects, 21 males and 6 females, with a golf handicap ranging from 5.0 to +2.8 were recruited for this study. Inclusion criteria were elite golf players with a golf handicap of 5 or better. A golfer's handicap in golf is a measurement of how skilled the golfer is. Usually, the higher skills a golfer has the lower handicap he gets. The golfer used in this study are elite golfers, and therefore many of them had a better golf handicap then 0, which is communicated as +. Exclusion criteria for the study were any musculoskeletal pain or any other health issue that may affect performance. The subjects all attended school of golf at Halmstad University or a sports upper secondary school and were recruited by personal invites. Descriptive data for anthropometrics is shown in table 1.

Table 1. Descriptive statistics for age, height, weight and handicap, (N=27)

	Median	Minimum	Maximum	Mean	Std. Deviation
Age (years)	18	16	23	18.9	2.2
Handicap	2	5	+2.8		
Height (cm)	180	161	192	179.2	8.4
Weight (kg)	76	55	107	76.2	10.8

1080 Quantum machine

1080 Quantum (1080Motion AB, Lidingö, Sweden) (figure 1) is a cable machine that has been validated for testing of the rotation power in a master thesis. The result of the study showed that

the studied rotation power test performed in the1080 Quantum machine is valid and reliable (Algotsson, 2016). Studying construct validity, Algotsson (2016) found a strong correlation between the quantum rotation test and standing medicine ball throw (r_s=0.80). The correlation between the Quantum power rotation test and sitting rotation test were moderate (r_s=0.52).
The 1080 Quantum is operated via a touch-screen (windows 8 or 10 as operation system) that controls the resistance modes, loads, speeds of the concentric and eccentric phases of movement. The Quantum machine can measure the average and maximum power, speed, force and endurance. The Quantum machine has an adjustable arm that can be placed from ground level and up to 2.3meters. The arm has a swivel pulley which is able to rotate 360∘. The max cable travel on the Quantum machine are 5 meters. The concentric velocity can be set from 0.1 to 8 meters per second. The eccentric velocity can be set from 0.1 to 6 m/s. The maximum concentric and eccentric load during 3 seconds is 75 kg. (1080 motion AB. 2016)


Figure 1. The 1080 quantum machine.

Testing procedures

The subjects attended two different test sessions. Session one measured club head speed and session two measured rotational power. The measuring of club head speed took place in a sports hall at Halmstad Univeristy. The rotation power was measured in the Human Movement laboratory at Halmstad Univeristy. The two sessions were separated to ensure that the results of the rotation test were not influenced by the club head speed test. The subjects were given at least

1 week between the tests. All the subjects were informed not to practice physical exercises in 24 hours before the testing-periods.

Testing session- Club head speed

Club head speed was measured using a TrackMan radar 3e (TrackMan A/S, Vedbaek, Denmark). A TrackMan software were downloaded and used on an external device to register the club head speed. TrackMan were positioned three meters behind an artificial tee. All subjects used the same type of club (Driver) and the same brand on the golf balls in the test. The subjects used their own driver when performing the test. The session began with a standardized warmup and then the subjects got a few light warmup golf swings, before the test started. Each subject stood on the artificial tee with their normal stance and was instructed to swing as fast as possible during each swing. The goal was to strike the golf ball with as much force and speed as possible (a straight shot with good aiming were not necessary). The golf ball was then caught and stopped by a net that was placed between the ceiling, walls and the floor in the middle of the sports hall. The first swing was a practice swing and were not regarded as a part of the result. After the practice swing the subjects made 5 repetitions with 30 seconds rest between each swing. Each subject was tested on their aiming side, which will be mentioned as dominant side in this paper. The highest value of all five swings were used for analysis (Gordon et al., 2009).

Testing session- Quantum rotation testing

The second session included the Quantum rotation test and began with a technical walk through of the rotation test. When the subjects properly understood the exercises, the session continued with a standardized active warm-up. After the warm-up, the subjects 1 repetition maximum (1 RM) in trunk rotation on both the dominant- and non-dominant side were determined by the 1080 Quantum machine. The subjects rested before they continued with the rotation power test.

