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Effects of Flexibility and Balance on Driving Distance and Club Head Speed in Collegiate Golfers

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ABSTRACT

International Journal of Exercise Science 10(7): 954-963, 2017. Good balance, flexibility, and strength are all required to maintain a steady stance during the kinematic chain to produce successful golf shots. When the body can produce more power, more club head speed is generated. This formation of power translates into greater distance and accuracy. Athletes today are seeking exercise programs to enhance these qualities of their golf swing. The purpose of this study is to investigate the correlations between flexibility and balance with club head speed and driving distance in the golf swing of male and female collegiate golfers. Five male and five female collegiate golfers participated in the study. They completed multiple range of motion tests, the Balance Error System Test, and multiple flexibility tests. Subjects then participated in a short hitting session. Ten shots were hit with the subject's own driver. The Optishot simulator measured distance and club head speed generated. There was a significant negative correlation between the BESS test score and average distance for male subjects (r=-0.850, p=0.034). There were also a few trends between the balance, flexibility, and club head speed findings of both male and female subjects. This data shows there is a significant relationship between better balance and driving the ball farther. Other trends show better balance and flexibility will result in greater driving distance and club head speed. Balance and flexibility exercises should be incorporated into a golfer's practice or workout regiment.

KEY WORDS: Balance Error Scoring System test, x-factor, kinematic chain, exercise program, velocity

INTRODUCTION

Proper swing mechanics and technique have been significant in the perfection of the golf swing by many players. Today players, golf professionals, and fitness instructors are interested to study how athletic physique influences the golf swing (10). During the sequence of the golf swing, athletes are required to maintain a steady stance during the kinematic chain to achieve the desired swing outcome or golf shot. The golf swing requires balance, flexibility, and strength to generate power to hit the ball with distance and accuracy (5). Club head speed is generally increased in the swing when a golfer is able to generate more power by forces of the core muscles and the limbs. When more power is generated, more work is done on the golf ball. This work allows the ball to be driven a particular distance (6). Golfers are now seeking golf-specific fitness programs while maintaining focus of swing technique to improve their game.

For example, subjects from an 8-week functional training program studied by Thompson found an average increase in club head speed of 3.9 mph (10). From this increase in club head speed, subjects saw an increased driving distance of 10-15 yards as well as more roll out from the ball once in came in contact with the ground. It was concluded a training program focusing on both flexibility and weight training was more beneficial than a program focused on just one element (5). Research in the field is aiming to determine what physiological and biomechanical factors enhance golf performance.

It is important to note other factors do influence overall driving distance aside from club head speed. The kinematic chain of the swing, club model, shaft specifics, and skill level all influence the results of the golf swing (4). An important component of the golf swing is "x-factor", the separation of axial rotation of the trunk and the pelvis during the take away and backswing segments (7). The separation of axial rotation of the trunk and pelvis requires significant flexibility. When torso-pelvis separation is maximized, the velocity of the club head is increased, allowing the ball to be hit further. In biomechanics, this swing component is derived from a stretch-shortening movement where muscles eccentrically load to increase power output during the concentric shortening (7). A sufficient x-factor requires substantial flexibility along with balance and strength (7).

Having a single fixed point of rotation with a two-lever, one-hinge moment arm to apply force on the ball are important principles of technique for golf performance. By the summation of force principle, greater angular club head speed and displacement of the ball will occur. Fast stretching of the hip, rotation of the trunk and shoulders during the backswing with maximized early x-factor during the downswing will allow the wrists to uncock in the lead arm and apply a great impact force on the ball (4).

During the backswing the stretch shortening movement of the torso contributes to the eccentric loading increasing power output during the concentric shortening. Electromyography showed erector spinae, abdominal obliques, rectus adbominus, latissimus dorsi and gluteal muscles were all active during the backswing (4). When separation between the torso and pelvis is larger, concentric contraction during the swing is increased to increase club head speed.

