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Original Article

Relationship between selected physical fitness indicators and golf performances among elite university golfers

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Abstract:
Nowadays, most golfers have incorporated physical conditioning regimes to become the best player on the field. That is why the new generation of golfers nowadays is leaner, muscular, and more flexible than the previous generation. The purpose of the current study was to investigate the relationship between physical fitness and golf performances among elite collegiate golfers at National Golf Academy, Universiti Utara Malaysia. Besides, a comparison analysis was also conducted to see which physical fitness has a significant difference between male and female elite golfers. An Independent t-test was used to seek the differences between male and female golfers on their physical fitness attributes, while a Pearson Correlation analysis was used to seek which physical fitness attributes correlates with the golf performances. Significant correlations were found between height, arm length, leg length and predicted Vo2max with the golf measures. Significant correlations were also noted between muscle power and arm strength with almost all the variables in golf measures. While the upper body performance was the only significant inversely correlated with putts per round ($r=-.559$, $p \geq 0.05$). When comparing the physical attributed between genders, differences between male and female golfers were found in anthropometric measures (i.e: arm length, leg length, height, mass and predicted Vo2max) and golf driver performances, golf 5-iron performances, average score and greens in regulations ($p \geq 0.05$). From the results it can be suggested that male and female elite golfers do have differences in terms of their physical fitness and their golf performances regardless being in the same elite category. Other than that, results also suggest the anthropometric data, peripheral muscle strength and cardiovascular endurance are correlated with golf performance. These results can be used in developing training programs as well as to be used for the development of talent identification programs.
Key Words: Golf, Fitness, Performance, Elite, University

Introduction

Around 80 million individuals worldwide are believed to play the sport of golf (HSBC, 2012). An estimated total of 3.36 million golfers have played a full length of golf courses across the globally. Golf movements appear simple, however, is one of the most technical sports that require an individual to learn and master relevant skills considering all factors that contribute to a successful performance (Smith, 2013). According to Wells et al. (2009), golf can be considered one of the most demanding physical games that require the player to create explosive power through a wide range of motion apart from the complexity and precision of the golf swing.

The sport of golf requires a mentally and physically complex skill; the majority of previous studies have analyzed only the performance of this sport (Jacobson et al., 2005). Although golf can be considered a leisure activity for both men and women (Kobriger et al., 2006), it is a very demanding physical game requiring the player to create explosive power through a wide range of motion apart from the accuracy and complexity of the golf swing (Wells et al., 2009). For example, a player could apply up to 900 kg of force to a golf ball in a millisecond during an impact (Cochran & Stobbs, 1968). Furthermore, a golf club head speed (CHS) could reach up to 160 $km.h^{-1}$ during a single golf swing within 0.2 seconds. Egret et al. (2006) demonstrated that a golf swing can create almost 730 W of power output during a maximum impact in a 0.2s golf swing. A healthy golfer requires approximately 8.2 ± 0.2 metabolic equivalents per 18 holes, and approximately 46 ± 2.6% of functional lung capacity on a flat course and up to 50 to 85% of functional lung capacity on a hilly course (Dobrosielski et al., 2002).

Currently, golfers have incorporated physical conditioning regimens to become the best player in the field. The new generation of golfers is leaner, more muscular, and more flexible than the previous generation

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(Wells et al., 2009). Golfers also physically prepare to prevent and recover from common injuries in golf such as low back pain and elbow injury (Grimshaw et al., 2002). This enables them to play at their high level of performance with consistency and without injury-related limitations (McHardy et al., 2006). Specifically, golfers who integrate physical conditioning into their training (flexibility, strength, and power) have significant increases in their CHS and driving distance (Hume et al., 2005). This is supported by the findings obtained by Fletcher & Hartwell (2004), Hetu et al. (1998) and Lephart et al. (2007) that plyometric training programs significantly impact the CHS and carrying distance (CD). Furthermore, according to Wells et al., (2009), most studies focused on the effects of physical conditioning and rather than on the relationship between conditioning elements and golf performances among elite university golfers. They investigated on the combination of strength, power, flexibility, and plyometric trainings (Wells et al., 2009). The relationships between physical fitness and golf performance have been previously evaluated (Gordon et al., 2009; Keogh et al., 2009; Loock et al., 2013; Parchmann & McBride, 2011; Read et al., 2013; Sorbie et al., 2021; Torres-Ronda et al., 2014). According to Torres-Ronda et al. (2011), previous studies the relationship between fitness and golf performance have some limitationss owing to differences in the methodological approaches and heterogenity issues among participants. The authors suggested that future research should focus on elite golf players. To date, studies on the relationship between physical attributes and golf performances among elite university golfers remain limited.