Figure 2. Rotation test, left picture displays the starting position, and right picture the end position.

Rotation test instructions

The subjects were instructed to stand with a stance of a width of their height divided by 3.3, as it has proven to be the most effective stance for creating rotational power with this rotation test (Algotsson, 2016). Standing in this position, the subjects had the right side of the body towards the Quantum machine when rotating to the right and vice versa. The bar, connected to a cable, was held with both arms. The bar was placed and sealed right under sternum with the subjects upper arm´s lower part placed at the bar, simultaneously seizing the bar with the hand of the same arm next to sternum. The other hand held the bar at the end with the connected cable (Hellström et al., 2009)(figure 2). Standing in this position, the subjects were told to rotate their upper body as forceful and quickly as possible with their knees a little bent and an upright straight upper body. The subjects were told to rotate until the bar were in line with/passed the distal knee (figure 2). In this study, a custom-made bar was attached with a link to the end of the cable. When performing the rotation test in this study, the concentric velocity was set at 8 m/s to let the subjects rotate as fast as they could, and the eccentric velocity were set at 1 to prevent the cable from flicking back into the machine to fast. The load varied between the individuals and the power were measured in watt.

Rotation test-warmup

The warmup consisted of 5 minutes on an ergonomic cycle followed by some warm-up sets of the rotation exercise. The warm-up sets consisted of 10 repetitions on each side (dominant and non- dominant) with an estimated resistance (about 50 % of 1 RM). The subject then made 8 repetitions on each side with a higher estimated resistance (about 60 % of 1 RM). The subjects continued the warm-up with 4 repetitions on each side with a higher resistance (approximately 80 % of 1 RM). The warm-up ended with 1 repetition on each side with approximately 90 % of 1 RM. (McBride, Haines & Kirby, 2011) A two minutes rest period were given after each warm-up set and 5 minutes of rest (Lindsay & Horton, 2006) were given before the 1 RM test in Quantum machine.

Rotation test- measuring of 1 RM

The 1 RM in rotational power were measured by giving the subjects an estimated starting weight (estimated from the warm-up) on each side (dominant- and non-dominant). If the subject managed to do one correct repetition on one side, the resistance (the weight) were raised. On the Quantum machine, weights (resistance) could only be raised by a full kg. If the subjects got a 1 RM not able to divide by 2 (to get 50 % of 1 RM) the resistance were rounded downwards (For example: 50 % of 15 were counted as 7). This continued until the subject failed to complete a correct repetition three times. The sides where tested alternately. A 4 minutes rest between the attempts were given (McGuigan, Winchester & Ericksson, 2006).

Rotation test- power test

The power test was tested with 50 % of the subjects 1 RM (Algotsson, 2016). The subjects performed three trials with two minutes of rest in between. The peak power was measured and the highest peak power on the dominant and non- dominant side were used in the analysis. Additionally, the subjects did the test in both directions by first performing the test on the dominant side. After the test were completed on the dominant side, the subject had the other side of the body towards the machine, rotating the other direction to test the non-dominant side.

Statistics

Shapiro Wilks test showed that the data was not normally distributed ($p<0.05$). Spearman's nonparametric rank correlations coefficient (r_s) was used to examine the relationship between rotational peak power and club head speed. Descriptive data is presented with median, min and max, and mean and standard deviation (SD) for comparison reasons with previous literature. A rotational peak power ratio between the left and right rotational power was calculated. To investigate the linear relationship between power ratios and club head speed the values from the ratio were ranged between 27 and 1, were number 27 had the best balance between the sides and number 1 the worst. The reference values that were used for strength of correlation coefficient were ± 0 to ± 0.4 for low, ± 0.4 to ± 0.6 for moderate and ± 0.6 to ± 1.0 for high correlation (Thomas, Nelson & Silverman, 2010, p. 100). SPSS version 20.0 (SPSS Inc., Chicago, IL) was used to process statistics.

