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Strength, Flexibility, and Balance Characteristics of Highly Proficient Golfers

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Abstract. Sell, T.C., Y.-S. Tsai, J.M. Smoliga, J.B. Myers, and S.M. Lephart. Strength, flexibility, and balance characteristics of highly proficient golfers. *J. Strength Cond. Res. 21(4):1166–1171. 2007.*—Despite the emergence of golf-specific training programs and training aids, relatively little research has been conducted examining the physical characteristics that are important to golf performance. We studied the strength, flexibility, and balance characteristics of golfers across 3 proficiency levels based on handicap index (HCP) (<0, 1–9, and 10–20) to determine the physical characteristics unique to highly proficient golfers. A total of 257 (age: 45.5 ± 12.8 years, height: 180.6 ± 6.5 cm, weight: 87.9 ± 12.6 kg) healthy, male golfers participated in the study. Testing included an assessment of strength (torso, shoulder, and hip), flexibility (torso, shoulder, and hip), and single-leg balance. Golfers in the highest proficiency group (HCP < 0) had significantly ($p < 0.05$) greater hip strength, torso strength, shoulder strength, shoulder flexibility, hip flexibility, torso flexibility, and balance (eyes open) than golfers in the lowest proficiency group (HCP 10–20). The results of this study demonstrate that better golfers possess unique physical characteristics that are important to greater proficiency. These characteristics have also been demonstrated to be modifiable through golf-specific training programs.

Key Words. golf, conditioning, training

Introduction

In 2004, the National Golf Foundation estimated that there were 12.8 million adult golfers who played at least 8 times per year in the United States (19). Among individuals 7 years and older, golf is the fourth most popular sport (1). It is an activity that individuals can enjoy from early childhood until late adulthood. Concurrent to this popularity and participation level have been the increasing presence and development of golf-specific physical training equipment, books, and videos available to the consumer. These programs have been designed to enhance strength, flexibility, and balance in an attempt to improve proficiency and driving distance. Although the goals of these programs are well intentioned, it is not clear if the training methods or targeted physical characteristics are important to improving golf proficiency. Training should be based on the needs of the specific sport. Scientific evidence to show the important physical characteristics for improving golf performance may provide clinicians ideas for developing more efficient training programs for golfers.

An initial step in the design of a golf-specific training program may be to determine the physical characteristics of highly proficient golfers. Mastery of the golf swing requires optimal balance, flexibility, and strength to coordinate the movements of multiple body segments in order to optimize proficiency and driving distance (14). Individuals who have mastered the golf swing demonstrate greater ball flight consistency (24) and greater club head speed (7), which should equate to increased driving distance (14, 21). The physical characteristics of highly proficient golfers are relatively unknown because there are very few studies that have examined and compared these physical characteristics across proficiency levels. Current studies have been limited to descriptive studies of a single cohort of golfers without comparisons across proficiency levels (3, 4, 12, 13, 16, 22, 25). None of these studies examined strength, flexibility, or balance.

Improving the strength, flexibility, and balance of golfers may have the dual benefit of improving performance and decreasing injuries. Understanding these physical characteristics would assist physical trainers, physical therapists, and athletic trainers in the design of golf-specific fitness programs. Therefore, the purpose of this project was to examine the strength, flexibility, and balance characteristics of golfers across proficiency level. We hypothesized that highly proficient golfers would possess significantly greater strength, flexibility, and balance ability than less proficient golfers.

Methods

Experimental Approach to the Problem

We employed a descriptive cohort study of 3 groups of golfers based on playing ability to determine the physical characteristics of highly proficient golfers.

Subjects

A total of 257 subjects (age: 45.5 ± 12.8 years, height: 180.6 ± 6.5 cm, weight: 87.9 ± 12.6 kg) participated in the study. Subjects were separated into 3 groups according to proficiency based on their handicap index (HCP) (<0, 1–9, 10–20). Subject group numbers and averaged demographics for each proficiency group are provided in Table 1. All subjects were men and right-handed golfers. Participants were excluded from the study if they had a current musculoskeletal injury that prevented participation in golf or experienced pain during the golf swing. All subjects signed an informed consent form according to the university's Institutional Review Board.