Meanwhile, the relationship between physical attributes and golf performances among elite intercollegiate golfers have been evaluated by some of researchers (Marshall & Llewellyn, 2017; Oranchuk et al., 2020; Parchmann & McBride, 2011). Parchmann & Bride (2011) reported that the one-repetition maximum (1RM) squat performance was significantly correlated with the club head velocity (r=0.869). Marshall & Llewellyn (2017) found that golfers tended to hit the ball further with better balance. Oranchuk et al. (2020) investigated the effects of 8-week strength and power training on the CHS among NCAA Division II golfers. They found that power clean, 1RM back squat and countermovement jump training yielded a positive increment in the CHS. Based on these previous findings, the current study was aimed to evaluate the relationship between the physical fitness indicators among elite university golfers and how these indicators influence their golf performances. The differences between male and female elite university golfers were also investigated.

Materials & Methods

Participants

In this study, purposive sampling was used among elite golfers which they were selected from the National Golf Academy located at Universiti Utara Malaysia, Sintok, Kedah. A total of 20 elite golfers (11 men and 9 women) were selected. The participants were free from any diseases or injuries at the time of testing. All of them had participated in competitive golfing for at least 5 years prior to the study and were actively involved in golf and performance training at the time of testing (Wells et al., 2009). The participants were the best elite golfers among university students in Malaysia and some of them were actively competing in local amateur tournaments aside from representing Malaysia in the ASEAN University Games, World University Golf Championship, and Universiade.

Procedures

Before testing, the descriptive data of all sparticipants (i.e: age, sex, date of birth, height, body mass index and history of competitive golf statistics including their current handicap, if any) were collected. The experimental golf data were collected as follows: a) during a physical testing session at an outdoor stadium, b) during a separate testing session at an indoor golf facility, and c) from an online database (www.shotzoom.com) containing data entered by the players to track their golf performances. Before testing, the players underwent a brief warm-up session led that consisted of light running and stretching 10 min led by a qualified trainer or coach. The physical test was conducted in a standard order to minimize fatigue and the players were provided at least a 5-min recovery period between the tests. The physical test was conducted in the morning and the golf performance test in the afternoon and at least 2h of rest was provided after completion of the physical test (Wells et al., 2009). The physical fitnesss measured included the following: a) anthropometric characteristics, b) muscle performance, and c) cardiovascular performance. The golf performance data collected for the driver and 5-iron clubs included the following: a) ball speed (BS) and b) carry distance (CD). All procedures for the physical test were adapted from the study by Wells et al. (2009).

Anthropometric Characteristics Assessment Protocol

The anthropometric characteristics measured were the: standing height, weight, total arm length, and total leg length. For the total arm and leg lengths, all measurements were conducted in the standing position. All length measurements were measured to the nearest 0.2 m using the roll-up measurement tape SECA 206, while the mass measurement was measured to the nearest 0.5 kg by using the digital weighing scale SECA 803.

Muscle Performance Protocol

The muscle power was measured using the vertical jump (VJ) test with both legs, followed by the dominant and non-dominant legs. The test outcomes were measured by recording the differences between the reach and jump heights in (centimeter). Three trials were formed, and the average of the best two jumps was considered the final result. Meanwhile, the muscle strength, was measured in kilograms for both the dominant and non-dominant hand using; a digital handgrip dynamometer (Takei 5401). It was measured in the standing

position while maintaining a straight arm (Wells et al., 2006). The upper body muscle endurance was tested by instructing the participants to perform push-ups for 1-min. The maximum number of repetitions within 1-min was recorded.

