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Trunk Motion of Male Professional Golfers Using Two Different Golf Clubs

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Low back problems account for the largest proportion of injuries among amateur and professional golfers. However, there is little data on how the trunk or spine moves during a golf swing. Also, it may be that different golf clubs produce different trunk motion characteristics. The purpose of this study was to compare trunk range of motion (ROM) and velocity in three movement planes during the execution of a full golf swing using a driver and a 7-iron. Forty-four members of the Alberta Professional Golf Association volunteered to participate in this study. Trunk ROM and velocities in the sagittal, frontal, and transverse planes were measured using a triaxial electrogoniometer. Results showed that significantly more trunk flexion was required when setting up to hit the ball with the 7-iron compared to the driver, $p < 0.05$. During the swing, significantly greater maximum flexion and left-side-bend ROM occurred when using the 7-iron, $p < 0.05$. Maximum right-side-bending velocity during the golf swing was also significantly greater with a 7-iron. These findings suggest that differences in shaft length and ball positioning associated with the different clubs affects swing mechanics and trunk/spinal motion. In particular, the shorter club (7-iron) tended to place more emphasis on lateral trunk motion than did the driver. The results from this study may help clinicians better understand how the golf swing creates stress on the back as well as how club fitting may affect trunk motion characteristics.

Key Words: biomechanics, axial rotation, lumbar spine

Introduction

Low back injuries account for the majority of musculoskeletal problems affecting amateur and professional golfers (McCarroll, 1996; McCarroll, Rettig, & Shelbourne, 1990; Sugaya, Tsuchiya, Moriya, Morgan, & Banks, 1999). The causes of such injuries have been attributed to poor or altered technique and overuse (Hosea & Gatt, 1996; McCarroll & Gioe, 1982; McCarroll et al., 1990). It has also been

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suggested that spinal injury may be related to the extreme ranges of motion and loads placed on the back during the golf swing (Stover, Wiren, & Topaz, 1976; Sugaya et al., 1999).

To date there has been little scientific reporting of spinal biomechanics during the golf swing. Hosea, Gatt, Galli, Langrana, and Zawadsky (1990) calculated spinal loads on the L3-4 segment of eight golfers during golf swings using a 5-iron. They reported that on average golfers produced spinal compression loads of over eight times body weight. In comparison, running produced compression loads of only three times body weight.

McTeigue, Lamb, Mottram, and Pirozzolo (1994) used an externally mounted instrumented spinal linkage apparatus to measure the trunk motion of 51 male PGA Tour players, 46 male Senior Tour players, and 34 male amateur players in an effort to determine differences in torso motions between average golfers and Tour players. Results showed that Tour players used significantly more side bend (lateral flexion) motion on the downswing than recreational golfers.

Morgan, Sugaya, Banks, and Cook (1997) used a 3-D motion analysis system to measure axial rotation and side bending in 10 male college golfers. They reported that the golf swing produced a distinctly asymmetric trunk motion involving a combination of left axial rotation and right lateral bending (right- handed golfers). Both axial rotation velocity and right-side-bending angles reached peak values almost simultaneously and just after ball impact.

While these studies have provided some kinematic information about the trunk during the golf swing, certain motion characteristics have not been reported, for example side bending velocity. Also, the available information has pertained to the use of a single type of golf club, typically the driver. Quantifying trunk motion using a variety of clubs would allow a better understanding of the stresses encountered by the structures of the trunk (e.g., the spine) during different golf shots. Therefore, it was the purpose of this study to compare trunk range of motion (ROM) and velocity in three movement planes during the execution of full golf swings using a driver and a 7-iron.

Methods

Forty-four male professional golfers from the Alberta Professional Golf Association (29.3 ± 4.9 yrs; 179.3 ± 6.1 cm; 83.1 ± 13.3 kg) volunteered to participate in this study. They all completed a Physical Activity Readiness Questionnaire (PAR-Q) and gave their informed consent prior to any testing procedures. The University of Calgary Conjoint Faculties Research Ethics Committee granted ethical approval for the study.

