Importance of Transverse Plane Flexibility for Proficiency in Golf

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Abstract

McHugh, MP, O'Mahoney, CA, Orishimo, KF, Kremenic, IJ, and Nicholas, SJ. Importance of transverse plane flexibility for proficiency in golf. *J Strength Cond Res* XX(X): 000–000, 2021—The extent to which the flexibility requirements for golf proficiency vary between the planes of motion has not been examined. The purpose of this study was to compare flexibility between proficient and average golfers with the hypothesis that proficient golfers have greater transverse plane flexibility than average golfers, with no differences in the sagittal and frontal planes. Twenty-five male golfers were categorized as proficient (handicap ≤5, $n = 13$) or average (handicap 10–20, $n = 12$). Fourteen flexibility tests were performed (4 shoulder tests, 4 trunk tests, and 6 hip tests) with tests in all 3 planes of motion for each body segment. In addition, trunk motion, pelvic motion, and hip motion during the golf swing were assessed with high-speed motion analysis. Ball speed and shot distance were recorded with a golf simulator. Proficient golfers had significantly better flexibility than average golfers in the transverse plane (shoulder $p = 0.021$, trunk $p = 0.003$, and hip $p < 0.0001$), with no differences in the sagittal plane or frontal plane (plane of motion by golf proficiency $p = 0.0001$). Transverse plane hip flexibility accounted for 48% of the variability in ball speed ($p < 0.0001$) and 45% of the variability in total distance ($p = 0.001$). During the golf swing, proficient golfers had greater separation between the pelvis and the trunk (x-factor) than average golfers ($p = 0.002$). In conclusion, transverse plane flexibility in the trunk and hips is an important requirement for golf proficiency. Sagittal plane flexibility and frontal plane flexibility were unrelated to proficiency. Developing and maintaining trunk and hip rotation flexibility is important for optimizing performance.

Key Words: trunk rotation, hip rotation, x-factor, biomechanics, ball speed

Introduction

The flexibility requirements for proficient golf performance have not been specifically established. Multiple studies have examined flexibility patterns in golfers and the relationship to either performance or swing biomechanics metrics (1,3,5–7,12,14). However, the results of these studies are not consistent, and no clear picture can be construed. Identifying specific flexibility patterns associated with golf proficiency can help optimize flexibility training programs for golfers.

The extent to which the flexibility patterns required for golf proficiency vary between body parts and the 3 planes of motion has not been examined. The golf swing involves the coupled motions of the hips, pelvis, trunk, and arms, and the motion requirements for these different body parts vary greatly between the planes of motion. For example, the trunk moves excessively in the transverse plane during the golf swing, with much less motion in the sagittal and frontal planes. Separation between the pelvic and trunk transverse plane rotation during the golf swing (referred to as the x-factor) is believed to be important for increasing club head speed (9) and ball speed (4). However, the relationship between trunk flexibility and golf performance has not been clearly established. Trunk rotation flexibility has been shown to be related to club head speed in some studies (1,5) but not in others (3,7). In addition, proficient golfers (lower handicap) seem to have greater trunk rotation flexibility (6,12), but other flexibility tests also differed between proficient and average golfers. In fact, Keogh et al. (6) suggested that low handicap golfers have a combination of greater trunk rotation flexibility and reduced hip internal rotation (HIR) motion. It was theorized that this combination might enhance the x-factor during the golf swing. Based on the available literature, it is unclear whether better whole-body flexibility is associated with golf proficiency or whether the relationship varies between different body parts and different planes of motion.

It is also not known whether the use of available motion in different body segments during the golf swing is related to golf proficiency. The potential advantages of greater flexibility for the golf swing are that it allows for generation of greater velocities through the greater available range of motion (ROM) and/or that it allows the swing to be executed well within the limits of ROM across different joints.

The purpose of this study was to compare flexibility in the trunk and hips, in all 3 planes of motion, between proficient and average golfers. Because golfing requires repeated axial rotation movements in a fixed stance, it was hypothesized that proficient golfers would have greater flexibility in the transverse plane of the trunk and hips but would not differ from average golfers in other flexibility tests. The relationships between flexibility and golf performance metrics (ball speed and total distance) and x-factor were also examined. Finally, trunk rotation ROM and hip internal and external rotation ROM during the golf swing were compared with the maximum motion measured during the flexibility tests to determine how much of the available motion is used during the swing. It was hypothesized that greater transverse flexibility in proficient golfers would provide 2 advantages vs. average golfers: (a) Proficient golfers would use greater hip and trunk rotation ROM during the swing, and (b) proficient golfers would use a smaller proportion of their available trunk and hip ROM during the golf swing, i.e., they operate well within their available ROM while average golfers would operate closer to the limits of their available passive motion.