Procedures

Strength Testing. Bilateral shoulder internal and external strength, hip abduction and adduction strength, and torso rotation strength were assessed with the Biodex System III Multi-Joint Testing and Rehabilitation System (Biodex Medical Inc., Shirley, NY). Torque values were automatically adjusted for gravity by the Biodex Advantage

TABLE 1. Subject demographics across proficiency level.*

	HCP < 0 (n = 45)		HCP 0–9 (n = 120)		HCP 10–20 (n = 92)		
	Mean	± *SD*	Mean	± *SD*	Mean	± *SD*	p value†
Age (y)‡§	39.2	13.0	43.7	12.7	50.9	10.7	<0.001
Handicap‖	2.0	2.3	−4.5	2.4	−13.7	2.9	<0.001
Self-reported driving distance (yd)‡¶	281.4	14.0	262.5	23.9	251.6	16.4	<0.001

* HCP = handicap index.
† p values for 1-way analysis of variance across proficiency level.
‡ Significant difference observed between HCP < 0 and HCP 10–20 ($p < 0.05$).
§ Significant difference observed between HCP 0–9 and HCP 10–20 ($p < 0.05$).
‖ Significant difference observed between each proficiency level ($p < 0.05$).
¶ Significant difference observed between HCP < 0 and HCP 0–9 ($p < 0.05$).

TABLE 2. Reliability for range of motion (ROM), flexibility, and strength measurements.*

	ICC	*SEM*
Shoulder flexion ROM	0.984	1.920°
Shoulder extension ROM	0.938	1.418°
Shoulder internal rotation ROM	0.824	3.248°
Shoulder external rotation ROM	0.935	3.337°
Shoulder abduction ROM	0.877	4.41°
Hip flexion ROM	0.940	1.846°
Hip extension ROM	0.855	2.318°
Hamstring flexibility	0.901	4.208°
Torso rotation ROM	0.863	4.587°
Left torso rotation strength, $60°\cdot s^{-1}$	0.906	12.4 (%BW)
Right torso rotation strength, $60°\cdot s^{-1}$	0.890	13.5 (%BW)
Shoulder internal rotation strength, $60°\cdot s^{-1}$	0.798	5.2 (%BW)
Should external rotation strength, $60°\cdot s^{-1}$	0.784	5.8 (%BW)
Hip abduction strength, isometric	0.647	15.8 (%BW)
Hip abduction, isometric	0.856	14.8 (%BW)

* BW = body weight.

Software v.3.2 (Biodex). Calibration of the Biodex dynamometer was performed according to the specifications outlined in the manufacturer's service manual. For each test, subjects were stabilized according to the manufacturer's guidelines. Practice trials (3 submaximal contractions followed by 3 maximal contractions) were provided before each strength test to ensure patient understanding and familiarity. An appropriate rest period of at least 60 seconds was also given before each of the strength tests. Reciprocal concentric isokinetic shoulder internal and external strength was tested at $60°\cdot s^{-1}$ (5 repetitions). Reciprocal concentric isokinetic left and right torso rotation strength was tested at $60°\cdot s^{-1}$ (5 repetitions). Isometric hip abductor and adductor strength was tested with subjects in the sidelying position while they performed 3 5-second alternating hip abduction and adduction isometric contractions. The reliability of strength testing using a Biodex System 3 has been previously established in our laboratory (Table 2).

Range of Motion and Flexibility. Range of motion was measured using a standard goniometer. A small level was attached parallel to the stationary arm of the goniometer to verify correct orientation to either a vertical or a horizontal frame of reference as needed. Shoulder flexibility and hip joint flexibility were measured passively by the same physical therapist using the methods described in the textbook of Norkin and White (20). Shoulder measurements included flexion/extension, internal/external rotation, and abduction. Hip measurements included flexion/extension and abduction/adduction. Hamstring flexibility was measured in a supine position using the active knee extension test (8). Torso rotational flexibility was measured from a seated position while subjects actively rotated their shoulders to end range while their pelvis was stabilized. The reliability of our range of motion and flexibility testing (except for hip abduction and adduction) has been previously established in our laboratory (Table 2).