Cardiovascular Performance Protocol

The cardiovascular endurance was assessed using the Léger multistage shuttle run test. This test requires individuals to run at a gradually increasing speed between lines separated by 20 m. It was described by Léger et al. (1988) and validated by Léger & Gadoury (1989). The equation that developed by Stickland et al. (2003) was used to predict the maximal aerobic capacity (V02max): Y is = 2.75X + 28.8 for men; Y is = 2.85X + 25.1 for women; and X is equal to the result of the last half-stage of the test that had been completed.

Golf Performance Assessment Protocol

A short stretching protocol and approximately 20 to 30 shots at a driving range next to the test facility were performed. The golf performance test was conducted using a calibrated assessment equipment [Foresight Sports GameChanger2 (GC2) Camera System]. The GC2 has a stereoscopic camera that allows it to capture and analyze ball characteristics and consequently record the BS and distance traveled. The variables measured by the device included the driver BS, driver CHS, driver carry CD, 5-iron ball speed (BS), 5-iron CHS and 5-iron CD. The tests were performed using driver and fairway iron (5-iron) clubs because they represent the two major types of club used in golf. Ten trials for both the driver and 5-iron were conducted. The golf performance statistics were recorded by the participants into the online database. These measurements included the mean score, number of greens in regulation and number of putts taken per round.

Data Analysis

The results were analysed using the Statistical Package for the Social Science version 25. All descriptive statistics were calculated and expressed as means ± standard deviations. The differences between the male and female participants were evaluated by using an independent t-test and the correlation between physical fitness and golf performance using Pearson correlation analysis. The statistical significance level was set at $p \leq 0.05$.

Results

The anthropometric characteristics of the participants are presented in Table 1. There were significant differences between in the mass, height, arm length, leg length and predicted Vo2max between the male and female participants ($p \leq 0.05$).

Table 1. Descriptive Statistics Of Anthropometric Characteristics For Male (n=11) And Female (n=9)

Variables	Combined (mean±SD)	Male (mean±SD)	Female (mean±SD)	Male vs Female
Age (years)	20.6 ± 2.1	20.1 ± 2.1	21.8 ± 1.7	$p \geq 0.05$
Mass (kg)	70.6 ± 11.9	74.6 ± 10.9	59.7 ± 7.3	$p \leq 0.05$*
Height (cm)	168.6 ± 0.08	173.1 ± 0.04	156.4 ± 0.02	$p \leq 0.05$*
Body Mass Index (BMI)	24.8 ± 11.9	24.9 ± 3.9	24.4 ± 2.6	$p \geq 0.05$
Arm length (cm)	49.2 ± 2.4	50.3 ± 1.7	46.4 ± 0.9	$p \leq 0.05$*
Leg length (cm)	88.5 ± 4.3	89.9 ± 3.8	84.4 ± 3.1	$p \leq 0.05$*
Predicted Vo2max	46.4 ± 6.8	49.8 ± 3.3	36.7 ± 2.6	$p \leq 0.05$*