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Methods

Experimental Approach to the Problem

A cross-sectional approach was used to examine the relationship between musculoskeletal flexibility and golf proficiency. Two groups of golfers were identified based on their official United States Golf Association (USGA) golf handicap index: a low handicap group (proficient) and an intermediate handicap group (average). A battery of flexibility tests was used to provide an assessment of hip, trunk, and shoulder flexibility in all 3 planes of motion. Golf swing biomechanics and shot performance were also assessed for their relationship to flexibility.

Subjects

Twenty-five male golfers were selected for inclusion in this study. The subjects were selected from a sample of golfers 40 golfers undergoing swing biomechanics and flexibility assessments at our facility (27 ± 6 vs. 48 ± 16 years, $p < 0.001$; range 18–35 years vs. 24–70 years). Thirteen players, categorized as proficient golfers, had an official USGA handicap index of 5 or lower (2 Professional Golfer's Association of America professionals, 4 U.S. college players, 1 teaching professional, and 8 amateur golfers). Twelve golfers, categorized as average golfers, had an official USGA handicap index between 10 and 20. Golfers with handicaps between 6 and 9 and greater than 20 were excluded. Female golfers were also excluded, given the likelihood of flexibility differences between men and women independent of golf proficiency. In addition, at the time of testing, all golfers had to be injury free and playing regularly. All subjects gave written informed consent, and the study was approved by the human research protection program at the Feinstein Institutes for Medical Research at Northwell Health.

Based on the intersubject variability in trunk rotation flexibility in a sample of 15 proficient golfers (5), it was estimated that with 2 groups of 12 golfers, there would be 80% power to detect an 18% difference in trunk rotation flexibility between proficient and average golfers at an alpha level of 0.05.

Procedures

Before flexibility and biomechanics testing, all golfers were weighed and had height recorded.

Flexibility Assessments. A total of 14 flexibility tests were performed, encompassing the shoulders (4 tests), the trunk (4 tests), and the hips (6 tests), with tests in all 3 planes of motion for each body segment (Table 1).

Shoulder flexion, shoulder internal rotation (SIR) and shoulder external rotation (SER) range of motion (ROM) were measured in supine, as described previously (8).

Shoulder Sagittal Plane Flexibility. For shoulder flexion, the arm was passively flexed by the examiner to the point at which scapular protraction occurred and the angle was recorded using a goniometer.

Shoulder Frontal Plane Flexibility. The posterior shoulder flexibility test (Tyler test) was performed in the side-lying position, with the shoulder and elbow flexed to 90°. The examiner manually stabilized the axillary border of the scapula when the arm was placed in 90° of shoulder abduction and 90° of elbow flexion (starting position). This scapular position was maintained as the arm was lowered against gravity. A digital level was aligned with the humerus, and the angle relative to the horizontal was recorded (cross-chest abduction angle). Values above horizontal were recorded as negative values to indicate tightness. Although the glenohumeral motion being measured in this test does not occur in the frontal plane, the test was categorized as a frontal plane flexibility test. The test assesses posterior shoulder tightness which controls scapular motion in the frontal plane. Manual scapular stabilization is a critical component of the test (8); in fact, cross-chest adduction stretching is only effective in improving posterior shoulder flexibility if the scapula is stabilized during the stretching (11).

Shoulder Transverse Plane Flexibility. Shoulder flexion, internal rotation ROM was measured with the shoulder in 90° of abduction and with the elbow in 90° of flexion. A digital level was aligned with the forearm while the shoulder was passively rotated. SER ROM was measured similarly.

Trunk Sagittal Plane Flexibility. For the toe-touch test, subjects actively flexed their spine while maintaining full knee extension at the knee, reaching as low as possible with the fingertips. The distance in centimeters from the fingertips to the floor was measured as a negative number. For subjects who could reach beyond the floor, the distance beyond zero was recorded as a positive number by having the subjects extend their wrists and fingers while measuring the distance from the most proximal hand contact point on the floor to the fingertips.

