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Shoulder Motions During the Golf Swing in Male Amateur Golfers

Kim Mitchell, BS, BA[1]
Scott Banks, PhD[2]
David Morgan, MS[3]
Hiroyuki Sugaya, MD[4]

Study Design: Prospective descriptive biomechanical analysis of shoulder motion in golf.
Objective: To characterize normal shoulder motion during the driving swing in male recreational golfers of various age groups.
Background: Shoulder trauma accounts for approximately 12% of all golf-related injuries. To design sport-specific rehabilitation programs for the injured golfer and exercise programs for the healthy golfer, clinicians and teachers need quantitative information describing range of motion requirements about the shoulder for the amateur player.
Methods and Measures: Sixty-five male golfers were divided into 3 age groups: college, middle, and senior. A high-speed, 6-camera motion analysis system recorded 3-dimensional bilateral shoulder motion (vertical elevation, horizontal adduction, external rotation, and shoulder turn) for 3 swings of the driver. Group means for ranges and functional end points of motion were compared using a single-factor 1-way ANOVA (α = 0.05).
Results: All maximum values of shoulder motion were lower in the senior group than in the other 2 groups. At peak backswing, senior golfers exhibited 38° less right-side shoulder external rotation than college golfers. However, from address, seniors horizontally abduct the right arm 18° more than college golfers. In the older golfers, total range of motion was reduced for both shoulders in the vertical plane and for the left shoulder in the horizontal plane.
Conclusions: This study describes shoulder motion for asymptomatic golfers of various age groups. These data may serve as a baseline reference for assessing disease- or injury-related changes in the golf swing and for designing sport-specific exercise and rehabilitation programs. *J Orthop Sports Phys Ther. 2003;33:196–203.*

Key Words: *aging, golf, range of motion, shoulder kinematics, 3-dimensional motion analysis*

Golf is one of the few sports that can be fully enjoyed at any age or skill level, which accounts for its widespread and increasing popularity. The golfing community in the United States has grown 33% in the last 10 years to over 26 million individuals of whom 20% are between 40 and 49 years old and another 25% are over age 50.[29]

Unfortunately, even though golf is considered a low-intensity activity, it is not an injury-free activity. Most golf-related injuries are associated with overuse or poor swing mechanics,[10,19,20,25,36] with 8% to 21% of these injuries occurring at the shoulder.[3,17,26,27,35] To develop effective training and rehabilitative techniques for any athlete, there must be a clear understanding of the mechanics involved in accomplishing the sport. Therefore, it is important for clinicians and instructors to be aware of the typical range of motion (ROM) seen in the amateur golfer to better serve this population.

Normal motions at the shoulder throughout the golf swing have been described using qualitative evaluations of shoulder motion in golf,[23,25,36] and using measures of EMG activity in the muscles surrounding the shoulder joint.[17,18,21,31] While both of these types of studies are important to understanding the golf swing, neither type has provided a quantitative kinematic analysis of normal motion about the shoulder. Further, these studies have only looked at professional or very low (n<5) handicap golfers and may not be representative of the typical recreational player. Numerous studies comparing professional and amateur golfers[1,9,15,17,26–28,32,34,36] have found significant differences in trunk biomechanics, weight shift, and injury patterns between these 2 populations.

[1] *Biomechanist, The Biomotion Foundation, West Palm Beach, FL.*
[2] *Technical Director, The Biomotion Foundation, West Palm Beach, FL.*
[3] *Applications Engineer, Intech, Inc., West Palm Beach, FL.*
[4] *Director, Shoulder and Elbow Service, Funabashi Orthopaedic Sports Medicine Center, Funabashi, Japan.*
Study approved by the Good Samaritan Medical Center Institutional Review Board.
Send correspondence to Kim Mitchell, The Biomotion Foundation, 1411 N. Flagler Drive, Suite 9800, West Palm Beach, FL 33401. E-mail: kmitchell@bellsouth.net

A review of the literature reveals that shoulder ROM and flexibility is strongly correlated to the age of the subject.[2,4,7,11] Studies discussing shoulder injuries in golf also frequently mention the effects of aging, including the relationship between degenerative changes and rotator cuff tears.[3,19,20,34,36,37] Data from McTeigue et al[28] revealed that Senior PGA Tour professionals had less upper body rotation at peak backswing than PGA Tour professionals. This leads us to ask not only what the normal motions at the shoulder throughout the golf swing are, but also if those motions change with aging and its associated reductions in flexibility and ROM.