The correlation analysis conducted in all participants revealed a significant correlation between the height and 5-iron CHS (r=.883, $p \leq 0.05$), 5-iron BS (r=.882, $p \leq 0.05$), 5-iron CD (r=.895, $p \leq 0.05$), driver CHS (r=.854, $p \leq 0.05$), driver BS (r=.858, $p \leq 0.05$), driver CD (r=.829, $p \leq 0.05$), mean score (r=-.899, $p \geq 0.05$) and number of greens in regulation (r=.645, $p \leq 0.05$). The weight significantly correlated only with the 5-iron CHS (r=.522, $p \leq 0.05$), 5-iron BS, (r=.522, $p \leq 0.05$) and 5-iron CD (r=.542, $p \leq 0.05$). The arm and leg lengths were significantly correlated with the 5-iron CHS (r=.745 and r=.621, $p \leq 0.05$), 5-iron BS (r=.609 and r=.623, $p \leq 0.05$), 5- iron CD (r=.614 and r=.607, $p \leq 0.05$), driver CHS (r=.579 and r=.664, $p \leq 0.05$), driver BS (r=.577 and r=.666, $p \leq 0.05$), driver CD (r=.560 and r=.706, $p \leq 0.05$) and mean score (r=-.709 and r=-.567, $p \leq 0.05$). Meanwhile, the predicted VO_2max was significantly correlated with the 5-iron CHS (r=.859, $p \leq 0.05$), 5-iron BS (r=.860, $p \leq 0.05$), 5-iron CD (r=.857, $p \leq 0.05$), driver CHS (r=.867, $p \leq 0.05$), driver BS (r=.864, $p \leq 0.05$), driver CD (r=.825, $p \leq 0.05$), mean score (r=-.829, $p \leq 0.05$) and number of greens in regulation (r=.646, $p \leq 0.05$).

Table 2. Correlational Analysis Results; Anthropometric Variables vs Golf Performance

	Correlation value (r)					
Variables	Age	Height	Weight	Arm Length	Leg Length	Predicted VO_2max
5-iron CHS	-0.321	0.883*	0.522*	0.745*	0.621*	0.859*
5-iron BS	-0.312	0.882*	0.522*	0.609*	0.623*	0.860*
5-iron CD	-0.306	0.895*	0.542*	0.614*	0.607*	0.859*
Driver CHS	-0.366	0.854*	0.419	0.579*	0.664*	0.867*
Driver BS	-0.374	0.858*	0.422	0.577*	0.666	0.864*
Driver CD	-0.304	0.829*	0.391	0.560*	0.706*	0.825*
Score	0.432	-0.899*	-0.372	-0.709*	-0.567	-0.829*
Greens in Regulations	-0.354	0.645*	0.403	0.521	0.364	0.646*
Putt per Round	0.047	-0.032	0.345	-0.092	-0.145	-0.093

The muscle performance of the participants is summarized in Table 3. A significant difference was found in the vertical jump (VJ) test performances (both, dominant and non-dominant legs) and handgrip strength (dominant and non-dominant hands). However, the upper body performance did not found significantly differ between them.

Table 3. Summary For Vertical Jump, Handgrip Strength And Push Up, Male (n=11) And Female (n=9)

Variable	Combined (mean±SD)	Male (mean±SD)	Female (mean±SD)	Male vs Female
Vertical jump (cm)	33.3 ± 9.8	37.9 ± 6.8	20.8 ± 3.1	$p \leq 0.05$*
Dominant leg vertical jump (cm)	18.3 ± 5.9	20.4 ± 5.1	12.5 ± 3.9	$p \leq 0.05$*
Non-dominant leg vertical jump (cm)	18.6 ± 6.5	21.6 ± 4.5	10.5 ± 3.2	$p \leq 0.05$*
Push-up	26.2 ± 8	26.7 ± 9.1	24.7 ± 4.6	$p \geq 0.05$
Dominant handgrip (N)	39.5 ± 9.3	44.2 ± 5.4	26.5 ± 1.4	$p \leq 0.05$*
Non-dominant handgrip (N)	38.5 ± 8.5	43 ± 4.2	26.1 ± 0.6	$p \leq 0.05$*

