Relationships between field-based measures of strength and power, and golf club head speed

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ABSTRACT

Increased golf club head speed (CHS) has been shown to result in greater driving distances and is also correlated with golf handicap. The purpose of this study was to investigate the relationships between field-based measures of strength and power, and golf CHS, with a secondary aim to determine the reliability of the selected tests. A correlation design was used to assess the following variables; anthropometrics, squat jump height (SJ) and squat jump peak power (SJPP), unilateral countermovement jump heights (RLCMJ and LLCMJ), bilateral countermovement jump heights (CMJ), countermovement jump peak power (CMJPP), and seated (MBST) and rotational (MBRT) medicine ball throws. 48 male subjects participated in the study (age 20.1 ± 3.2 years, height 1.76m ± 0.07m, mass 72.8 kg ± 7.8, handicap 5.8 ± 2.2). Moderate significant correlations were reported between CHS and MBRT ($r = 0.67$; $p < 0.01$), MBST ($r = 0.63$; $p < 0.01$), CMJPP ($r = 0.54$; $p < 0.01$) and SJPP ($r = 0.53$; $p < 0.01$). Weak significant correlations ($r = 0.3$-0.5) were identified between club head speed and the other remaining variables excluding LLCMJ. Stepwise multiple regression analysis identified that the MBST and SJ were the greatest predictors of CHS, explaining 49% of the variance. Additionally the ICCs reported for tests of CHS and all performance variables were deemed acceptable ($r = 0.7$-0.9). The results of this study suggest that the strength and conditioning coach can accurately assess and monitor the physical abilities of golf athletes using the proposed battery of field tests. Additionally, movements that are more concentrically dominant in nature may display stronger relationships with CHS due to MBST and SJ displaying the highest explained variance following a stepwise linear regression.

KEYWORDS: field testing; golf; strength and power, driving performance

INTRODUCTION

The primary goal of the golf drive is to maximize displacement of the golf ball, which is a direct function of linear velocity at the point of impact between club head and the golf ball (17). An established method of measuring golf driving performance has been to determine the magnitude of club head speed (8, 10, 14, 19, 20),which is dependent on many factors including the amount and direction of ground reaction force produced (1), and the use of the kinetic chain sequencing (34).

Within the available literature, increases in club head speed have been reported following strength training and plyometric interventions (8, 9), correlating with lower handicaps (11), and overall golf performance (37). Despite the apparent associations between physical performance and golf drive performance, reliable field-based assessments to predict club head speed remain unclear.

Investigations into the relationships between physical performance and club head speed have involved a range of approaches. Keogh et al, (2009) analyzed a range of anthropometric, flexibility and muscular strength measures of low and high handicap players (0.3 ± 0.5 and 20.3 ± 2.4 respectively), reporting that a golf specific cable wood chop displayed the highest overall association (r = 0.70) with club head speed. Additionally, trends were evident that low handicap players achieved significantly greater (30%), bench press scores (19). The impact of chest strength is further evident as Gordon et al. (2009) noted increased strength of the chest, measured using an 8-repition maximum on a pec deck machine, as a significant indicator (r = 0.69) of club head speed in low handicap players (4.9 ± 2.9). This is likely due to the fact that the pectoralis major is highly active in the acceleration phase of the downswing (18). Whilst the above mentioned strength tests have reported significant correlations with club head speed, it should be noted that they are time in-efficient and require equipment which may not be available in a number of golf facilities delivering strength and conditioning programmes. Therefore, in-expensive, reliable field based performance measures optimizing efficiency in testing may be a more prudent strategy in the physical assessment of golf athletes.

Hellstrom, (2008) assessed the profiles of thirty male elite golfers (+5 to 0) and reported significant correlations between a range of performance measures and club head speed, with back squat (r = 0.54) and vertical jump peak power (r = 0.61) displaying the greatest associations. The results of Hellstrom, (2008) suggest that physical factors such as whole body dynamic strength and power have greater associations with club head speed and should be considered by players and strength and conditioning coaches alike, to enhance golf drive performance. A limitation of this study was the exclusion of a trunk rotational exercise within the test battery; a movement pattern inherent to effective golf performance, represented by lower handicap scores (26). The importance of trunk rotary strength and power has been highlighted previously, with lower handicap players (< 0) displaying significantly greater (p=<0.001) hip and torso strength than higher handicap players (10 – 20) (31), with the majority of work done on the golf shaft generated from the torso (23). Additionally, significant correlations (r = 0.54) have been noted with a medicine ball rotational throw, an assessment of dynamic rotational power (14. When interpreting the results of the above research, it should be highlighted that the correlations reported are moderate (range, r = 0.5 – 0.8), as such, there is a large amount of unexplained variance. To the authors knowledge no previous research has extended beyond single linear regression equations to examine the possible combined effects of multiple variables on golf club head speed.