The primary objective of this investigation was to provide quantitative, age-related data for motion about the shoulder joint in the amateur golfer. This objective was accomplished using high-speed motion analysis of the driving swing in 3 different age groups of golfers. It was hypothesized that ranges and functional end points of shoulder motion would decline with increasing age.

METHODS

Subjects

One hundred ninety-eight golfers volunteered to participate in a larger study on motion analysis in golf. All participants signed an informed consent approved by the Good Samaritan Medical Center Institutional Review Board and completed an activity and medical history questionnaire.

Of these 198 golfers, 65 right-handed, male golfers were selected for analysis of shoulder kinematics. Subjects met the inclusion criteria for this study in that they had to be right-handed, injury-free, male golfers with a self-reported average score of less than 20 strokes over par. The subjects were divided into 3 age groups: college (18–24 years, based on typical age of college athletes), senior (≥50 years, based on Senior PGA Tour qualifier), and middle (25–49 years, participants that did not fall into other 2 groups) (Table 1).

TABLE 1. Data (mean and range) from study participants.

Group	n	Age (y)	Handicap
College*	19	20 (18–4)	3 (0–3)
Middle†	24	36 (27–48)	9 (0–19)
Senior‡	22	68 (50–86)	14 (0–19)

* <25 y
† 25–49 y
‡ ≥50 y

Data Collection and Reduction

Subjects were instrumented with 26 reflective spherical markers placed over selected anatomical landmarks (Figure 1). To assist in identifying specific events in the golf swing, 2 additional markers were placed on the individual's driving club (1 below the grip and the other at the hosel) and a piece of reflective tape was placed on the golf ball.

After performing their usual pregame warm-up (stretching and hitting practice shots with a 7 iron or driver), subjects hit a minimum of 5 balls with the driver into a net suspended from the ceiling. The testing session was considered complete when at least 3 acceptable swings had been recorded. Acceptance of a swing was based on data quality (lowest marker residuals, complete data on follow-through) and verbal feedback from the participant. Subjects hit from an artificial grass surface and the ball traveled approximately 4.5 m before hitting the net. The motion of the markers was recorded at a frequency of 180 Hz using a 6-camera motion analysis system (Motion Analysis Corp., Santa Rosa, CA). Three-dimensional marker coordinates were tracked using ExpertVision software (Motion Analysis Corp., Santa Rosa, CA). The raw data were smoothed using a fourth-order, zero-phase-shift, low-pass Butterworth filter with a cutoff frequency set at 12 Hz. Prior experiments demonstrated that a video recording frequency of 180 Hz was sufficient to capture the motions of the golf swing without collecting excessive data frames. Filtering with a 12-Hz cutoff frequency provided adequate smoothing without significant high-frequency signal attenuation.

The markers used to define shoulder mechanics in this study were placed bilaterally at the shoulders (tip of the acromion process), the elbows (lateral epicondyle of the humerus), and the wrists (between

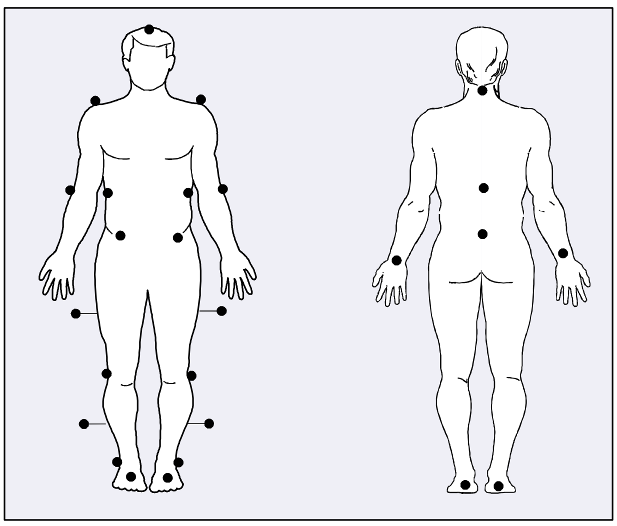

FIGURE 1. Anatomic location of 26 markers adhered to the skin during testing.

