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Spine Biomechanics Associated with the Shortened, Modern One-Plane Golf Swing

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ABSTRACT

The purpose of this study was to compare kinetic, kinematic, and performance variables associated with full and shortened modern backswings in a skilled group of modern swing (one-plane) golfers. Shortening the modern golf backswing is proposed to reduce vertebral spine stress, but supporting evidence is lacking and performance implications are unknown. Thirteen male golfers performed ten swings of each swing type using their own 7-iron club. Biomechanical-dependent variables included the *X*-Factor kinematic data and spine kinetics. Performance-related dependent variables included club head velocity (CHV), shot distance, and accuracy (distance from the target line). Data were analysed with repeated measures ANOVA with an a priori alpha of 0.05 (SPSS 22.0, IBM, Armonk, NY, USA). We found significant reductions for the *X*-Factor ($p < 0.05$) between the full and shortened swings. The shortened swing condition ameliorated vertebral compression force from 7.6 ± 1.4 to 7.0 ± 1.7 N (normalised to body weight, $p = 0.01$) and significantly reduced CHV ($p < 0.05$) by ~2 m/s with concomitant shot distance diminution by ~10 m ($p < 0.05$). Further research is necessary to examine the applicability of a shortened swing for golfers with low back pain.

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Introduction

Low back pain (LBP) is the most frequently reported injury experienced by golfers (accounts for up to 50% of all complaints) and is responsible for reducing sport participation in both amateur and professional golfers (Evans, Refshauge, Adams, & Aliprandi, 2005; Gluck, Bendo, & Spivak, 2008; Gosheger, Liem, Ludwig, Greshake, & Winkelmann, 2003; Hosea & Gatt, 1996; Lindsay & Horton, 2002; McHardy, Pollard, & Luo, 2006, 2007). Swing mechanics and physical limitations (e.g. spine hypomobility) are two factors associated with LBP in golfers (Hosea & Gatt, 1996; Lindsay & Horton, 2002, 2006; Lindsay & Vandervoort, 2014). Consequently, the modern, one-plane swing is associated with axial rotation as the trunk and shoulders rotate about a relatively fixed pelvis, which coils the trunk creating an '*X*-Factor' (Hume, Keogh, & Reid, 2005). This swing requires spine mobility, and Lindsay and Horton found that golfers with LBP perform greater active trunk rotation during their golf swing when compared to their pain-free active voluntary trunk rotation obtained in the clinic. Therefore, golfers exceeding their usual or pain-free rotational range of motion during the golf swing potentially overstress the spine, and this may be related to their pain (Lindsay & Horton, 2002). Therefore, if spine mobility is a limitation of individuals with LBP, and yet spine mobility is requisite for the modern golf swing, then the golfer faces the challenge of either adopting a novel swing, modifying their existing swing, or perhaps limiting their golf participation.

Furthermore, only a few studies have examined spinal mechanics during a full golf swing. Previous work shows that spinal compressive forces exceed 6,000 and 7,000 N for amateur and professional golfers; respectively, during the full modern one-plane golf swing and these forces peaked close to ball impact (Hosea & Gatt, 1996). Since the full golf swing is associated with large lumbar compressive forces then it is plausible that shortening the backswing would reduce spinal rotation, and the inherent forces incurred. No studies to date have examined spine kinetics associated with the shortened one-plane golf swing.

The purpose of this study was to compare various kinetic, kinematic, and performance variables between the full and shortened golf swings of skilled golfers. The data from this study would provide information regarding the concept of golf-swing modification and its effect upon the human spine and golf performance. We hypothesised that a shortened swing would ameliorate spinal stresses by reducing axial rotation and subsequently decreasing performance-related club head velocity (CHV). Given that CHV and spine forces are related, we also surmise these both peaks close to ball impact for both swing types. If forces acting upon the lumbar spine are reduced from swing modification, and if the majority of LBP syndromes are associated with cumulative stress, then it may stand to reason that swing modification could be acceptable for some individuals with LBP.