Research has explored relationships between physicality of the golf swing and performance. One study focused on the influence of an eight-week training program in relation to the mechanics and physical attributes of the golf swing. Results showed an improvement in athlete's overall strength, flexibility, balance, and power (10). When the athlete was able to improve in these areas, club head speed as well as driving distance increased. Another study proposed that increased flexibility would allow for the joints involved to create more mechanical work during contact with the ball (6). With greater generation of club head speed, the golf ball should carry farther. Efficiency of the golf swing has been connected to chest strength, flexibility of the trunk, and total body rotational power (6).

When comparing golfers of different skill level and proficiency, it was found higher skilled golfers had better unipedal static balance (9). Unipedal static balance may improve weight shift during the golf swing and aid in overall balance. Static balance was conducted on a force pedal in unipedal stance with ground reaction force shifting the platform. The test was conducted when the subject had their eyes open and eyes closed. Greens in regulation and average putt distance left after a chip shot positively correlated with better unipedal static balance of highly proficient golfers (9). This suggests the weight shift from the backswing to the downswing and follow requires proficient balance. Standing on uneven ground during particular lies also suggests the outcome of the shot may be related to the skilled balance of the golfer.

Inspecting the effect of balance on the golf swing found golfers with a handicap less than zero had better single leg balance than golfers of a higher handicap. Golfers with better single leg balance may have greater ability to shift-weight properly in swing sequence, generating better overall performance (1). These studies do indicate balance and flexibility have increased golf swing performance, but each study used has different measures to achieve results on flexibility and balance. Accessing balance and flexibility should be done in a way to recreate the similar balance and flexibility characteristics required by the golf swing. Research also should be done to compare muscular strength needed for the golf swing in relation to other physical attributes (4). In general, more research on this topic should be conducted with female golfers as majority of the studies were conducted on male golfers.

The purpose of this study was to investigate the correlations between flexibility and balance with club head speed and driving distance in the golf swing in male and female collegiate golfers. It was hypothesized that better balance performance and increased flexibility would show greater club head speed and longer driving distance.

METHODS

Participants

Subjects were recruited from the Nebraska Wesleyan men's and women's golf teams. Ten total Nebraska Wesleyan University golfers volunteered to participate in the study. Of this total, five were female, and five were male with ages ranging from 18 to 22 years old. Handicaps of the golfers ranged from 2-22. All ten of the participants were right hand dominant. Inclusion criteria for participants included being a member of the NWU women's or men's golf team by using the sampling technique of a selected team. The study took place during the off-season in the Weary Center and indoor golf facility. All subjects signed an informed consent to participant in the study.

Table 1. Subject characteristics of age, handicap, balance and swing performance.

Characteristic		Mean ± SD	Minimum	Maximum
Age	**Female**	19.2 ± 0.84	18	20
	Male	19.2 ± 1.09	18	20
Handicap	**Female**	14.8 ± 6.3	22	8
	Male	2.0 ± 0.0	2	2
ROM Total	**Female**	1413 ± 40	1347	1448
	Male	1534 ± 331	1433	2110
Sit & Reach Max (cm)	**Female**	34.6 ± 4	31	41
	Male	32.0 ± 7.4	22	42
BESS Test (errors)	**Female**	15.4 ± 4	9	21
	Male	12.8 ± 6	5	19
Distance Average (yards)	**Female**	233.8 ± 14	216.0	247.7
	Male	280.0 ± 16	266.8	304.6
Distance Max (yards)	**Female**	264.8 ± 18.6	237.0	283.0
	Male	298.0 ± 14.8	288.0	323.0
Club Head Speed Average (mph)	**Female**	85.7 ± 6.8	76.0	91.7
	Male	107.6 ± 7.0	102.8	119.5
Club Head Speed Max (mph)	**Female**	100.0 ± 11.8	84.0	114.0
	Male	118.0 ± 6.0	112.0	128.0

Protocol

Subjects first filled out a questionnaire to gather information regarding age, hand dominance, USGA Handicap, and questions regarding personal regular workouts or fitness exercises. Then, multiple ranges of motion measurements were taken of joints related to the golf swing. Subjects then performed a series of flexibility tests as well as The Balance Evaluation Systems Test. Lastly, subjects completed the hitting portion of the test to record club head speed and total driving distance of ten drives. Testing for each subject took place in a single thirty-minute session. This included the range of motion measurements, flexibility tests, balance assessment, and hitting session. Subjects were expected to complete all portions of testing in the single session.