Assessing relationships between physical performance tests and golf club head speed may be critical for the purposes of training, testing, and ultimately, performance enhancement. It has previously been speculated that accurate assessment and training methods will enable golfers of all levels to achieve their playing goals (33). Owing to the simplicity, time efficiency and minimal equipment requirements, field-based methods are often desirable for physical performance testing. However, currently there is not a suggested battery of field-based performance tests to determine the club head speed of golfers. Therefore, the aim of this study was to examine the reliability of a range of field-based physical tests and subsequently examine their relationships with golf club head speed.

METHODS

Experimental Approach to the Problem

A correlation study design was used to investigate if significant relationships are present between field-based measures of physical performance and golf club head speed. Within the research, club head speed was the dependent variable, whilst anthropometric measures, squat jump height and peak power, unilateral and bilateral countermovement jump heights and peak power, and seated and rotational medicine ball throws were selected as the independent variables. In addition, multiple trials of each field-based performance test were collected to assess the reliability of the measures. During the study, subjects attended on three separate occasions with a minimum of 48 hours between sessions. Day 1 involved a familiarization session for all performance tests and club head speed analysis, and anthropometric testing was also completed. On Day 2 data was collected for club head speed, and on Day 3, data was obtained for vertical jump and medicine ball throws assessments. Multiple trials were completed to reduce the influence of a learning effect, and the order of performance tests were randomized using a counterbalanced design. Additionally, subjects were instructed to refrain from high intensity physical activity 48 hours prior to each testing session and eat according to their normal diet.

Subjects

48 male subjects volunteered to participate in the study (age 20.1 ± 3.2 years, height 1.76m ± 0.07m, mass 72.8 kg ± 7.8, handicap 5.8 ± 2.2). Subject pre-requisites involved a minimum of two years golf playing experience with single figure handicap classifications. Upon commencement of the study, participants were in the early stages of the golf season, free from injury, had no quantifiable strength training experience, no prior experience of the performance tests, and were only involved in golf practice and competitions. Informed consent was gained prior to participation and ethical approval was granted by the University Research Ethics Committee, in accordance with the Declaration of Helsinki.

Procedures

Anthropometry Protocol

Height (cm) was recorded using a Seca (274, Milan, Italy) measurement platform. Weight (kg) was recorded using calibrated Seca (786 Culta, Milan, Italy) scales. Total arm length (AL) was measured in a standing position with the elbow fully extended with anatomical reference points, the greater tuberosity of the humerus and ulnar styloid.

Golf drive performance

Club head speed was measured using a flight scope (Kudu Launch Monitor, Stellenbosch, South Africa) placed one metre behind the ball in set up position. Subjects performed a standardized warm up including dynamic stretching and five practice shots. Subsequently, three recorded drives were completed separated by 60 second rest periods with instructions to swing maximally as has been suggested previously (15). The highest of the three swing speed values was used to report club head speed values. Subjects were blinded of their results to ensure no subsequent changes in technique. The same driver (Callaway Diablo, Callaway, USA) and make of golf ball (Titleist Pro-V1, Titleist, USA) was used throughout.

Performance testing

Vertical jumps. The highest of three maximal attempts of a countermovement jump (CMJ), squat jump (SJ), right leg countermovement jump (RLCMJ) and left leg countermovement jump (LLCMJ) were recorded, and used for subsequent analysis. Participants were instructed to jump as high as possible, avoid bending knees whilst airborne, and to keep hands in contact with hips throughout the test. The CMJ, RLCMJ and LLCMJ involved lowering into a quarter squat followed immediately by an explosive concentric contraction. Performance of the squat jump involved lowering the hips until the thighs were parallel to the floor followed by a four second isometric pause and subsequent explosive concentric only jump with no countermovement. Trials were repeated if a visible countermovement was used. All jumps, were measured using a contact mat (Kinetic Measurement System, Optimal Kinetics, USA), with peak power calculated using previous recommendations (28). Recent support for this approach highlighted strong correlations to peak power measured against force plate data (r = 0.96 and 0.95) for the CMJ and SJ respectively (9).