TABLE 3. Reliability for single-leg balance.*

	ICC	*SEM*
Eyes open; anterior/posterior GRF (*SD*)	0.814	0.187
Eyes open; medial/lateral GRF (*SD*)	0.775	0.288
Eyes open; vertical GRF (*SD*)	0.857	0.328
Eyes closed; anterior/posterior GRF (*SD*)	0.879	0.537
Eyes closed; medial/lateral GRF (*SD*)	0.876	0.671
Eyes closed; vertical GRF (*SD*)	0.759	1.616

* GRF = ground reaction force.

Postural Stability Assessment. Postural stability was assessed according to Goldie and colleagues (9, 10) using a Kistler force plate (Kistler Corp., Amherst, NY) at a frequency of 100 Hz. Each subject was asked to complete a single-leg standing balance test (barefooted) for each leg under 2 conditions (eyes open and eyes closed). Three 10-second trials were collected for each leg under each condition as subjects remained as erect as possible with feet shoulder width apart and hands on hips. Subjects were instructed to focus on a target located approximately 2 m in front of them at eye level during the testing session with eyes open. During the testing session with eyes closed, the subjects were directed to focus on the target, maintain balance, and then close eyes prior to data collection. The reliability of balance testing has been previously established in our laboratory (Table 3).

TABLE 4. Strength comparisons across proficiency level.*

	HCP < 0		HCP 0–9		HCP 10–20		
	Mean	± *SD*	Mean	± *SD*	Mean	± *SD*	*p* value†
Right hip abduction (%BW)‡§	153.5	41.5	127.7	36.1	121.6	34.4	<0.001
Right hip adduction (%BW)‡§	132.6	41.4	112.3	35.3	109.0	38.1	0.014
Right shoulder internal rotation (%BW)§	59.4	12.8	54.3	15.8	48.6	14.1	0.003
Right shoulder external rotation (%BW)§	40.5	7.4	38.5	7.1	36.0	9.3	0.029
Left hip abduction (%BW)‡§	153.9	40.4	134.4	34.4	124.6	35.5	<0.001
Left hip adduction (%BW)	128.0	36.2	112.5	33.9	110.7	39.4	0.077
Left shoulder internal rotation (%BW)	53.8	11.9	50.5	14.3	47.5	13.2	0.110
Left shoulder external rotation (%BW)§	40.1	7.2	36.9	8.1	35.1	7.8	0.019
Right torso rotation (%BW)‖	157.3	31.3	136.9	36.7	122.7	33.4	<0.001
Left torso rotation (%BW)‖	154.9	31.5	138.8	34.9	125.2	34.1	<0.001

* HCP = handicap index; BW = body weight.
† *p* values for 1-way analysis of variance across proficiency level.
‡ Significant difference observed between HCP < 0 and HCP 0–9 ($p < 0.05$).
§ Significant difference observed between HCP < 0 and HCP 10–20 ($p < 0.05$).
‖ Significant difference observed between each proficiency level ($p < 0.05$).

TABLE 5. Shoulder range of motion comparisons across proficiency level.*

	HCP < 0		HCP 0–9		HCP 10–20		
	Mean	± *SD*	Mean	± *SD*	Mean	± *SD*	*p* value†
Right shoulder flexion (°)	177.1	10.2	177.7	11.7	173.9	11.5	0.120
Right shoulder extension (°)‡§	47.8	9.1	45.4	10.3	41.2	9.8	0.005
Right shoulder abduction (°)‡	180.9	18.5	186.8	19.0	171.9	17.9	0.001
Right shoulder internal rotation (°)	59.7	13.7	58.4	13.8	57.7	17.6	0.841
Right shoulder external rotation (°)‡§	106.3	11.5	101.4	14.4	95.0	18.4	0.003
Left shoulder flexion (°)‡	176.9	8.3	177.5	12.3	172.7	11.3	0.036
Left shoulder extension (°)§	48.7	8.9	44.2	10.2	42.0	9.8	0.013
Left shoulder abduction (°)‡	185.3	22.3	189.8	21.2	173.3	18.7	0.006
Left shoulder internal rotation (°)	65.4	12.8	63.2	14.4	61.4	13.3	0.421
Left shoulder external rotation (°)	99.3	12.2	95.5	14.7	91.6	17.9	0.082

* HCP = handicap index.
† *p* values for 1-way analysis of variance across proficiency level.
‡ Significant difference observed between HCP 0–9 and HCP 10–20 ($p < 0.05$).
§ Significant difference observed between HCP < 0 and HCP 10–20 ($p < 0.05$).