styloid processes of the radius and ulna), and 3 markers defined the pelvis at the anterior superior iliac spines (ASISs) and L5 sacral interface. After the initial tracking with the commercial software described above, the data were further analyzed to determine shoulder kinematics according to the conventions described by Dillman et al.[8] Shoulder joint centers were calculated by translating the bilateral shoulder markers inferiorly 8.25 cm along the direction of the trunk and laterally 3.5 cm along the line of the shoulders. The magnitude of the translation was verified using radiographs from 8 subjects, taken of the right shoulder with a reflective marker attached. Hip joint centers were calculated by translating the bilateral ASIS markers inferiorly, posteriorly, and laterally based on a percentage of the distance between the ASIS markers of each subject.

Shoulder Kinematics

Shoulder kinematics were described using the angles illustrated in Figure 2 and described below.

Vertical Elevation (VE) Absolute angle between the humerus and a vector connecting a point midway between the shoulder joint centers to a point midway between the hip joint centers (trunk vector). Clinically, this is a combination of shoulder forward flexion and shoulder abduction. An angle of 0° is defined when the upper arm is parallel to the trunk vector and next to the body.

Horizontal Adduction (HA) Motion of the humerus in the plane perpendicular to the trunk vector described above (transverse plane of the body). An angle of 0° is defined when the upper arm lies in the plane defined by the trunk vector and the vector connecting the shoulder joint centers.

External Rotation (ER) Lateral rotation of the humerus about its long axis. This angle was determined by calculating the angle of the forearm in the plane perpendicular to the humerus. The reliability of this angle calculation is reduced when the elbow flexion angle is less than 10° due to the pin joint segment model (2 markers per segment on the upper extremity).

Shoulder Turn (ST) Upper body rotation in the transverse plane of the global coordinate system. This is the angle between the vector connecting the shoulder joint centers and the x-axis of the room (target line). When the golfer's shoulders are parallel to the target line, this angle is 0°.

Events

The golf swing was segmented at the following 6 events, which are illustrated in Figure 3.

Address (AD) The instant before the club begins to move toward the backswing.

Backswing Horizontal (BH) The club is parallel to the ground during backswing.

Peak Backswing (PK) The club changes direction from backswing to downswing.

Downswing Horizontal (DH) The club is parallel to the ground during downswing.

Impact (IM) The club strikes the ball.

Follow-Through Horizontal (FH) The club is parallel with the ground during follow-through.

Data Analysis

The 3 highest quality accepted trials for each golfer were averaged and shoulder kinematics were com-