The muscle performance of the participants and golf performance is summarized in Table 4. The vertical jump (VJ) test performance was found to be significantly correlated with the 5-iron CHS (r=.801, $p \leq 0.05$), 5-iron BS (r=.800, $p \leq 0.05$), 5-iron CD (r=.796, $p \leq 0.05$), driver CHS (r=.822, $p \leq 0.05$), driver BS (r=.824, $p \leq 0.05$), driver CD (r=.796, $p \leq 0.05$), mean score (r=-.815, $p \leq 0.05$) and number of greens in regulations (r=.539, $p \leq 0.05$). The dominant and non-dominant leg vertical jump (VJ) test performance were significantly correlated with the 5-iron CHS (r=.544, r=.739 $p \geq 0.05$), 5-iron BS (r=.537, r=.733, $p \leq 0.05$), 5-iron CD (r=.548, r=.740, $p \leq 0.05$), driver CHS (r=.555 and r=.751 $p \leq 0.05$), driver BS (r=.549 and r=.749, $p \leq 0.05$), driver CD (r=.519 and r=.725, $p \leq 0.05$), and mean score (r=-.639 and r=-.714, $p \leq 0.05$). Furthermore, only the non-dominant leg VJ test performance was correlated with the greens in regulations (r=.596, $p \leq 0.05$). Conversely, the dominant and non-dominant handgrip strengths, were found to be significantly correlated with the 5-iron CHS (r=.828 and r=.852, $p \leq 0.05$), 5-iron BS (r=.823 and r=.850, $p \leq 0.05$), 5-iron CD (r=.825 and r=.861, $p \leq 0.05$), driver CHS (r=.830 and$r$=.840, $p \leq 0.05$), driver BS (r=.833 and r=.843, $p \leq 0.05$), driver CD (r=.798 and r=.824, $p \leq 0.05$), average score (r=-.889 and r=-.935 $p \leq 0.05$) and greens in regulations (r=.687, r=.733, $p \leq 0.05$). The upper body muscle endurance was significantly and negatively correlated with the number of putts per round (r=-.559, $p \leq 0.05$).

The golf performance of the participants is summarized in Table 5. There were significant differences between in the driver BS, driver CHS, driver CD, 5-iron BS, 5-iron CHS, 5-iron CD, mean score, and number of greens in regulations between male and female golfers. The only variable that was not found to be significantly different was the number of greens in regulations. However, a correlation analysis of the golf performance was not conducted because it was not a main objective of the study.

Table 4. Correlational Analysis Results; Muscle Performance vs Golf Performance, Male (n=11) And Female (n=9)

Variables	Correlation value (r)					
	Vertical Jump	Dominant VJ	Non-dominant VJ	Dominant Hand Grip	Non-dominant Hand Grip	Push Up
5-iron CHS	0.801*	0.544*	0.739*	0.828*	0.852*	0.232
5-iron BS	0.800*	0.537*	0.733*	0.823*	0.850*	0.232
5-iron CD	0.796*	0.548*	0.740*	0.825*	0.861*	0.218
Driver CHS	0.822*	0.555*	0.751*	0.830*	0.840*	0.375
Driver BS	0.824*	0.549*	0.749*	0.833*	0.943*	0.376
Driver CD	0.7796*	0.519*	0.725*	0.798*	0.824*	0.412
Score	-0.815*	-0.639*	-0.714*	-0.889*	-0.935*	-0.315
Green in Regulations	0.539*	0.404	0.596*	0.687*	0.733*	0.234
Putt per Round	-0.135	-0.39	-0.252	-0.157	-0.090	-0.559*

Table 5. Summary For Golf Performance, Male (n=11) And Female (n=9)

Variables	Combined (mean±SD)	Male (mean±SD)	Female (mean±SD)	Male vs Female
Driver BS (km/h)	225 ± 27.4	239.2 ± 12.1	183.9 ± 7.1	$p \leq 0.05$*
Driver CHS (km/h)	154.3 ± 19.2	164.2 ± 9.2	126.3 ± 5.3	$p \leq 0.05$*
Driver CD (m)	210.7 ± 35	228.6 ± 19.5	163.9 ± 10	$p \leq 0.05$*
5-iron BS (km/h)	186 ± 20.9	197.6 ± 7.9	153.9 ± 7.2	$p \leq 0.05$*
5-iron CHS (km/h)	128.6 ± 14	135.5 ± 5.3	105.7 ± 5.3	$p \leq 0.05$*
5-iron CD (m)	158.3 ± 25.6	172.5 ± 8.6	118.9 ±8.2	$p \leq 0.05$*
Average score	80.2 ± 5.6	77.2 ± 2.6	88.5 ± 1.5	$p \leq 0.05$*
Greens in regulations	8.9 ± 3.4	10.4 ± 2.2	4.8 ± 2.5	$p \leq 0.05$*
Putts per round	31.1 ± 1.7	31.2 ± 1.9	30.8 ± 1.1	$p \geq 0.05$