Trunk Frontal Plane Flexibility. For the side-bending test, subjects stood with the back to the wall, with feet shoulder width apart and arms by the side with the palms of the hand on the lateral thigh. The distance the fingertips moved down the lateral thigh as the subject laterally flexed the spine was measured while ensuring that both feet remained flat on the floor and both knees remained extended. Side-bending distance was expressed as a percentage of height.

Trunk Transverse Plane Flexibility. Trunk rotation was recorded in sitting and in standing. For the seated test, subjects sat on a stool with a wooden dowel held across the scapulae, with the arms abduction 90°, the elbows flexed 90°, and the shoulders rotated 90°. While seated in neutral rotation, the dowel was aligned with a large protractor on the floor behind the subject. The subject actively rotated in each direction as far as possible while first hooking the

Table 1

Flexibility tests by body part and plane of motion.

	Sagittal	Frontal	Transverse
Shoulder	Flexion	Posterior shoulder flexibility (Tyler test)	External rotation Internal rotation
Trunk	Toe touch	Side bend	Trunk rotation (seated and standing)
Hip	Thomas test Straight leg raise	Ober test Hip abduction	External rotation Internal rotation

right foot over the left foot when rotation to the right and vice versa when rotating to the left. A plumb line was dropped from the end of the dowel to record the rotation angle on the protractor. After the seated test, subjects stood with the dowel held in the same position, with feet shoulder width apart, and placed on either side of the midpoint of the protractor zero line. They then rotated maximally in each direction, and the rotation angle was recorded.

Hip Sagittal Flexibility. Hip flexor tightness was assessed using the Thomas test. The subject lay with the knees to chest with the pelvis close to the end of the plinth. The tester then lowered 1 leg with the knee passively flexed while maintaining the knee to chest position on the contralateral side. A digital level was placed on the anterior thigh, and the angle relative to horizontal was recorded while the leg was allowed to hang passively.

Hip Frontal Plane Flexibility. The Ober test was performed in side-lying with the lower leg held with the knee to chest by having the subject hook his arm under the thigh and gripping the side of the plinth. The tester then lifted the upper thigh into hip abduction while in neutral hip flexion with the knee at 90°. With the assistance of gravity, the tester allowed the thigh to fall into adduction while preventing it from falling into hip flexion. A digital level was placed on the lateral thigh, and the angle at which the thigh hung against gravity was recorded. For the Thomas and Ober tests, angles above the horizontal were recorded as negative values and below horizontal as positive values (i.e., negative values equate to tightness).

Hip Transverse Plane Flexibility. Hip internal rotation ROM and hip external rotation (HER) ROM were measured in prone with the knee flexed to 90°. For HIR, the leg was allowed to rotate out while the tester aligned a goniometer with the tibia as the hip rotated into IR. Similarly, for HER ROM, the leg was allowed to fall inward with knee flexed to 90°. The straight leg raise (SLR) and hip abduction tests were performed in supine. For SLR, the leg was passively raised by the tester with the knee maintained in extension until posterior pelvic rotation occurred. A goniometer was aligned with the lateral thigh, and the hip flexion angle was recorded. For hip abduction ROM, the leg was abducted by the tester until the point at which lateral pelvic tilting occurred.

Golf Swing Biomechanics and Performance Metrics. Twenty-four retroreflective markers were placed on the lower extremities, arms, and trunk. The marker locations were as follows: C7 vertebra, right and left acromia, right and left medial elbow, right and left lateral elbow, right and left ulnar styloid, right and left distal radius, right and left anterior superior iliac spine, right and left posterior superior iliac spine, sacrum, right and left lateral femoral condyle, right and left lateral malleolus, right and left calcaneus, and right and left base of the fifth metatarsal. Five additional markers were placed on the golf club along the shaft and club head. The golf ball was also covered in retroreflective tape to determine the moment of impact with the club. Kinematic data were recorded with 10 infrared cameras at 500 Hz (BTS Bioengineering, Quincy, MA). After warm-up, subjects hit 5 shots with the driver, and the best 3 swings by distance were analyzed. Two performance metrics, ball speed and total distance, were measured with a radar-based ball launch monitor (TrackMan Golf, Scottsdale, AZ).