Data Reduction

The average peak torque for each of the strength tests was normalized to each individual subject's body weight to facilitate comparisons between subjects and across handicap levels. The variability (*SD*) during the balance tests was calculated and averaged across 3 trials for each leg under each condition (eyes open and eyes closed) for the vertical, anterior/posterior, and medial/lateral ground reaction forces.

Statistical Analyses

A 1-way analysis of variance was performed for each variable across proficiency level to determine if significant differences existed among the different handicap groups ($p \leq 0.05$). A Bonferroni multiple-comparison posthoc test was performed when the 1-way analysis of variance demonstrated statistical significance.

RESULTS

Strength

Bilateral hip abduction, hip adduction, shoulder internal rotation, shoulder external rotation, and torso rotation strength data, including *p* values, are presented in Table 4. The HCP < 0 group had significantly greater right hip abduction, right hip adduction, left hip abduction, right torso rotation, and left torso rotation strength than both the HCP 0–9 and HCP 10–20 group. The HCP < 0 group also had significantly greater right shoulder internal rotation, right shoulder external rotation, and left shoulder external rotation strength than the HCP 10–20 group. The HCP 0–9 group had significantly greater right torso rotation and left torso rotation strength than the HCP 10–20 group.

Range of Motion and Flexibility

Bilateral shoulder flexion, extension, abduction, internal rotation, and external rotation data along with the corresponding *p* values are presented in Table 5. The HCP < 0 group had significantly greater range of motion than the HCP 10–20 group for right shoulder extension, right shoulder external rotation, and left shoulder extension. The HCP 0–9 group had significantly greater right shoulder extension, right shoulder abduction, right shoulder external rotation, left shoulder flexion, and left shoulder abduction than the HCP 10–20 group.

Bilateral hip flexion, extension, abduction, and adduction and the corresponding *p* values are listed in Table 6. The HCP < 0 group had significantly greater right hip extension, left hip flexion, and left hip extension than the HCP 10–20 group. For active knee extension, the HCP < 0 group had significantly less right active knee extension (Figure 1) than the HCP 0–9 group ($p = 0.006$). Finally, both the HCP < 0 and HCP 0–9 groups had significantly greater ($p < 0.05$ [posthoc comparison]) right torso rota-

TABLE 6. Hip range of motion comparisons across proficiency level.*

	HCP < 0		HCP 0–9		HCP 10–20		
	Mean	± *SD*	Mean	± *SD*	Mean	± *SD*	*p* value†
Right hip flexion (°)	132.7	7.7	131.3	9.2	129.6	8.6	0.185
Right hip extension (°)‡	22.2	7.4	19.1	7.1	18.0	6.6	0.013
Right hip abduction (°)	30.4	9.2	32.8	8.7	30.8	9.2	0.332
Right hip adduction (°)	14.5	5.1	16.4	5.2	17.1	4.8	0.107
Left hip flexion (°)‡	134.3	8.9	132.3	9.7	129.5	8.9	0.024
Left hip extension (°)‡	20.8	6.3	18.2	7.2	15.9	6.1	0.002
Left hip abduction (°)	33.9	9.5	32.2	7.6	33.5	9.2	0.587
Left hip adduction (°)	16.6	3.8	16.7	5.2	16.9	4.3	0.957

* HCP = handicap index.
† *p* values for 1-way analysis of variance across proficiency level.
‡ Significant difference observed between HCP < 0 and HCP 10–20 ($p < 0.05$).

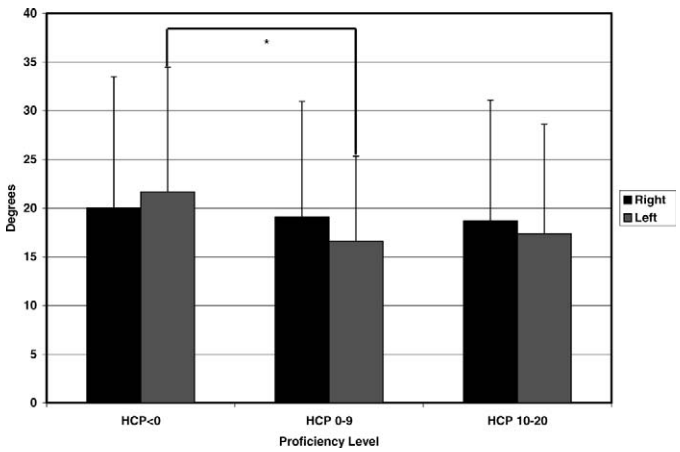

FIGURE 1. Left and right active knee extension across proficiency levels. * Significant difference ($p < 0.05$). HCP = handicap index.