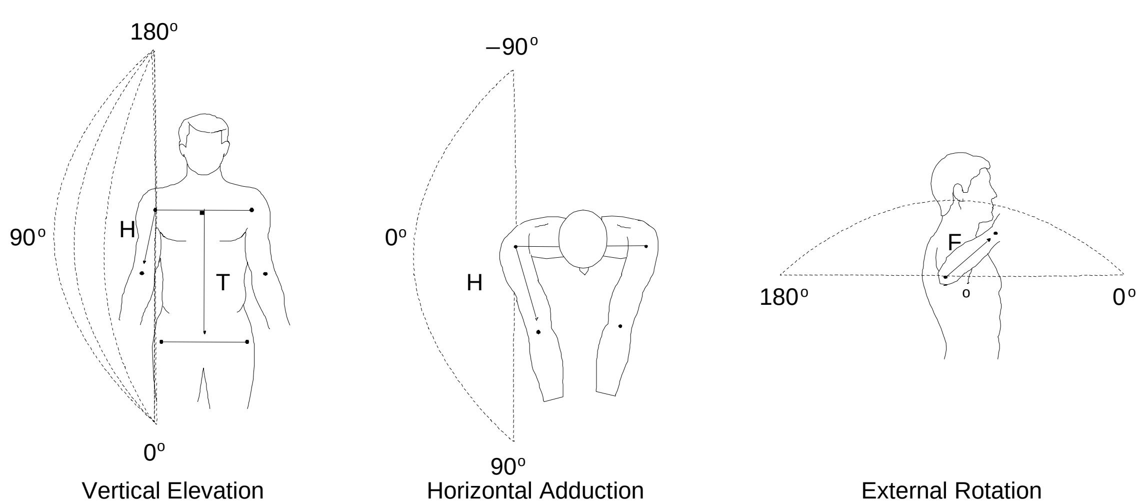

FIGURE 2. Shoulder kinematics were described using a combination of vertical elevation, horizontal adduction, and external rotation. Abbreviations: H, humerus; T, trunk vector; F, angle of forearm.

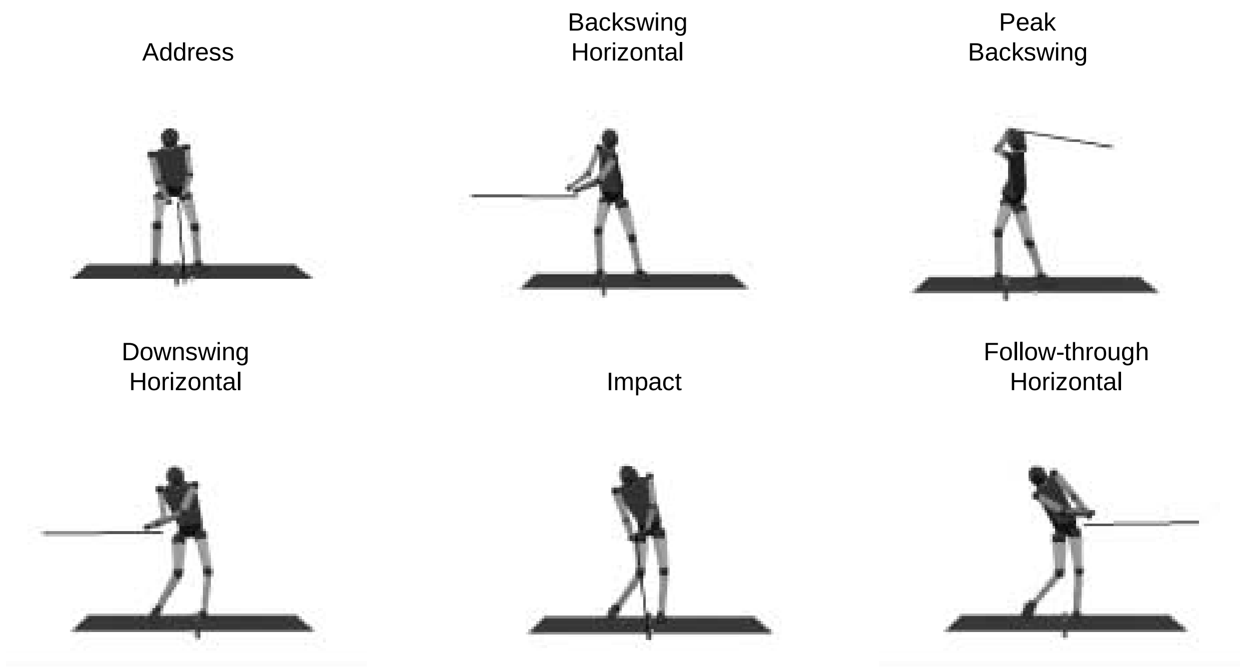

FIGURE 3. Shoulder kinematics were analyzed in relation to 6 specific events of the golf swing.

puted for the full swing and at each event. Group ranges and functional end points of motion (minimum and maximum values) were compared for most kinematic parameters across the entire swing. External rotation was not computed during the portion of the swing when the elbow flexion angle was less than 10°. When this occurred, it was between address and backswing horizontal, and between impact and follow-through horizontal.

Curves for horizontal adduction, vertical elevation, and shoulder turn were obtained by normalizing each golfer's swing from AD to FH (0%–100%) and averaging for each group. Normal curves were not computed for external rotation due to the limitations of the marker setup. The percent of the swing for each event was computed by taking the number of frames between events and dividing by the total number of frames (AD to FH). A cubic spline interpolation of the kinematic data was then fit to each swing segment to obtain the normalized parameter.