Ethical and social considerations

Ethical considerations

In this research the subjects were recruited with personal invites. The subjects were also made fully aware, that it is no obligation to attend the research because a request has been made. Furthermore the subjects were informed about eventual risks and benefits of the experiment without any judgment based on gender, ethnicity or other components (Connelly, 2014).
The subjects in this research were informed in written about the procedures and structure of the research before any decisions regarding declining or joining the experiment was made. All questions the subjects had were answered until each subject understood the research and their part of it. When the subjects accepted participation they signed a written consent. If the subjects wanted to leave the study, they had the right to withdraw from the research without any consequences (Connelly, 2014).

The procedures in this research were developed with the health and safety of the subjects in consideration, to minimize the risk of injuries in connection to the experiment. The subjects had access to their own results only. All personal information was safely stored and, the individual names and additional information were not published and all data was presented on a group level to further protect integrity.

Social Considerations

This research can contribute to more knowledge about the relationship between the golf swing and rotational power. The results can be used for further understanding for the complexity of the golf swing and may be used to develop new techniques for optimizing the golf strike. Additionally, the work creates opportunities to use this new test to train and evaluate rotational power to other sports specific skills within other sports.

Result

Descriptive data for club head speed, rotational peak power on dominant and non- dominant side and rotational peak power ratio shown in table 2. The difference in rotational peak power between the dominant and the non-dominant side were 3.9 W. Twelve subjects had a stronger dominant side while 14 subjects were stronger on the non-dominant side. One subject were equally strong between the sides.

Table 2. Descriptive statistics.

	Median	Minimum	Maximum	Mean	Std. Deviation
CHS (Km/h)	180	142	196	175.3	16.4
RPPDS (W)	658	404	1587	750.1	289.7
RPPNDS (W)	691	432	1422	754	292.7
Ratio (RPPDS/RPPNDS)	1	.7	1.4	1	.2

Descriptive statistics for club head speed (CHS), rotational peak power on the dominant side (RPPDS) and the non-dominant side (RPPNDS). And the rotational peak power ratio (rotational peak power on the dominant side/ rotational peak power on the non- dominant side). (N=27)

Club head speed and peak trunk rotational power

The correlation between club head speed and peak trunk rotational power on the dominant side was moderate, r_s=0.58 (p=0.01) and is shown in figure 3.

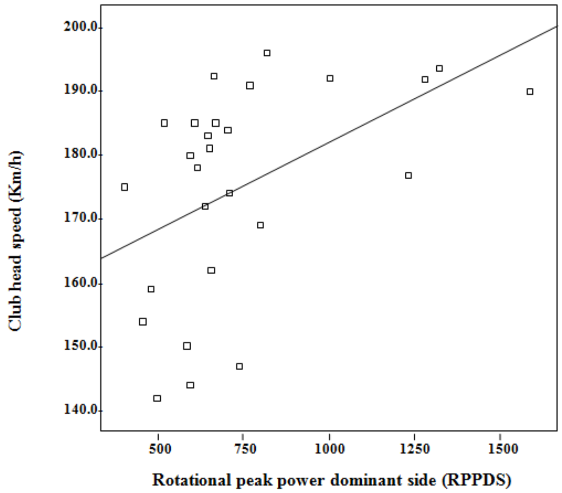

Figure 3. Correlation between club head speed and rotational peak power on the dominant side, r_s=0.58. (N=27)

Bilateral peak trunk rotational power

The correlation between the peak trunk rotational powers on the dominant and non- dominant side were high, r_s=0.82 (p=0.01) indicating a symmetric trunk rotational strength in many of the subjects (figure 4).

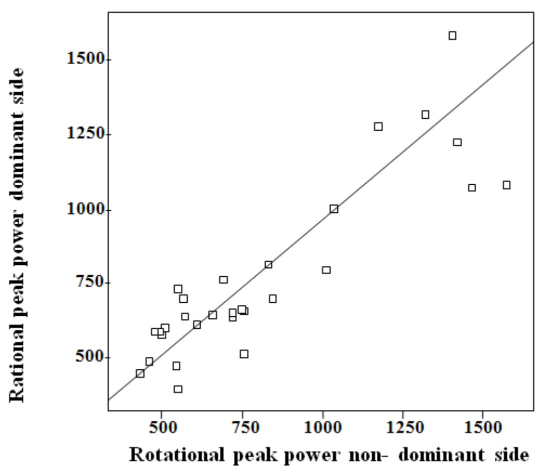

Figure 4. Correlation between the peak trunk rotational powers on the dominant and non-dominant side. r_s=0.82. (N=27)

The relationship between club head speed and rotational peak power ratio (RPPDS/RPPNDS), shown in figure 5, were ranged to investigate the linear relationship.