Statistical Analyses

The effects of body segment and plane of motion on flexibility differences between proficient and average golfers were assessed using a $3 \times 3 \times 2$ mixed-model analysis of variance (ANOVA) with repeated measures on body segment (shoulders, trunk, and hips) and plane of motion (sagittal, frontal, and transverse) and with golf proficiency as the between-subject factor (proficient vs. average). To perform the 3×3 ANOVA, the 14 flexibility tests were converted to 9 metrics (1 for each body segment in each plane of motion). The 9 metrics were (a) the average of right and left shoulder flexion angle (shoulder-sagittal), (b) the average of right and left posterior shoulder flexibility (shoulder-frontal), (c) the average of right and left total shoulder rotation (SIR + SER) (shoulder-transverse), (d) toe-touch distance (trunk-sagittal), (e) the average of right and left side bend distance (trunk-frontal), (f) the average of right and left seated and standing trunk rotation (trunk-transverse), (g) the average of right and left hip flexion (Thomas test) plus SLR ROM (hip-sagittal), (h) the average of right and left Ober test and hip abduction test (hip-frontal), and (i) the average of right and left total hip rotation (HIR + HER) (hip-transverse). Because some tests were measured as angular displacements and others as linear displacements, all values for each test were converted to z-scores for the full factorial analyses. Bonferroni corrections were applied to planned pairwise comparisons between proficient and average golfers. For example, because there were 3 comparisons between proficient and average golfers (sagittal plane, frontal plane, and transverse plane) for each body segment, the p value for the pairwise comparison was multiplied by 3.

The association between the individual flexibility tests and the performance measures (ball speed and total distance) was assessed using Pearson correlation coefficients. Flexibility tests that had significant correlations with performance measures (including any tests with a p value of <0.10) were entered in a stepwise multiple regression to examine whether combinations of flexibility tests better explained the variability in performance measures than any single test.

Differences in trunk and hip rotation motion during the golf swing between proficient and average golfers were assessed by independent t-tests. Pearson correlation coefficients were used to assess the relationships between hip or trunk motion during the swing and ball speed and total distance.

Effect sizes for flexibility comparisons between proficient and average golfers were computed using Cohen's d statistic with the magnitude of effects considered either small (0.20–0.49), medium (0.50–0.80), or large (>0.80). Mean ± SD is reported in the results.

Results

Demographics of the Study Subjects

Proficient golfers were younger (27 ± 6 vs. 48 ± 16 years, $p < 0.001$) but did not differ from average golfers in height (1.79 ± 0.05 vs. 1.75 ± 0.06 m, $p = 0.299$) or body mass (76.6 ± 12.5 vs. 84.3 ± 22.4 kg, $p = 0.052$). USGA handicap index was 0.7 ± 4.1 (−8 to 5) for proficient golfers and 15.0 ± 4.1 (10–20) for average golfers ($p < 0.001$). Ball speed (156 ± 7 vs. 129 ± 12 $m \cdot s^{-1}$) and total distance (253 ± 18 vs. 210 ± 24 m) were greater for proficient vs. average golfers ($p < 0.001$).

Differences in Flexibility Between Proficient and Average Golfers

Differences in flexibility between proficient and average golfers were dependent on the plane of motion of the test (proficiency by plane of motion $p = 0.0001$, Table 2) but not the body segment of the test (proficiency by body segment $p = 0.619$; proficiency by

Table 2

Flexibility differences between proficient and average golfers assessed by body segment and plane of motion of the flexibility test.*†

	Sagittal		Frontal		Transverse			
	Flexion		Posterior shoulder flexibility		SIR		SER	
	Right	Left	Right	Left	Right	Left	Right	Left
Shoulder								
Proficient	152 ± 32°	154 ± 33°	5 ± 12°	5 ± 12°	64 ± 14°	71 ± 9°	100 ± 11°	94 ± 7°
Average	148 ± 12°	153 ± 10°	−2 ± 17°	1 ± 19°	55 ± 13°	62 ± 13°	92 ± 10°	86 ± 9°
p	0.999		0.951		**0.021**			
Effect size	0.11 (−0.16 to 0.37)		0.38 (0.08 to 0.68)		**0.85 (0.49** to **1.21)**			

	Sagittal	Frontal		Transverse			
		Side bend		Trunk rotation			
				Seated		Standing	
	Toe touch	Right	Left	Right	Left	Right	Left
Trunk							
Proficient	−3.5 ± 13.0 cm	13 ± 5%	13 ± 5%	74 ± 18°	77 ± 20°	135 ± 24°	140 ± 24°
Average	−9.6 ± 13.6 cm	10 ± 3%	10 ± 2%	55 ± 17°	53 ± 17°	103 ± 16°	106 ± 15°
p	0.792	0.249		**0.003**			
Effect size	0.48 (0.16 to 0.79)	0.78 (0.43 to 1.13)		**1.70 (1.26 to 2.14)**			