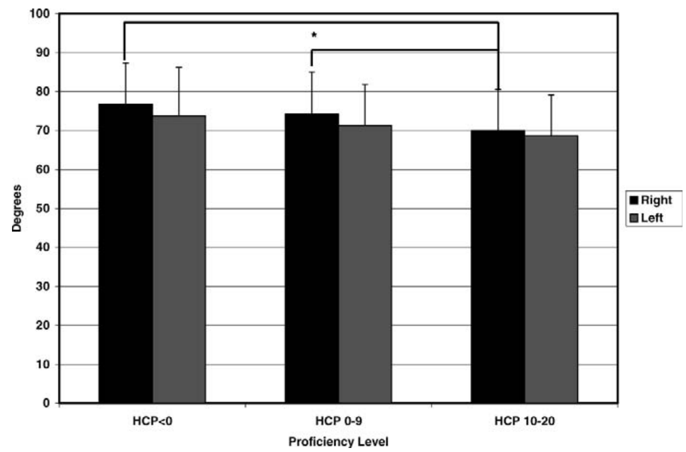

FIGURE 2. Left and right torso rotation across proficiency levels. * Significant difference ($p < 0.05$). HCP = handicap index.

tion range of motion (Figure 2) compared with the HCP 10–20 group ($p = 0.003$).

Balance

Bilateral single-leg balance testing (eyes open and eyes closed conditions) data and the corresponding *p* values are presented in Table 7. The HCP < 0 group had significantly better balance on the right leg under the eyes open condition for the medial/lateral and anterior/posterior ground reaction force *SD* compared with the HCP 10–20 group. The HCP < 0 group also had significantly better balance on the right leg under the eyes open condition for the anterior/posterior ground reaction force *SD* compared with the HCP 0–9 group.

DISCUSSION

Golf has become a popular sport among many age groups (1, 19). Concurrently, a wide variety of golf-specific train-

TABLE 7. Balance comparisons across proficiency levels.*

	HCP < 0		HCP 0–9		HCP 10–20		
	Mean	± *SD*	Mean	± *SD*	Mean	± *SD*	*p* value†
Right leg eyes open; anterior/posterior GRF‡§	2.42	1.17	3.66	2.50	3.80	2.36	0.005
Right leg eyes open; medial/lateral GRF§	3.19	2.04	4.98	4.48	5.64	4.91	0.014
Right leg eyes open; vertical GRF	4.72	3.34	7.87	8.70	8.16	7.85	0.053
Right leg eyes closed; anterior/posterior GRF	7.13	6.24	7.67	4.06	7.38	3.85	0.838
Right leg eyes closed; medial/lateral GRF	10.40	6.19	13.01	6.19	12.43	6.40	0.150
Right leg eyes closed; vertical GRF	20.61	24.74	20.44	15.19	19.94	15.79	0.982
Left leg eyes open; anterior/posterior GRF	2.85	2.07	3.61	2.85	3.96	3.79	0.186
Left leg eyes open; medial/lateral GRF	3.47	3.00	4.61	3.73	5.04	4.01	0.095
Left leg eyes open; vertical GRF	5.89	6.42	8.48	13.66	8.12	9.66	0.457
Left leg eyes closed; anterior/posterior GRF	6.66	3.72	7.70	3.21	7.91	4.06	0.286
Left leg eyes closed; medial/lateral GRF	10.61	6.60	13.01	5.68	12.60	5.70	0.159
Left leg eyes closed; vertical GRF	14.89	10.18	21.88	17.72	21.74	17.38	0.111

* HCP = handicap index; GRF = ground reaction force.
† *p* values for 1-way analysis of variance across proficiency level.
‡ Significant difference observed between HCP < 0 and HCP 0–9 ($p < 0.05$).
§ Significant difference observed between HCP < 0 and HCP 10–20 ($p < 0.05$).

ing programs have been developed that have been designed to improve characteristics that anecdotally may be important to improved golf performance and driving distance. The goal of this project was to examine the strength, flexibility, and balance characteristics of golfers in 3 different proficiency groups based on golf handicap. We hypothesized that golfers with a HCP < 0 would possess significantly greater strength, flexibility, and balance ability than less proficient golfers. In the current study, golfers with a HCP < 0 demonstrated significantly greater hip strength, torso strength, shoulder strength, shoulder flexibility, hip flexibility, torso flexibility (right), and balance (eyes open) than golfers with HCP 10–20.