There were no significant correlation between the ranged rotational peak power ratio (where number 27 had the best ratio and number 1 the worst) and club head speed, (r_s=0.30, p=0.1), shown in figure 6. This indicates that a better balance between the power of the dominant and the non-dominant side not necessarily leads to, or has any connection with, a higher club head speed.

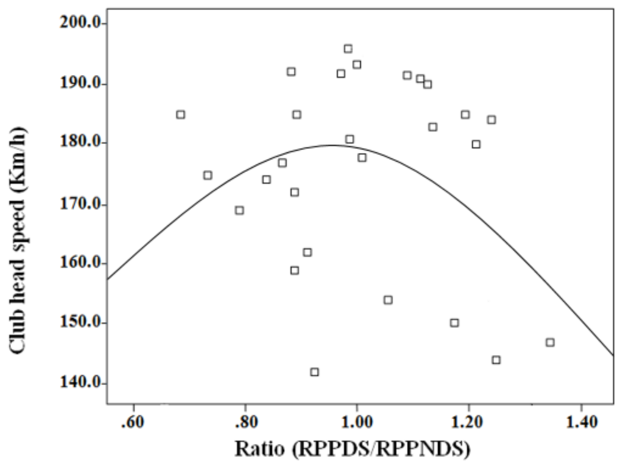

Figure 5. Relationship between club head speed and rotational peak power ratio (RPPDS/RPPNDS). (N=27)

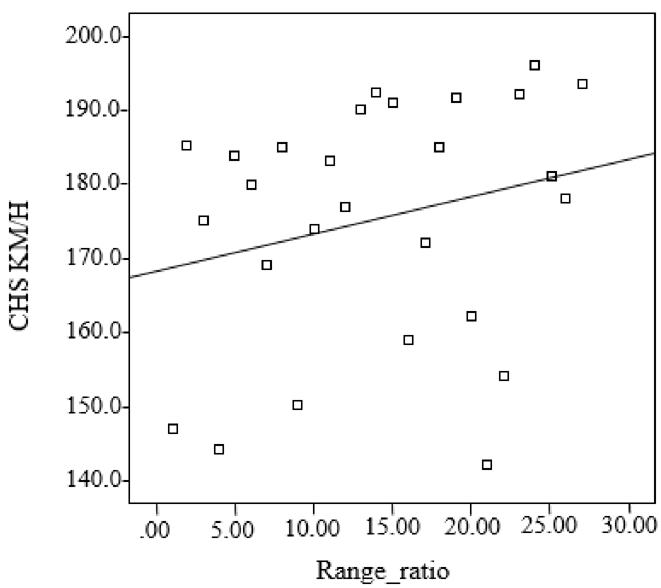

Figure 6. Relationship between club head speed and the ranged rotational peak power ratio (RPPDS/RPPNDS*)*. r_s=0.30 (p=0.1). (N=27). Range ratio is based on the ranking order from the best ratio (number 27) to the worst ratio (number 1).

Discussion

This study examined the correlation between peak trunk rotational power on elite golf player's dominant side, and club head speed. It also examined how well the bilateral peak trunk rotational powers correspond. A moderate correlation was found between club head speed and peak trunk rotational power on the dominant side. This indicate that a stronger trunk rotation may lead to a higher club head speed, and thus an enhanced golf performance. A high correlation was seen between the peak trunk rotational powers on the dominant and non- dominant side. This shows that an elite golfer's dominant and non-dominant side correspond. If the elite golfer's non-dominant side has a "low" power, the power on the dominant side is likely to also be "low" and vice-versa.