Spinal motion characteristics during the golf swing were assessed using a device known as a lumbar motion monitor (Wellness Design™, Chattanooga Group Inc., Hixson, TN). The lumbar motion monitor (LMM) is a triaxial electrogoniometer capable of assessing the instantaneous 3-D motion of the thoracolumbar torso. The device consists of an exoskeleton that is anchored to the upper (scapula) and lower (pelvic) parts of the back by means of a chest harness and pelvic strap (Figure 1). Potentiometers attached to the exoskeleton detect voltage changes as the torso moves. The voltage signals are sampled at 60 Hz via an analog-to-digital converter and processed to provide a representation of trunk position, velocity, and acceleration as a function of time.

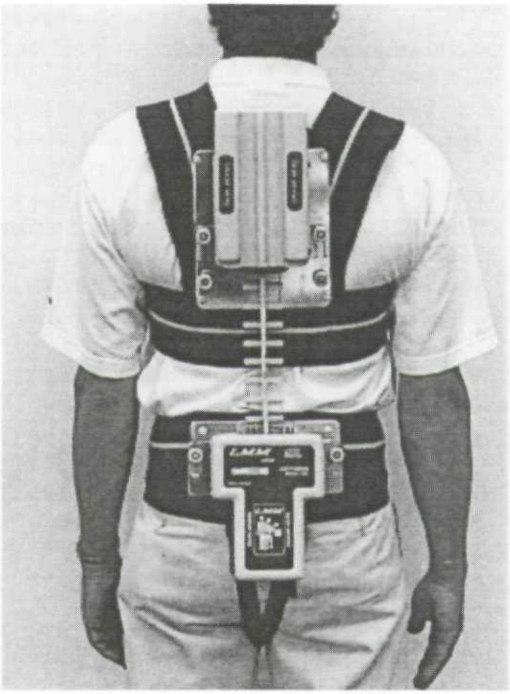

Figure 1 — Positioning of the lumbar motion monitor (Wellness Design™, Chattanooga Group Inc., Hixson, TN).

Position accuracy of the LMM compared to a 3-D reference frame has been reported at over 98%, while velocity and acceleration correlation coefficient values using high-speed motion analysis for comparative purposes have also shown a very high degree of agreement, $r > 0.95$, $p < 0.0001$ (Marras & Fattalah, 1992). Furthermore, a single-participant comparison of trunk motion obtained from the LMM and a 6-camera motion analysis system (Motion Analysis Corp., Santa Rosa, CA) at the University of Calgary Human Performance Laboratory revealed a high degree of consistency for all motions, with only the maximum flexion angles showing more than 10% variation between systems. Pilot trials and interviews indicated that the LMM did not restrict a player's normal movements during the golf swing.

The testing protocol was carried out at a local driving range and lasted approximately 30 minutes. Each golfer received an explanation of the testing procedure, followed by a warm-up that involved stretching exercises and several practice swings. The LMM was then attached and golfers were instructed to strike golf balls until they felt they were ready to be tested.

Immediately prior to data collection, the LMM was calibrated with the golfer standing in an upright and anatomically neutral posture. The angles recorded from each golfer during testing were therefore a measurement of ROM deviation from this anatomically neutral position. After the LMM was calibrated, the golfers were given their driver or 7-iron and asked to assume a normal address position. Trunk angles in this position were then recorded. Following the address position measurement, the golfers were required to perform three maximal-effort shots each with the driver and the 7-iron. Spinal ROM and velocity in the three movement planes were recorded for each shot with the two clubs. The club to be tested first (the driver or the 7-iron) was randomly assigned.

All data were found to be normally distributed (Kolmogorov-Smirov Test). Statistical differences in ROM and velocity between the driver and the 7-iron were determined with paired *t*-tests. Statistical analyses were performed with SPSS.

Results

The results presented below are described relative to a right-handed golfer. Right trunk rotation would mean the player turned his torso to the right, away from the target, for example during the back-swing.

Trunk angles associated with the static address position are shown in Table 1. A significantly greater amount of forward flexion, $p = 0.02$, was noted when setting up to hit the ball with the 7-iron compared to hitting with the driver. The maximum ROM recorded in the different movement planes during swings with the different clubs are shown in Table 2. The only significant differences in maximum ROM between the driver and the 7-iron were for the flexion and left-side-bending angles. Trunk velocity results are shown in Table 3. The 7-iron produced a significantly higher right-side-bending velocity, $p = 0.02$, than did the driver.