Strength, especially around the hips, pelvis, and lower back (core strength), is essential to optimal performance in golf. An effective golf swing requires the golfer to maintain a stable base (lower extremities and pelvis) while rotating the mass of the torso, upper extremities, and head. The higher the velocity of rotation of this mass, the greater the strength of the core required. In the current study, the HCP < 0 group had significantly greater hip and torso strength than the HCP 10–20 group, demonstrating the need to improve torso strength to develop the power and torso velocity necessary to drive the ball a longer distance. Our research has demonstrated that there is a relationship between maximum torso velocity (during the downswing) and ball velocity (18), which should equate to a greater driving distance. Another important result of the current study is that the lowest handicap group also had significantly greater shoulder strength than the highest handicap group. Shoulder strength, specifically of the rotator cuff, is important for injury prevention and joint stability during the golf swing because the shoulder is a frequent site of injury both in professional and in amateur golfers (2, 11).

Flexibility may also be important for improved golf performance. During an efficient and effective golf swing, individuals attain positions that require good flexibility. In the current study, the HCP < 0 had significantly better flexibility and range of motion for the shoulders, hips, and torso than the HCP 10–20. One example of how increased flexibility may improve performance includes torso flexibility. Improving the separation of the upper torso and lower torso (X factor) requires good torso flexibility. Without good torso flexibility, individuals will not be able to create the separation necessary for improved driving distance, especially at the top of the backswing. X factor at the top of the back swing and maximum X factor are both significantly related to ball velocity (18).

Balance has always been considered an important component to the complete golf swing. Balance has different meanings for golfers and clinicians. In golf, balance typically indicates good rhythm or tempo, although golfers with poor rhythm or tempo may lose their balance and finish with poor results. Balance (also postural stability), from a clinical perspective, is the ability to maintain the body in equilibrium by maintaining the projected center of mass within the limits of the base of support (23). Sensory information for this stability is derived from vision, the vestibular system, and somatosensory feedback (15). In the current study, only 1 of the variables was significantly different among the groups; the HCP < 0 group had significantly better balance on the right leg under the eyes open condition for the medial/lateral and anterior/posterior ground reaction force *SD* compared with the HCP 10–20 group. A closer examination of the data demonstrates that the HCP < 0 group had lower (better scores) than both of the other groups in 11 of the 12 variables measured. From a clinical perspective, these results would indicate that the best golfers demonstrate the best single-leg balance among the 3 groups. From a performance perspective, individuals with better single-leg balance may be able to handle the significant weight shift that occurs during the golf swing. The shifting of the weight and subsequent vertical ground reaction force would require the golfer to control the center of mass movement within the base of support of both feet and within 1 foot when the majority of weight is on 1 leg or the other. Another important consideration regarding single-leg balance and performance is the difficult stances that occur during a round of golf. Very often, individuals are required to perform the same golf swing when they have an unlevel lie, uphill/downhill lie, or even a lie that requires 1 foot in a sand trap and 1 foot on the grass.

Practical Applications

The data presented in this study should provide clinicians with ample evidence for the design of training regimens to improve golf performance because highly proficient golfers demonstrated superior strength and flexibility at multiple joints, as well as greater balance. Previous training programs have demonstrated that these physical characteristics are indeed modifiable (5, 17). Golf-specific training programs have been demonstrated to improve driving distance, driving consistency, and putting distance control (5, 6, 17). The results presented here may also provide evidence for the relationship between driving distance and physical characteristics. Although not the primary purpose of the study, there was a significant correlation ($r = -0.4824$, $p < 0.001$) between HCP and self-reported driving distance such that as the HCP decreased, driving distance increased. This result would seem reasonable because there is also a significant relationship between club head speed and HCP, that is, as handicap decreases, club head speed increases (7).

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