Parameter means between age groups were analyzed using a 1-way ANOVA (α = 0.05) and a Tukey post hoc test was used for pairwise comparisons when a significant difference was found.

A Pearson product moment correlation was used on the entire sample to identify relationships between age, handicap, and the kinematic parameters. The effect of handicap (indicative of subjects' skill level) on each swing parameter was then analyzed within each age group also using a Pearson correlation statistic.

RESULTS

The different movement patterns between the 3 age groups are illustrated in Figures 4 and 5 by a plotting of horizontal and vertical motions together from AD to FH. In the address position, the right arm for all 3 groups is elevated approximately 40° (due primarily to forward lean of the trunk) and horizontally adducted 80° to 95° (Figure 4). Moving from AD to PK, the right arm is vertically elevated to approximately 60° by all 3 groups. At PK, however, HA ranges from less than 20° in the senior group to almost 40° in the college group. The college and middle groups quickly lower the right arm through the downswing to approximately 20° VE while maintaining roughly the same horizontal position. In contrast, the senior group minimally lowers the right arm while increasing HA. After impact, all 3 groups elevate and adduct the right arm to approximately 50° VE and 95° HA at FH.

The left arm (Figure 5) begins the driver swing around 40° VE and 95° HA in all 3 groups. At PK, VE ranges from 95° in the seniors to approximately 110° degrees in the other 2 groups. All golfers lowered and abducted the left arm through the downswing, returning near the AD position at IM. At FH, VE was between 30° and 40° for all groups. Average left arm adduction at FH ranged from 75° in the college-aged golfers to less than 60° in the seniors.

The maximum values reached for horizontal adduction, vertical elevation, external rotation, and shoulder turn were lower in the senior group ($P<0.05$) than in the other 2 groups (Table 2). The

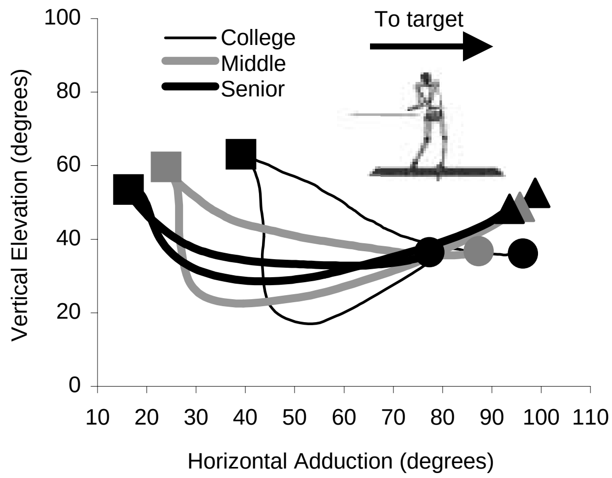

FIGURE 4. Right shoulder horizontal versus vertical motion from address (●) through peak backswing (■) to follow-through horizontal (▲). This figure illustrates different movement patterns between the 3 age groups. Note: values don't perfectly match the data in Table 2 because of the process of averaging the movement pattern across subjects.

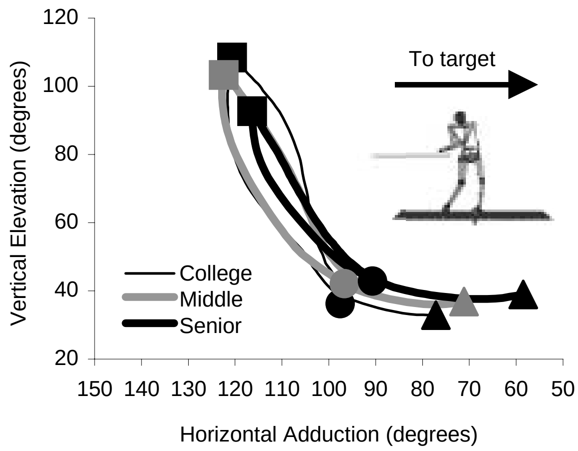

FIGURE 5. Left shoulder horizontal versus vertical motion from address (●) through peak backswing (■) to follow-through horizontal (▲). This figure illustrates different movement patterns between the 3 age groups. Note: values don't perfectly match the data in Table 2 because of the process of averaging the movement pattern across subjects.

significantly lower value ($P<0.05$) exhibited by the middle and senior golfers for minimum HA on the right side indicates that these groups bring the right arm farther back horizontally (less horizontal adduction) during peak backswing than the younger group. It can also be noted that the college-aged golfers had less left horizontal adduction during follow-through than the other 2 groups, but the difference was not statistically significant.