Discussion

The objective of the current study was to evaluate the relationship between physical fitness and golf performance among elite university golfers. The physical indicators measured were the muscle performance (upper and lower body), cardiovascular performance, and anthropometric characteristics. Significant correlations were found between some of the physical fitness indicators and golf performances.

The comparison of anthropometric characteristics revealed significant differences between the the male and female golfers. The differences were as expected and are consistent with other previous reports (Wells et al., 2009; Wells et al., 2006). Moreover, there was a significant correlation between the anthropometric characteristics such as height, arm length, and leg length and golf performance. Based on these results, athletes who have longer arms and legs could generate more force at impact than those who have shorter arms and legs. This is supported the findings obtained by Wells et al. (2009) and can then be used as a basis for future talent identification. One of the reasons why athletes can generate greater force and faster BS is that longer lever arms can create much longer angular displacements and thus increase the range of motion of the swing. Interestingly, the current study found that an increase in the aerobic capacity could lead to an increase in the swing speed and consequently in the BS (both driver and 5-iron) and decrease in the mean score per round. This is very interesting because other studies have found that playing golf requires anaerobic power more than aerobic capacity. However, Burgomaster et al. (2005) found that anaerobic training can significantly improve the aerobic capacity. This is also supported by the findings obtained by Elliot et al. (2007) who suggested golfers should undergo aerobic training while simultaneously maintaining power and strength training.

The muscle performance test in the current study revealed that the leg power and arm strength had a significant relationship with the golf performance, especially with an increasing speed and CD. Generally, the golf ball will travel much farther by increasing the speed and CD making its distances closer to the hole and thus making it much easier for golfers to make fewer strokes. The leg power may be critical in developing power during the golf swing. This is supported bythe findings obtained by Wells et al. (2009) and Doan et al. (2006) that the muscle powers in the legs, arms and upper torso were correlated with the swing speed. Read et al. (2013) also found that the upper body and lower body powers were significantly correlated with the CHS. The results from the current study show the importance of power and strength training in the improvement of driving distance. A previous study showed that those who participated in non-dominant arm strength exercises would be more effective in improving driving distance (Sung et al., 2016). In the comparison between men and women in the current study, it was found that women tended to have a slower swing speed for both thedriver club and 5-iron clubs than did the men. To date, only a few studies have compared the differences in the golf swings between men and women (Bourgain et al., 2022; Parker et al., 2019; Wells et al., 2009). One of the possible reasons why the swing speed is much slower in women than in men is that women use different movements in their swings to compensate for their weaker upper body. Female golfers also rely on their shoulder and hip rotations on the backswing to achieve a wider swing, compared male golfers who use more knee flexions to transfer their weight to the right side on the backswing (Egret et al., 2006).

Conclusions

This study evaluated the physical fitness indicators among elite golfers and how they fitness can influence golf performance. Herein, there were differences found in the outcomes between male and female golfers. Thus, male and female golfers may found respond differently to training (Sung et al., 2016). The study also found significant correlations between physical fitness and golf performance. This finding can be used as a basis in developing golf-specific training programs in addition to talent identification programs. The current study suggests that every golfer should include power, strength and cardiovascular endurance training in their golf conditioning programs to improve their golf performances. However, owing to the small sample population and limited findings of the current study, future research, focusing on the differences between elite and non-elite golfers with special consideration to female elite golfers is recommended. Future research should also focus on whether the fitness level and swing mechanic of golfers are affected by the use of a single length iron club.

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