	Sagittal				Frontal				Transverse			
	Thomas test		SLR		Ober test		Hip abduction		HIR		HER	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Hip												
Proficient	−1 ± 15°	−2 ± 14°	64 ± 9°	62 ± 9°	1 ± 10°	2 ± 9°	34 ± 14°	35 ± 15°	44 ± 12°	43 ± 10°	42 ± 9°	42 ± 13°
Average	5 ± 17°	5 ± 15°	60 ± 8°	56 ± 8°	−3 ± 11°	−2 ± 8°	25 ± 7°	24 ± 6°	29 ± 8°	29 ± 8°	27 ± 7°	24 ± 10°
p	0.999				0.129				**<0.0001**			
Effect size	0.13 (−0.14 to 0.40)				0.71 (0.37 to 1.05)				**2.23 (1.76** to **2.70)**			

*SIR = shoulder flexion, internal rotation; SER = shoulder flexion, external rotation; SLR = straight leg raise; HIR = hip internal rotation; HER = hip external rotation.

†Mean ± *SD* is reported; body segment by plane of motion by proficiency $p = 0.784$; plane of motion by proficiency $p = 0.0001$; body segment by proficiency $p = 0.619$; p values for comparisons between proficient and average golfers within each body segment are adjusted for multiple comparisons (the p value for the comparisons between proficient and average golfers for each plane of motion has been multiplied by 3). Effect sizes are Cohen's d statistics with 95% confidence intervals. Significant effects are in bold italics.

plane of motion by body segment $p = 0.784$). Proficient golfers had significantly better flexibility than average golfers in all 3 transverse plane tests with large effect sizes for each test (Table 2): shoulder rotation (IR plus ER 165 ± 12 vs. 147 ± 18°, $p = 0.021$), trunk rotation (standing plus seated 212 ± 39 vs. 158 ± 27°, $p = 0.003$), and hip rotation (IR plus ER 86 ± 17 vs. 55 ± 11°, $p < 0.0001$). Flexibility did not differ between proficient and average golfers in the sagittal plane and frontal plane tests (Table 2).

Association Between Flexibility and Driving Performance Metrics

Ball speed was correlated with total hip ROM ($r = 0.693$, $p < 0.0001$) and trunk rotation ROM ($r = 0.464$, $p = 0.034$). Total distance was correlated with total hip ROM ($r = 0.671$, $p = 0.001$) and hip abduction ROM ($r = 0.510$, $p = 0.018$). Total hip ROM (IR + ER averaged between right and left sides) accounted for 48% of the variability in ball speed with no other flexibility test improving the predictive value based on multiple regression. Similarly, total hip ROM accounted for 45% of the variability in total distance with no other flexibility test improving the predictive value.

Use of Available Transverse Plane Trunk and Hip Range of Motion During Golf Swing

During the golf swing, the peak separation between the pelvis and trunk occurred just after the initiation of the downswing with greater separation in the proficient vs. average golfers (Table 3). However, the magnitude of trunk rotation during the golf swing relative to the available passive ROM was not different between proficient and average golfers (89 vs. 97%, $p = 0.492$; Table 3). Total hip rotation ROM during the golf swing was greater in the rear leg vs. the lead leg (73 ± 14° vs 41 ± 12°, $p < 0.001$; Table 3). Hip rotation ROM during the golf swing was not different between the proficient and average golfers on either the lead leg or the rear leg (Table 3). However, proficient golfers used significantly less of their available passive hip ROM during the golf swing compared with average golfers with large effect sizes for each comparison (45 vs. 80% on the lead leg, $p = 0.001$; 88 vs. 112% on the rear leg, $p = 0.036$; Table 3).

Peak separation between the trunk and pelvis (x-factor) during the golf swing was strongly correlated with ball speed ($r = 0.733$, $p < 0.001$) and total distance ($r = 0.737$, $p < 0.001$). By contrast, HIR ROM and HER ROM during the golf swing were unrelated to ball speed or total distance ($p \geq 0.183$).