Medicine Ball Seated Throw (MBST). A 45° incline bench was used to facilitate the optimal trajectory and ensure standardization (5). Subjects used a 3kg medicine ball (Jordan Fitness, Cambridgeshire, UK), performing a warm up throw followed by three recorded attempts, with the best distance reported. For each trial the ready position was assumed with the subject placing the ball against their chest and it was held statically for four seconds. Instructions were to throw maximally using a concentric only motion. Subjects had to maintain their back and head in contact with the bench ensuring their feet remained on the floor. This test has previously been deemed a reliable method of assessment, with the intra-class correlation co-efficient (ICC) reported at 0.92 (5).

Medicine Ball Rotational Throw (MBRT). Using a 3kg medicine ball (Jordan Fitness, Cambridgeshire, UK), subjects assumed a golf stance and rotated away in a backswing type action followed by an immediate rotation towards the target as in a golf swing, aiming for maximal distance. Feet were required to remain in contact with the floor, although the rear heel was allowed to rise in the follow through action promoting triple extension of the ankle knee and hip as would be present in the golf swing. Three tests were recorded with the best score reported. This test has been performed previously with the ICC reported at (r = 0.89) (14).

For both the MBST and MBRT a measuring tape was placed on the floor with the near end anchored under the frame of the bench. To ensure accuracy of measurement the throwing area was covered in sand and this was re-raked before each test. Additionally, a pre-determined landing width was marked out (1.5m) on each side for which the ball must land in to be classified as a legitimate throw.

Statistical Analysis

Descriptive statistics (mean ± SD) were calculated for anthropometric data, club head speed, and all physical performance tests. Intra-session reliability for all tests was established using intraclass correlation coefficients (ICC). The strength and direction of the relationships between variables were initially examined using a Pearson correlation coefficient, with magnitudes of correlations based on a previously reported scale (7). Following this, all variables were entered into a multiple stepwise regression analyses to identify the main determinants of club head speed. The assumption of independent errors was tested using the

Durbin-Watson test, whilst multicollinearity was tested using both tolerance and VIF collinearity diagnostics. The level of significance for all tests was set at alpha level $P \leq 0.05$. Descriptive statistics were computed along with a multiple stepwise regression analysis via SPSS® V.18 for Windows.

RESULTS

Within-test reliability for club head speed, and all other performance tests was calculated using intra-class correlations (ICC) and are displayed in table 1. Based on previous research (16), the ICCs reported were deemed acceptable (r = 0.7-0.9) for all variables.

Insert table 1 near here

Descriptive statistics and correlations between club head speed, anthropometrics and the range of field tests conducted are shown in table 2.

Insert table 2 near here

Significant correlations were reported between club head speed and medicine ball standing rotational throw (r = 0.67; p < 0.01), medicine ball seated throw (r = 0.63; p < 0.01), countermovement jump peak power (r = 0.54; p < 0.01) and squat jump peak power (r = 0.53; p < 0.01). Whilst the relationships between other performance measures and club head speed were predominantly significant, the correlations were deemed weak (r = < 0.3) to moderate (r = 0.3-0.5). From the multiple regression analysis the medicine ball seated throw and squat jump height were the greatest predictors of club head speed, explaining 49% of the variance. For the model reported, there was no evidence of multi-collinearity as suggested by acceptable values for tolerance (> 0.1) and variance inflation factor (< 10).

DISCUSSION

The results of this study demonstrate that a wide range of strength and power performance measures are significantly correlated with CHS. In particular, concentric only actions including; squat jump and seated medicine ball chest throw. Moderate correlations were also evident with; CMJ and a medicine ball rotational throw, with low level significant correlations reported with; anthropometrics and RLCMJ. As such, strength and power development may positively impact golf CHS.