Total ROM in the vertical plane was lower in older golfers for both the left and right shoulders (Table 3). In the horizontal plane, total motion on the left was less in the senior group than in the college golfers, while on the right, the younger golfers exhibited less total motion.

Correlation on the entire sample revealed a moderate relationship between age and handicap ($r = 0.645$, $P<0.001$). Correlations within each age group, however, revealed no significant relationship between handicap and any of the kinematic parameters.

DISCUSSION

With more individuals golfing, particularly in the senior sector, injuries are bound to occur. The shoulder joint ranks among the top 5 most injured sites, with reports ranging from 8% to 21% of all golf injuries.[3,17,26,27,35] Problems at the shoulder due to aging include loss of flexibility, rotator cuff degeneration, and acromioclavicular joint degenerative arthri-

TABLE 2. Maximum and minimum shoulder joint angles (mean ± SD in degrees). Swing phase refers to the event of the swing when the indicated angle occurs.

	College	Middle	Senior	Swing Phase*
Horizontal adduction				
Left-side max	125 ± 7[a]	126 ± 7[a]	119 ± 6	Near PK
Right-side max	121 ± 8[b]	114 ± 7[b]	108 ± 8[b]	After FH
Left-side min	14 ± 16	26 ± 21	23 ± 15	After FH
Right-side min	29 ± 20	12 ± 23[c]	11 ± 20[c]	Near PK
Vertical elevation				
Left-side max	110 ± 10[a]	107 ± 9[a]	94 ± 8	After PK
Right-side max	112 ± 8[a]	114 ± 11[a]	103 ± 11	After FH
External rotation				
Left-side max	80 ± 11[a]	77 ± 14[a]	59 ± 14	After FH
Right-side max	86 ± 19[b]	71 ± 16[b]	48 ± 17[b]	Near PK
Shoulder turn				
Away from target	106 ± 10[a]	100 ± 12[a]	85 ± 12	After PK
Towards target	160 ± 12[b]	142 ± 18[b]	124 ± 22[b]	After FH

Abbreviations: PK, peak backswing; FH, follow-through horizontal.
[a] Significantly different than senior ($P<0.05$).
[b] Significant difference between all groups ($P<0.05$).
[c] Significantly different than college ($P<0.05$).

TABLE 3. Total range of motion in the golf swing (means ± SD in degrees).

	College	Middle	Senior
Horizontal adduction			
Left side	111 ± 19[a]	99 ± 19	96 ± 17
Right side	92 ± 18	101 ± 21	97 ± 22
Vertical elevation			
Left side	80 ± 11[a]	74 ± 8[a]	59 ± 10
Right side	96 ± 12[a]	94 ± 14[a]	78 ± 13

[a] Significantly different than senior ($P<0.05$).

tis,[4,7,13,37] all of which can be aggravated by the repetitive nature of the golf swing.[19,27]

The literature abounds with the importance of sport-specific warm-up, training, and rehabilitation programs.[12,14,16,20,22] A significant factor in the design of these types of programs is familiarity with the required ROM for the activity, yet no studies to date have looked at age-based typical ROM about the shoulder joint in the amateur golf swing.

According to the National Golf Foundation,[29] the majority of golfers regularly score over 90 strokes on an 18-hole course (>18 handicap). Consequently, the subjects in this study would be considered skilled golfers for their respective age groups (handicap range, 0–19). However, as the primary goal of this investigation was to establish age-based normative data, we required our subjects to have a consistent swing pattern, which is not usually found in beginning players. While a golfer's handicap is influenced by a large number of factors and may be heavily weighted by 1 aspect of his game, it is 1 of the few criteria that can be used to distinguish capable players from less skilled players.