A low correlation was found between the ranged rotational peak power ratio and club head speed. This indicates that a better balance between the power of the dominant and the non-dominant side not necessarily leads to a higher club head speed. For instance, a golfer who had one of the worst balances between the power of the dominant and non-dominant side had a higher club head speed than an elite golfer with a better balance between the sides (Figure 6).

Results discussion

The present study found a moderate correlation between club head speed and peak trunk rotational power on the dominant side (r_s=0.58). Other studies have found a strong relationship between club head speed and rotational power. Winqvist & Grenzdörfer (2013) found a high correlation between club head speed and rotational power, measured using a standing medicine ball side throw (r=0.79, p=0.01) and a seated cable torso rotation (r=0.80, p=0.01). Jönsson & Söderström (2014) found a high correlation between club head speed and rotational power in elite golf women using a medicine ball rotational throw (r=0.81, p=0.19). Read et al. (2013) also found a high correlation between club head speed and rotational power using a medicine ball rotational throw (r=0.63, p<0.01). Algotsson (2016) correlated rotational power using a Quantum rotation test and found a high correlation between Quantum rotation test and standing medicine ball throw (r_s=0.80, p<0.01), and a moderate correlation between Quantum rotation test and sitting rotation test (r_s=0.52, p=0.05). The present study used the same rotation test to examine the differences between rotation power and club head speed. Similar to the current study, Gordon et al. (2009) got a moderate correlation between club head speed and rotational power using a medicine ball throw ($r=0.54$, $p<0.05$). Most of the studies who examined the relationship between club head speed and peak trunk rotational power found a high correlation, while the current study only got a moderate correlation. The lower correlation found in this study can be due to the golfers unfamiliarity with the new rotation test used in this study. Medicine ball side throw are the golden standard when measuring the rotation power (Gordon et al., 2009; Read et al., 2013; Grenzdörfer & Winqvist, 2013) which suggests that the golfers are more familiar to this test than the rotation test used in the current study. Club head speed measured with radar devices are also a familiar test for golfers (Read et al., 2013; Turner, 2016). A speculation may be that two familiar tests increases the chance of getting a higher correlation, due to the earlier training and familiarity with both of the tests, than one familiar test and one non-familiar test. That speculations may be an explanation to why the correlation in this study were a little lower than in previous studies with two familiar tests. The golfers used in the current study were unfamiliar with the rotation test and that may have affected the result.

The current research found a high correlation in peak trunk rotational power between the dominant and the non- dominant side ($r_s=0.82$, $p=0.01$), indicating that many of the subjects had a symmetric trunk rotational strength. The number of golfers who were stronger on the non-dominant side were more (14 non-dominant, 12 dominant, 1 perfect symmetric) which were interesting. The fact that golf is a very unilateral sport creates an expectation of a more powerful rotation from the aiming side. In contrast to this study, Bae et al (2012) research showed higher values on the dominant side. The findings in the present study is supported by the study from Winqvist & Grenzdörfer (2013) who tested both the dominant and non- dominant side on golfers when measuring the correlation between rotation power using a seated cable torso rotation and club head speed. No difference was seen between the sides ($r=0.80$, $p=0.01$ for both dominant and non-dominant side). Ellenbrecker & Roetert (2004) tested elite tennis player's trunk rotational strength and their research, in similarity with this research, showed that the players had symmetric trunk rotational strength (Left rotation/right rotation ratios ranged from 95 to 98% for males and from 94 to 96% for females). Bae et al (2012) measured trunk rotation strength in Korean male professional golf players and discovered, in contrast with the present study, that the Korean golfers had a higher rotational strength in their aiming side than of the non- aiming side (140.58±30.92 Newton metre (Nm) in the aiming side rotation and 131.83±27.87 Nm in the non-aiming side rotation). Asymmetry in the body has previously been linked with injury amongst athletes (Bampouras & Jones, 2010). According to Lindsay & Horton (2006), asymmetric pattern in the trunk rotation during the golf swing may cause side- to side imbalances in endurance characteristics and rotational strength amongst frequently playing/practicing elite golf players. Additionally, these imbalances may be a contributing factor to an increased risk of developing low back pain (Lindsay & Horton, 2006).