Discussion

As hypothesized, greater flexibility in the transverse plane was associated with greater golf proficiency, whereas flexibility in the sagittal and frontal planes did not differ systematically between proficient and average golfers. These data indicate that hip rotation flexibility, trunk rotation flexibility, and, to a lesser extent, shoulder rotation flexibility are key for golf proficiency.

One confounding factor was that the proficient golfers in this study were younger than the average golfers and flexibility decreases with age. It is possible that the flexibility differences observed here were due to the effects of aging and not golf. However, the fact that the

Table 3

Transverse plane trunk and hip rotation during the golf swing relative to the available passive ROM.*†

	Trunk rotation		Lead hip rotation		Rear hip rotation	
	Angle	**% of passive ROM**	**Angle**	**% of passive ROM**	**Angle**	**% of passive ROM**
Proficient	62 ± 5°	89 ± 24%	41 ± 12°	45 ± 14%	73 ± 13°	88 ± 26%
Average	49 ± 12°	97 ± 33%	41 ± 9°	80 ± 24%	61 ± 15°	112 ± 29%
p	**0.002**	0.492	0.990	**0.001**	0.051	**0.036**
Effect size	**1.50 (1.08 to 1.92)**	0.29 (0.01 to 0.58)	0.00 (−0.25 to 0.25)	**1.88 (1.43 to 2.33)**	0.89 (0.53 to 1.26)	**0.91 (0.55 to 1.28)**

*ROM = range of motion.

†Mean ± *SD* is reported. Trunk rotation angle is the peak separation between the pelvis and trunk during the swing which occurred just after the top of the backswing. Trunk rotation angle is expressed as percentage of seated trunk rotation ROM in the backswing direction. Hip rotation angle is the combined internal and external rotation during the swing. Effect sizes are Cohen's *d* statistics with 95% confidence intervals. Significant effects are in bold italics.

flexibility differences were specific to the transverse plane points to the effect being attributable to golf; it is unlikely that decreased flexibility with aging is disproportionally seen in the transverse plane. In an attempt to further resolve this issue, flexibility was compared between proficient and average golfers who were 24–36 years old (9 proficient vs. 5 average). For this subset of golfers, total hip rotation ROM was markedly greater for the proficient golfers (85 ± 20 vs. 59 ± 6°, $p = 0.002$). Although the groups did not differ significantly in other tests, trunk rotation ROM was 33° greater for proficient vs. average golfers ($p = 0.164$). Thus, for the entire sample, the greater trunk rotation flexibility (19–36°) and hip rotation flexibility (14–18°) in the proficient golfers seem to be attributable to golf and not age.

It is notable that not only did proficient golfers have greater hip rotation ROM than average golfers, but they used significantly less of their available ROM during the golf swing (45 vs. 80% on the lead hip; 88 vs. 112% on the rear hip). By contrast, proficient golfers had greater trunk flexibility than average golfers but used a similar proportion of the available trunk ROM during the golf swing (89 vs. 97%). The strong association between trunk rotation during the golf swing and the performance metrics (ball speed and total distance) indicates that the greater trunk flexibility in proficient golfers is important for performance because it enables a greater separation between the pelvis and trunk during the golf swing. The lack of association between hip rotation during the golf swing and performance metrics indicates that the greater HIR and HER flexibility in the proficient golfers allowed them to function well within their available ROM. ROM on the rear hip during the golf swing exceeded the available passive ROM in 12 of 25 golfers (4 of 13 proficient golfers and 8 of 12 average golfers) but for only 2 of 25 on the lead leg (both average golfers). The greater ROM used on the rear hip vs. the lead hip during the golf swing may explain the higher prevalence of intraarticular hip injuries in the rear hip in golfers (2). Furthermore, decreased HIR ROM has been associated with low back pain in professional (13) and amateur (10) golfers. Thus, the combination of a greater available hip rotation ROM, and using a smaller proportion of the available ROM, may be protective against injury. However, no prospective studies have examined hip rotation flexibility as a risk factor for injury in golfers.