Table 1 Spinal Range of Motion Means (deg) and Standard Deviations for the Address Position

Club	Flexion	Right side bend	Left rotation
Driver	28.9 ± 10.9	6.9 ± 3.4	6.3 ± 3.3
7-iron	35.1 ± 12.8	6.7 ± 3.2	5.6 ± 4.5
	$p = 0.02$	$p = 0.75$	$p = 0.42$

Table 2 Maximum Spinal ROM Means (deg) and Standard Deviations for the Golf Swing

Club	Flexion	Extension	Left side bend	Right side bend	Right rotation	Left rotation
Driver	45.6 ± 9.7	2.8 ± 9.9	7.1 ± 6.0	26.3 ± 5.2	37.0 ± 8.4	44.5 ± 10.5
7-iron	51.0 ± 9.9	3.0 ± 8.9	9.8 ± 5.9	27.9 ± 4.8	34.8 ± 8.8	40.4 ± 10.1
	$p = 0.01$	$p = 0.89$	$p = 0.04$	$p = 0.14$	$p = 0.24$	$p = 0.06$

Table 3 Average Maximum Spinal Velocities (deg/sec) During the Golf Swing

Club	Flexion	Extension	Left side bend	Right side bend	Right rotation	Left rotation
Driver	60.9	137.9	38.4	109.2	88.2	194.8
	±33.7	±47.3	±14.9	±25.3	±20.5	±54.6
7-iron	57.5	138.3	40.7	121.7	83.5	180.3
	±32.6	±43.7	±13.5	±24.8	±20.1	±50.8
	$p = 0.63$	$p = 0.97$	$p = 0.46$	$p = 0.02$	$p = 0.28$	$p = 0.20$

Discussion

The results of the study showed that golf swings of elite players involved considerable trunk ROM and velocity. It was also clear that different golf clubs, in this case the driver and the 7-iron, produced different trunk motion characteristics.

The professional golfers in this study averaged 28.9 ± 10.9° of forward flexion when addressing the ball with the driver (Table 1). These findings were consistent with McTeigue et al. (1994), who observed 28 ± 8° of forward flexion among PGA Tour players. No previous study has measured trunk ROM while using golf clubs other than a driver. The address-position flexion angles recorded in this study using the 7-iron (35.1 ± 12.8°) were significantly higher than the driver results, $p = 0.02$. These findings were not unexpected, considering that the 7-iron is approximately 18 cm shorter than the driver, and the ball was positioned on the ground when using the 7-iron compared to an elevated tee when using the driver. The shorter shaft length and lower ball position likely also accounted for the significantly greater maximum flexion angle observed during actual swings with the 7-iron compared to the driver. While it was not the purpose of this study to determine causes of low back pain among golfers, it is feasible that the increase in flexion associated with the use of a 7-iron would result in increased stress on the low back.

The explanation for increased left-side bending using the 7-iron may also relate to club shaft length and its associated influence on swing plane. Swing plane refers to the oblique plane in which the golf club is moved during the swing. The shorter 7-iron typically requires the ball to be positioned closer to the body than does the driver. This, in combination with a lower ball position, requires a more vertical orientation of the7-iron shaft during the setup (Figure 2) as well as during the actual swing, compared to the driver. As the club is accelerated, the centrifugal force associated with a more vertical or steeper swing plane may drive the hips laterally, thus increasing the side-bend motion of the trunk. Table 2 shows greater left- and right-side-bend motions during swings with the 7-iron, although only the former was significant. Side bending of the spine during the golf swing has been postulated to be a contributing factor to low back injury (Morgan, Cook, Banks, Sugaya, & Moriya, 1999; Sugaya et al., 1999).