Range of motion measurements of the shoulder, trunk, and hip were taken using a goniometer. Goniometry measurements included: shoulder flexion, shoulder extension, shoulder abduction, shoulder adduction, shoulder internal rotation, shoulder external rotation, trunk rotation, and hip flexion. Three measurements were taken and the average of the three were used as the official measurement.

Shoulder flexion was taken while the subject was lying supine. The axis of rotation was the center of the humeral head near the acromion process. The stationary arm is parallel to the midaxillary line and the moving arm is along the midline of the humerus and lateral epicondyle. Shoulder extension occurs in the same position with the same axis, stationary arm and moving arm positions. The subject was prone.

Shoulder internal rotation is measured in the prone position with 90 degrees of abduction and 90 degrees of elbow flection. Should external rotation occurs in the supine position with 90 degrees of abduction and 90 degrees of elbow flexion. Both measurements use the olecranon process as the axis. The moveable arm should be placed parallel to the long axis of the ulna and the stationary arm should be placed perpendicular to the trunk.

Trunk rotation was measured having the subject sitting on a stool without back support and having feet flat on the floor. Axis for the measurement is the center of the superior aspect of the head. The stationary arm is aligned with the anterior superior iliac spine and moving arm is aligned with the acromion process.

For hip flexion subjects laid supine with the knee flexed while the hip is flexed. The joint axis is the greater trochanter of the femur with the moveable arm parallel to the femur and stationary arm parallel to the midline of the trunk.

The flexibility tests included the Sit and Reach Test, Thomas Test, and Scratch Test. Previous researched showed fast stretching of the hip, rotation of the trunk and shoulders during the backswing, with maximized x-factor during the downswing, allowed for a greater impact on the golf ball. These three tests examined the flexibility of the shoulders, hips as well as the low back and hamstring muscles flexibility making them more relevant test measures for golfers.

For the Modified Sit and Reach Test subjects sat on the floor with shoes off and legs outstretched. Feet are placed against the box and the subject reaches forward as far as possible along the measuring line. The Thomas Test assesses the flexibility of the hip flexor muscles, iliopsoas and rectus femoris. The subject laid supine on the table and flexes one hip as they bring the knee into the chest to hold it. If the opposite leg lacks flexibility the thigh will stay off of the table. For the Apley Scratch Test the subject attempted to touch the opposite scapula with one shoulder abducting and external rotating while the other is adducting and internally rotating.

The Balance Error Scoring System Test (BESS test) was used to assess balance and differentiate between deficits. The BESS test evaluates biomechanical constraints, stability limits/verticality, transitions/anticipatory, reactions, sensory orientation, and stability in gait. The BESS test proved to be an objective method of assessing static postural stability. This assessment is portable and cost-effective. Subjects removed shoes for this test. Testing occurred first on ground surface and then on a foam pad. The purpose of the foam pad is to create an unstable surface for challenging balance task.

A double leg stance, single leg stance, and tandem stance were all held for twenty seconds with the subject's eyes closed and hands on iliac crests. The BESS test score card is used to determine proficiency in the test. For every error the subject has, one point is incurred. Types of errors include: hands lifting off the iliac crest, opening eyes, stumbling, stepping, falling, moving the hip into more than 30 degrees of abduction, lifting forefoot or heel, and remaining out of the test position for more than five seconds. A stopwatch was used to time the twenty-second balances.

Subjects used his or her own driver golf club. It is important to note subjects own clubs are specially fit to their height, natural swing sequence, and swing speeds, and personal preference to increase distance and accuracy. Hitting sessions took place inside the Weary Center indoor golf facility. Participants teed off of indoor golf mats, made of spring crimped nylon material, into nets. They were given five minutes to warm up and hit balls before conducting the test. Each subject then hit ten drives where the club head speed and total driving distance of each swing was noted. An Optishot golf simulator measured club head speed and driving distance.