As hypothesized, ranges and functional end points of motion were lower in older golfers for most of the parameters. The most notable difference was in maximum shoulder external rotation. On the right side, seniors showed 23° and 38° less external rotation compared to the middle group and the college group, respectively ($P<0.05$). On the left side, seniors had 18° less external rotation than the middle group and 21° less than college golfers ($P<0.05$).

Seniors showed reduced ranges in the horizontal and vertical planes as well. On the right side, seniors had 16° less total ROM in the vertical plane than the middle group, and 18° less than the college group ($P<0.05$) (Figures 4 and 5). On the left side, seniors had 21° less total ROM in the vertical plane than the college group and 15° less in the horizontal plane ($P<0.05$). The observed reductions in the senior golfers' shoulder motions are not surprising as similar age-related decreases in shoulder flexibility are seen in the general population.[2,7,11]

Sports-related shoulder injuries are commonly classified as injuries either caused by acute trauma or those which result from overuse. The latter are most often described in those athletes participating in overhead sports such as swimming, tennis, baseball, and volleyball.[16,30] A frequently mentioned mechanism of injury in these athletes is the cocking phase, in which the arm is elevated in preparation for the acceleration portion of the activity. The joint is placed under additional stress as the muscles move to decelerate the limb. Shoulder injuries can result with constant repetition of this cycle.[8,12] Even though golf is not typically considered an overhead sport, these data show that the left arm of the college and middle groups spends over 30% of the swing time (AD to FH) vertically elevated above 90°. Unfortunately, this is while the left shoulder is also maximally adducted in the horizontal plane. This combination of horizontal and vertical extremes has been shown to be a mechanism for shoulder injury, particularly with the number of repetitions required during the course of play and practice.[19,25,34,36]

The only area where older golfers had greater shoulder motion was in the horizontal plane on the right side near peak backswing (minimum HA). Seniors horizontally abducted their right shoulder 18° more than the college group at PK. McTeigue et al[28] compared spine and hip motion in 131 golfers in a study that included a comparison of upper body rotation (ie, shoulder turn) between PGA Tour professionals, Senior PGA Tour professionals, and amateurs. The data revealed a 10% decrease in the seniors' shoulder turn at PK as compared to the other 2 groups. Our data show a 20% difference in maximum shoulder turn at PK between the senior and college groups. Because the maximum amount of shoulder turn at the top of the backswing has been related to power and club head speed,[6,23,28,32] the increased right-side horizontal abduction seen in seniors at this event may be a strategy used by proficient older golfers to compensate for reduced shoulder turn. By bringing the right arm farther back at PK, older golfers may be able to increase the arc of the backswing without having to increase the amount of shoulder turn or axial rotation of the spine. This observation may lead to a teaching alternative when working with individuals lacking the degree of spinal rotation required for a full backswing.

The differences noted between age groups in ranges and functional end points of motion could possibly be linked to skill, denoted specifically by handicap. However, there were no statistically significant relationships between handicap and shoulder motions within any of the age groups, therefore, these variations are more likely related to the degenerative changes and losses in flexibility associated with aging.[4,5,13,24,33] Support of this theory can be found in the data of McTeigue et al,[28] where it appears that age, not expertise, is the factor responsible for reduced upper body rotations. While specific studies that isolate the effects of aging from those of skill were not found, it appears that as a player ages, his handicap increases. This relationship is implied by the number of separate senior golfing events at both the professional and amateur or recreational levels.

CONCLUSION

Most shoulder motions decrease with age in healthy amateur golfers. The only exception is in the horizontal plane where seniors bring the right arm in significantly more horizontal abduction at peak backswing than younger golfers. This appears to be a strategic modification of swing mechanics used by older golfers to obtain the power in the backswing that may be lost due to age-related decreases in trunk flexibility (rotation).

The age-based ranges and functional end points of motion obtained in this study give instructors, coaches, and trainers sport-specific guidelines for shoulder ROM in amateur golfers. Additionally, this work establishes a database from healthy, asymptomatic male golfers that can be used as a foundation for future studies investigating mechanisms of injury in the less skilled amateur golfer and provides a baseline for assessing disease-related changes in the golf swing.

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