The flexibility tests for this study were divided into 3 body segments in 3 planes of motion. Each of the transverse plane shoulder, trunk, and hip flexibility tests were bidirectional (rotations measured in both directions). However, in the frontal plane, the shoulder flexibility test was unidirectional (posterior shoulder flexibility), and in the sagittal plane, the shoulder, trunk, and hip tests were all unidirectional. The absence of shoulder extension, trunk extension, and hip extension flexibility tests and a shoulder abduction flexibility test is a limitation. The reasons for these omissions were twofold (1): The golf swing does not involve a lot of shoulder, trunk, and hip extension or shoulder abduction, and (2) preference was given for tests routinely used clinically or in athlete screening. In addition, one could argue that the posterior shoulder flexibility test is not a frontal plane flexibility test. The intent was to include a shoulder test that included scapular motion, and the scapula moves primarily in the frontal plane.

Loss of SIR and gain in SER on the dominant vs. nondominant arm is common in throwing athletes such as baseball pitchers (8). The same pattern was evident in the golfers in this study (Table 2) with 7° less SIR and 6° greater SER on the right (lead) arm vs. the left arm (all golfers were right-handed). It is notable that there were no such asymmetries in hip rotation ROM with very similar ROM between the right (rear) and left (lead) hips (Table 2). The greater ROM in the rear hip vs. the lead hip during the golf swing (Table 3) did not translate into a greater passive hip rotation ROM on the rear hip. In a sample of 36 amateur golfers with an average handicap of 15.7, passive HIR was 31° on the lead hip and 32° on the rear hip (10). These HIR values are very similar to the 29° for the average golfers in the current study (average handicap 15.0). However, in that previous study, passive HER was 44° on the lead hip and 45° on the rear hip, whereas in this study, HER was only 24 and 27°, respectively. The same measurement techniques were used in both studies, and the ages of the groups were similar (48 ± 16 vs. 54 ± 14 years). The previous study did include some female golfers, and this possibly contributed to the greater HER ROM. Lower values for HIR ROM were reported for 28 healthy professional golfers (17° and 20° on the lead and rear sides), but method of measurement was not reported, and HER was measured indirectly using the flexion abduction external rotation (FABER) distance test (13).

In a flexibility comparison between 10 low and 10 high handicap male golfers (6), seated trunk rotation for the low handicap golfers was 68 ± 12 and 70 ± 12° in the follow-through and backswing directions, respectively, whereas the respective values for the high handicap golfers were 58 ± 16 and 60 ± 12°. Although the differences between the low and high handicap golfers were not significantly different ($p = 0.128$ and $p = 0.097$, respectively), a mean difference of 10° in each direction may have equated to a greater total rotation in the low handicap golfers (comparison not reported). In this study, backswing trunk rotation was 74° vs. 55° for the low vs. high handicap golfers, and in the follow through direction, the values were 77 vs. 53°. Thus, in this study vs. the previous study (6), seated trunk rotations were a little higher for the low handicap golfers and a little lower for the high handicap golfers.

There are some limitations to consider when placing these findings in context (1). Golf proficiency was determined based on the USGA handicap index and not a swing proficiency performance metric such as driving distance or ball speed. However, by excluding players with handicaps between 6 and 9, it was hoped that the groups would be clearly distinct in terms of swing proficiency. The goal was to use a golf proficiency measure that is universal to all golfers (2). As previously mentioned, the age difference between proficient and average golfers is a confounding factor (3). Female golfers were excluded to avoid the confounding effects of sex-based differences in flexibility; therefore, the importance of transverse flexibility shown here is specific to male golfers. Its importance for female golfers remains to be determined (4). Because this is a cross-sectional study, the extent to which improvements in transverse plane flexibility might improve golf performance is unknown.

In conclusion, compared with average golfers, proficient golfers had greater transverse plane flexibility and used greater trunk rotation flexibility during the golf swing. Trunk rotation during the backswing (x-factor) was predictive of ball speed and shot distance, whereas HIR flexibility and HER flexibility were also predictive of ball speed and shot distance.

Practical Applications

Fitness assessments for golfers have become very popular with various flexibility tests and movement screens performed in conjunction with swing analysis. Based on the findings here, the utility of flexibility and movement screening for golfers may be improved by focusing on the plane of movement being assessed. Transverse plane flexibility in the trunk and hips, and to a lesser extent in the shoulders, seems to be important for golf proficiency. Flexibility in the frontal and sagittal planes does not seem to be important. Optimal training programs should address the joint-specific movement demands of the sport. Golfers and their coaches should appreciate the potential limitations of having insufficient hip internal and external rotation flexibility or limited trunk rotational flexibility. Developing and maintaining trunk and hip rotation flexibility is important in the overall fitness of a golfer and for optimizing performance.

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