Statistical Analysis
SPSS Statistics was utilized to analyze data. Pearson-r correlations were used to measure the strength of relationship between two variables. The alpha-level used for determination of significance was p=0.05 and p=0.05-1.00 for trends.

RESULTS

Some significant and trending correlations were found from the male data analysis. There was a significant negative correlation between the BESS test score and average distance (r=-0.850, p=0.034, Table 2, Figure 1).

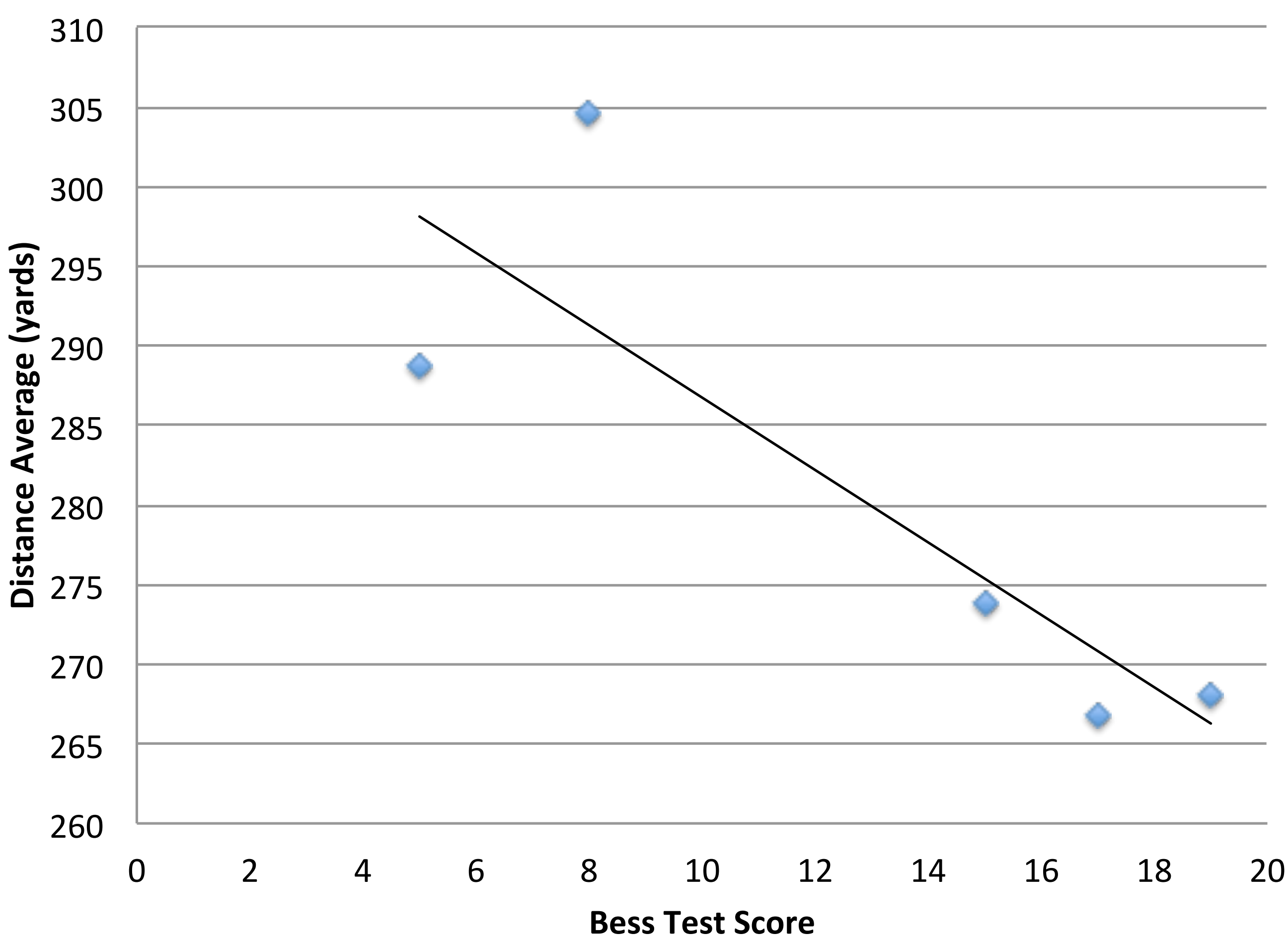

Figure 1. Significant correlation between male BESS test score and distance average. $p < 0.05$.

Table 2. Male correlations between flexibility, balance and swing performance.

Male N = 5	ROM Total	Sit & Reach Max	Bess Test
ROM Total			
Sit & Reach Max	0.431		
Bess Test	0.105	-0.789+	
Distance Average (yards)	-0.261	0.432	-0.850*
Distance Max	-0.422	0.185	-0.694+
Club Head Speed Average	-0.094	0.023	-0.392
Club Head Speed Max	-0.397	0.292	-0.710+

*Correlation significant at p = 0.05. +Correlation trends at p = 0.05 – 1.00.

There were no significant correlations found from the female data analysis (Table 3). There were not any other significant relationships found. There were also no other non-linear relationships present. Subject characteristics of age, handicap, flexibility, balance and swing performance are noted with mean and standard deviation (Table 1).

This data shows there is a significant relationship between balance and driving distance. A negative trend between the sit and reach maximum and BESS test correlation were found (r=-0.789, p=0.056, Table 2). Another negative trend found was between the BESS test and distance maximum correlation (r=-0.694, p=0.097, Table 2). The last negative trend found in the male data was of the BESS test score and club head speed maximum correlation (r=-0.710, p=0.090).

There were a few negative trends in the female data from the balance test, flexibility test, and swing performance. A negative trend was found between the BESS test score and distance average correlation (r=-0.714, p=0.088, Table 3). Another negative trend was between the sit and reach maximum and driving distance maximum (r=-0.712, p=0.084, Table 3). The final negative trend was between the sit and reach maximum and club head speed maximum (r=-0.735, p=0.078, Table 3).