Due to the current lack of evidence in golf with regards to valid and reliable field based measures of physical performance, strength and conditioning practitioners are faced with a challenge as to how they should effectively assess athletic abilities. The current study reported high reliability in the range of field tests used and statistical significance with CHS in all performance measures apart from LLCMJ. By comparison, lower levels of reliability have been reported in previous work (37) and a range of other studies assessing physical relationships with CHS did not report reliability statistics for the physical performance tests (15, 19). The medicine ball rotational throw used in the current study displayed high reliability (ICC = 0.90) and this is comparable to other work using the same test (14). Additionally in assessing the characteristics of a range of strength, flexibility and power measures in elite golfers high reliability was reported (31), however, 15 tests were used which may have time implications. Therefore; the development of an effective / efficient range of field tests with high levels of validity and reliability will allow effective long term tracking of athletic development within elite golf programmes.

The current study highlighted that squat jump and medicine ball seated throw explained the highest variance (R^2 = 49%) in club head speed. This is in contrast with previous research that suggests the stretch shortening cycle (SSC) is the major muscle action contributing to the golf swing (17). The SSC has previously been classified into either fast or slow actions dependent on contraction times (</> 250ms) and angular joint displacements (29). The current study identified strong relationships between club head speed and performance tests requiring largely concentric muscle actions. Therefore, the golf swing may not reflect fast-SSC activity, which is dependent on large contributions from stretch reflex properties and elastic energy reutilization (3), but rather slow-SSC activity, which takes advantage of an increased time for cross-bridge formation (35). This notion is supported by research that has reported the time from downswing to impact as approximately 290ms for male professional players (22). Speculatively, this may suggest that the back swing merely allows increases in force production through the eccentric action, providing an increase in impulse (force x time), compared with a downswing without a pre-stretch (24).

The significance of the SJ reported in the current study highlights the importance of lower limb concentric strength to initiate a powerful downswing. Interestingly, Nesbit and Serrano, (2005) noted that lower handicap players worked at slower rates initially in the downswing and were then faster through impact than less skilled players. As such, better players may generate more force initially as evidenced by the slower speeds (due to the force/velocity relationship) and greater total work done. Additionally, the lower body has been shown to initiate the downswing while the upper body and club continue the backswing (13). This generates what has been referred to as the “X-factor stretch” (22), increasing the eccentric action, subsequently generating increases in muscular force.

Another finding of this study was that the highest correlation to CHS and greatest explanation of variance was the MBST, a concentric only chest dominant movement. Previous research has examined the impact of chest strength on CHS (14), and noted that increased chest strength was a significant indicator of CHS ($r = 0.69$). This is supported by the fact that the pectoralis major is highly active in the acceleration phase of the downswing (18). However, in a range of other sports involving high levels of trunk rotation such as boxing (12) and baseball (32), there is evidence of a definite synchronization between leg, trunk and arm actions playing a major role in increasing the force of a strike. Further to this the force generation sequence up the kinetic chain has also been identified (36) with mastery in the shot put involving a shift from the shoulder to the leg muscles. In the current study the subjects were physically untrained, and as such, may have over utilized upper body mechanics with less contribution from the legs and hips. It should be noted that the golf swing involves a sequential utilization of the kinetic chain to produce force, commencing from the ground, moving up to the distal segments during the downswing (13). Therefore, upper body dominant strategies may not be suitable for optimizing club head speed.

Future research may wish to investigate correlations of various physical performance tests with club head speed in physically trained golfers to assess if there is an increased relationship of leg power and a transition from upper body dominance as has been seen in other rotational based sports. Additionally field testing with different age ranges, specifically looking at youth populations could be implemented to assess relationships during different periods of growth and maturation.

PRACTICAL APPLICATIONS

The range of field tests utilized in this study, namely; squat jump, countermovement jump, medicine ball seated chest throw and standing rotational throw displayed high reliability statistics and moderate correlations with club head speed in single figure handicap golfers. This has implications for performance, as increases in CHS relate positively to reductions in handicap via increased driving distances (11). Strength and Conditioning coaches may also accurately and efficiently assess the physical abilities of their golf athletes using the aforementioned field tests as part of a primary assessment and then periodically to highlight the effectiveness of subsequent training interventions. Based on the results of this study, concentric dominant movements may be more effective in assessing the magnitude of CHS due to the association between MBST, SJ and CHS.

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