Left rotation (toward the target) using the driver produced about 10% more ROM than did the 7-iron (Table 2). This difference fell just short of reaching sta-

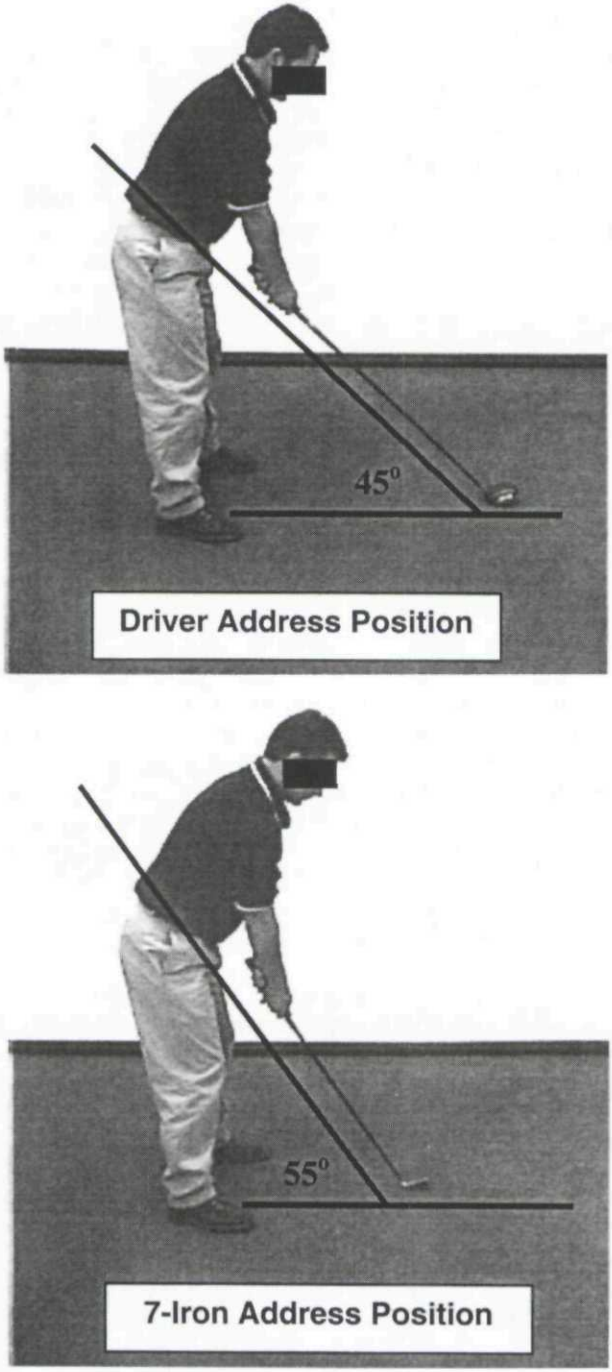

Figure 2 — Comparison of shaft angles and address postures using the driver (top) and the 7-iron (bottom) golf clubs.

tistical significance, $p = 0.06$. The higher left rotation ROM may be explained by the higher left rotation velocity achieved with the driver on the downswing (Table 3), resulting in greater momentum to push the trunk into left rotation at the finish of the swing. The high amount of left rotation suggests that golfers should stretch and warm-up properly before swinging aggressively, especially with a driver, otherwise injury could occur from overexertion.

The only significant difference in trunk motion velocity between clubs was right-side bending, $p = 0.02$, with the 7-iron producing the higher values. This was somewhat surprising as the club head speed achieved with the driver is typically much higher than with the 7-iron. It would therefore seem logical that trunk velocity at impact would also be greater for the driver. These findings may again be related to the 7-iron requiring a more vertical swing plane, thus producing more lateral vs. rotational motion on the downswing.

Although no significant differences were found in left rotation velocity between clubs, a noticeably higher average velocity was observed with the driver. As the driver is capable of hitting a golf ball the farthest distance of all golf clubs, it is likely that golfers tend to swing harder with this club, thus resulting in greater left rotation velocities. Morgan and colleagues reported maximum axial rotation velocities with a driver of $202 \pm 19°/s$ (Morgan et al., 1999) and $248 \pm 85°/s$ (Morgan et al., 1997), which were reasonably consistent with the results of the present study for the same club ($194.8 \pm 54.6°/s$).

In concluding, it is evident that different clubs produce different trunk motion characteristics. These findings offer valuable information for teachers when assessing the swing techniques of their students. Furthermore, the resultant effect of these motions on the spine, especially in terms of increased flexion and side bending when using shorter clubs, may have implications for clinicians in the prevention or control of low back pain. Clearly, more research is needed to help us understand the implications of golf club design and construction, not only on the kinematics of the spine but also the rest of the body. Gender and age factors also need to be studied.

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