Table 3. Female correlations between flexibility, balance and swing performance.

Female N = 5	ROM Total	Sit & Reach Max	Bess Test
ROM Total			
Sit & Reach Max	-0.602		
Bess Test	0.424	-0.123	
Distance Average (yards)	-0.320	-0.144	-0.714+
Distance Max	0.168	-0.722+	0.141
Club Head Speed Average	-0.360	-0.210	-0.673
Club Head Speed Max	0.283	-0.735+	0.172

+Correlation trends at p = 0.05 – 1.00.

The Thomas test and Apley Scratch test were conducted as part of the flexibility assessment. These tests occur at the shoulder joint and hip joint where flexibility is essential for proper swing mechanics. Two out of the ten subjects tested positive for the Thomas test indicating limited flexibility of the hip flexor muscles including the iliopsoas, and rectus femoris. The Apley Scratch test is used to determine limited shoulder motion. It may also indicate shoulder pathology. Three out of ten subjects tested positive when the right shoulder was externally rotated over the head and the left should was internally rotated behind the back. Four out of ten subjects tested positive when the left shoulder was externally rotated over the head and right shoulder internally rotated behind the back. This limited range of motion is likely due to the repetitive nature of the one-sided golf swing.

DISCUSSION

This study found significant correlations between flexibility, balance, and swing performance. In the male subjects, a lower error on the BESS test correlates to greater driving distance. The female data also supports this notion. A previous study found skilled golfers had better unipedal static balance. It is likely golf posture is better maintained from proficient balance and will lead to less destabilizing movements. (3) Another previous study found lower handicap groups had better right leg balance during anterior/posterior ground reaction force. Balance may attribute to greater x-factor during the swing and while maintaining posture with a strong base throughout the changing phases of the swing. (9) There were a few trends between the male and female results that associated to lower number of errors of the BESS test to increase driving distance and driving distance maximum. Golfer's looking to increase swing performance should consider incorporating balance exercises as an integral part of their training.