The current study found a low correlation between a ranged rotational peak power ratio and club head speed (r_s=0.30, p=0.129), this indicates that the balance between the sides not necessarily has a relationship with how high the golfers club head speed is. The ratio ranged from 0.7 to 1.4, with 12 players over 1.0, 14 players under 1.0 and 1 golf player on 1.0. The players who had a ratio over 1.0 were better with their dominant side, and players with a ratio under 1.0 were better with their non-dominant side. The player with 1.0 were perfectly balanced between the sides. If a better balance between the sides showed to correlate with a higher club head speed, it could be a new way for the elite players to increase their performance. As already stated, higher club head speed may lead to higher initial ball speed, longer striking distance and lower scores which are connected to better performance in golf (Wells et al., 2009). No other study known to the author of this paper have investigated the relationship between the rotational peak power ratio and club head speed.

In the quadratic correlation (inverted u-shape) seen in figure 5, a stronger balance of the peak power between the sides (closer to 1.0) seemed to have a relationship with a higher club head speed. When the ratio was ranged, the linear relationship showed to be weak. Most of the golfers were fairly balanced between the sides and only a few of them were far from 1.0. To range them and use the statistics in a nonparametric test could therefore have affected the correlation result because the distance between them will be the same.

Methods discussion

One possible factor of error in the measuring of the club head speed could be the standardization of the golf club. The subjects had to use a driver club, but were free to choose which driver club. If the clubs varied much in size and quality, it may have affected the club head speed.

The rotation test used in this study has been tested for validity and reliability in a study by Algotsson (2016). The test has never been used for examining the relationship between peak rotational trunk power and club head speed before. A concern with the rotation test were standardization of the rotation. Most of the golfers wanted to rotate with their upper body in a bent position to get a more familiar movement. When the resistance got to big, most of the subjects compensated this by bending their arm to get more force. It could be hard to decide if the trial were executed properly or not.

Another possible source of error could be time pressure. A few of the subjects were stressed and therefor may not have been entirely honest in their efforts when testing their 1 RM. That led to a lower resistance then 50 % of 1 RM when the power test was tested, which led to an unusually large peak power. They are displayed in the scatterplot as the outliers.

The subjects were asked to not perform any hard training the day before the testing sessions. Many of the elite golfer's had training every day around the testing sessions, which may have led to a level of fatigue, which could affected the result of the study.

This study analyzed the ratio between the dominant and non-dominant side by first comparing the ratio and club head speed with a quadratic correlation. To be able to examine the linear relationship between ratio and club head speed, the ratio was then ranged from 1-27 (were 27 had best balance and 1 worst balance). When the ratio becomes ranged, it loses its actual distance, therefore it would be interesting to further examine the quadratic correlation on a more profound level to see if there are a stronger relationship then the linear relationship suggests.

This research have contributed with more data, proving a correlation between club head speed and rotational peak power in the trunk. It has observed an interesting relationship between the rotational peak power ratio between the dominant and non- dominant side and club head speed.

More research has to be done to confirm the observed relationship between the peak trunk rotational power ratio between the dominant and non- dominant side.

Conclusion

This study concludes that club head speed and peak trunk rotational power on the dominant side have a moderate correlation, which is a slightly lower correlation than found in earlier studies. This could be due to the golfers unfamiliarity with the rotation test used in this study.

Peak trunk rotational power between the dominant and non- dominant side had a high correlation indicating symmetrical strength. This means that elite golfers not are as one-sided as one can argue for, due to the golf sports one sided motions. No significant correlation was found between a ranged rotational peak power ratio and club head speed, this indicates that the balance between the sides not necessarily (or at all) has a relationship with how high the golfer's club head speed is. Future research should further examine the relationship between the dominant and non-dominant sides on elite golfers and amateur golfers, to validate the results of this study. Additionally, future research should also analyze the quadratic correlation between ratio and club head speed on a more advanced level.

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Appendix 1

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:

Ann Bremander, professor vid Högskolan i Halmstad

ann.bremander@hh.se

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____

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