Negative trends between sit and reach maximum and swing performance showed subjects with greater sit and reach lengths were likely to hit the ball farther and generate greater club head speed. Previous studies investigated the relationships between trunk flexibility and swing speeds. They found lower flexibility of the torso did not impact ability to produce maximum speed. (2) Another study found lower handicap groups to have greater hip extension and flexion than the higher handicap groups. These results and previous studies show there are relationships between increased flexibility and swing performance. This study showed a relationship between increased flexibility improved club head speed. Future research could incorporate using the sit and reach test, range of motion measurements, and other flexibility tests to investigate the differences in each flexibility test. Perhaps certain flexibility tests are better indicators of swing performance than others.

There was a negative trend from the male data indicating a lower number of errors on the BESS test correlated to a higher score on the sit and reach test. Previous studies indicated a relationship between balance and flexibility with increased swing performance, but each study had varying methods to determine balance and flexibility. This study used consistent testing between participants to further investigate the relationship. Further, most studies in the literature are focused on strength and various exercise programs with their relation to golf performance. This study investigated balance and flexibility, rather than strength and various exercise programs, and its outcome on driving distance and club head speed.

A limitation on this study was the material used to measure club head speed and driving distance. The Optishot program uses an infrared sensor to measure club head speed and points of contact on the face of the golf club. These infrared sensors fire around 10,000 pulses per second to bounce off the clubface to measure club head speed, club angle, and swing path.

The club is tracked slightly before and after impact but it does not track the golf ball like a launch monitor. The Optishot does not take into consideration twisting of the club head during off center hits that may alter shot shape. One popular device used in the profession of golf is Trackman launch monitor. This portable device measures spin rate, club head speed, dynamic loft, attack angle, club path, face angle, launch angle, carry, smash factor, and ball speed. The trackman uses radio waves to reflect off objects and return back to the radar device. Other research on the topic use technology in human motion analysis labs to collect data.

Another possible limitation was the influence of outside golf practice and play during the period in which data was collected. While the study was conducted during the formal off-season, and there was not formal practice, some of the subjects were out playing and practicing on their own. Some subjects also did report exercising during the period when data was collected.

Each subject used his or her own driver for the hitting session. Some of the subjects may have been fit for drivers by professionals in the industry to improve their rate of successful shots. Differences in driver loft, driver weight, shaft stiffness, and shaft weight all influence the outcome of driving the golf ball. Still, it would not be appropriate to use the same driver for each subject due to personal swing biomechanics and swing speeds.

Lastly, small sample size limited the statistical power and significance of the study. Low statistical power reduces the chance of detecting a true difference between groups. Statistical significance allows the study to extend the results rendered for the sample size onto the whole population.

This study shows a relationship between balance and increased driving distance of the golf ball. A next step for this study would be to create an eight-week exercise program to increase strength, balance, and flexibility. This eight-week fitness program should include Body Mass Index, strength, flexibility and current fitness level in the inclusion criteria. This inclusion criterion precisely measures the changes in each participant's golf game. A set training period during the off season would address insufficiency by showing an athletes progression of physical fitness and golf attributes during a regimented program. Results could lead to a better understanding of how these three components improve driving distance and club head speed. This study could also track fairways in regulation and greens in regulation hit during the fall tournament season, followed by athletes completing the off-season exercise program. Then again, fairways and greens in regulation could be tracked during the spring tournament season. Perhaps increased balance, strength, and flexibility will lead to more fairways and greens hit in regulation.

Balance and flexibility are keys to swing performance. This study investigated the relationships between balance and flexibility with club head speed and driving distance. It was found that lower scores on the BESS test correlated to greater driving distance. Subjects with greater sit and reach lengths were more likely to hit the ball farther and generate more club head speed. Golfers looking to enhance swing performance should incorporate balance training and flexibility exercises into their practice and workouts.

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