Methods

Thirteen participants participated after providing written, informed consent approved by the Institutional Review Boards (IRB) of the University of South Alabama, USA and University of Tennessee at Chattanooga, USA. Participants were 38.8 ± 4.2 in years of age, 1.8 ± 0.1 m in height, weighed 83.6 ± 3.0 kg, and had 16.0 ± 1.4 years of experience with a skill-level of 7.1 ± 0.8 strokes according to United States Golf Association (USGA) handicap (means ± SEM). An IRB-approved flier describing the study was placed at local golf courses for participant recruitment. Participants were excluded with a history of any injury or surgery within the last year. Furthermore, participants should have been playing golf for at least three years with a USGA handicap of ten or less. In the first session, informed consent was obtained and descriptive information was collected from each golfer. Additionally, a physical assessment was performed by a physical therapist certified by the Titleist Performance Institute as a Golf Fitness Instructor (lead author) to ensure the participants' safety and ability to participate in this study (D'Amico, Betlach, Senkarik, Smith, & Voight, 2007).

A professional golf instructor, certified by the Professional Golf Association of America, taught the shortened backswing technique to each participant. Each golfer was to produce their usual swing, but with decreased trunk rotation during the backswing. This technique was described and taught as the lead shoulder moving to a position directly over the back foot during the backswing during their usual swing, which effectively shortened the

(a) (b)

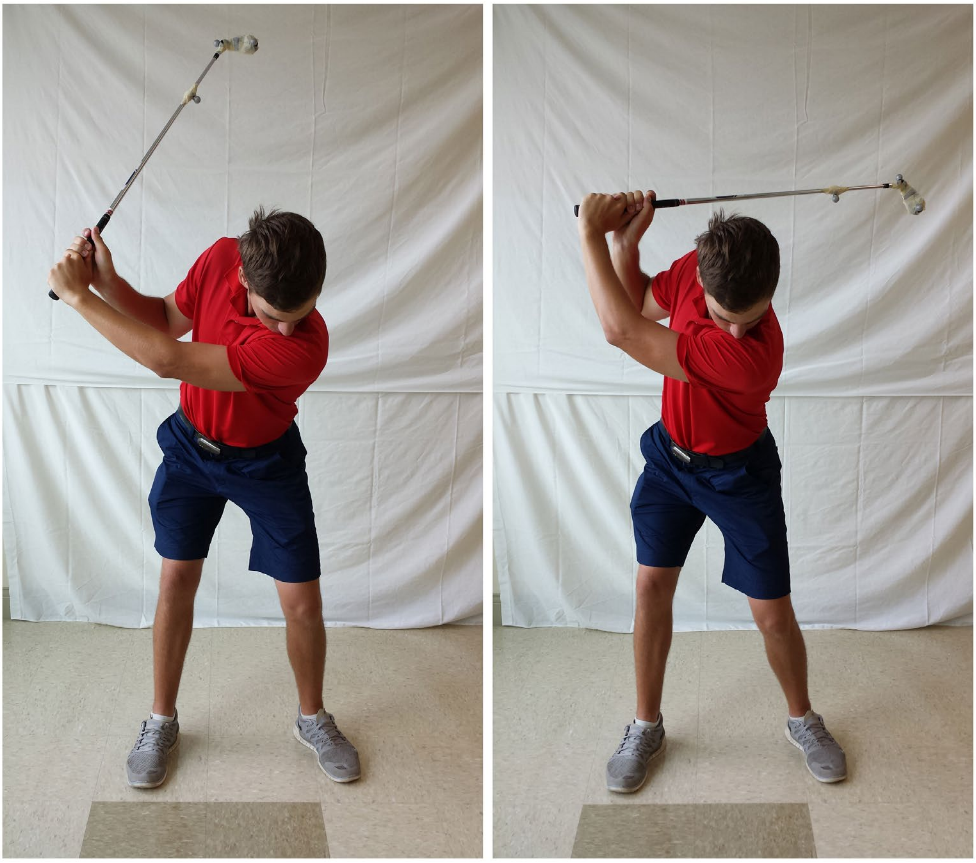

Figure 1. (a) and (b) Photographs of the modern golf swing: shortened (a) and full backswings (b).

backswing (Figure 1a) (Bulbulian, Ball, & Seaman, 2001). Participants performed several practice swings to achieve an acceptable backswing angle, during which feedback was given from two-dimensional (2D) frontal plane view camera data and from the instructor's observation. The participant could proceed with data collection once they felt comfortable with the modified swing and consistently met the appropriate backswing angle (see operational definitions below) for five consecutive swings according to 2D camera data. We found that participants could consistently produce the modification typically with 5–15 practice swings.

Participants performed a total of 20 swings that were divided into 4 sets of 5 swings. Players alternated between the shortened and full swings with each set of five swings, yielding a total of ten swings for each swing type. The alternating sequence of five swings was used to minimise the chance of an ordering effect. The order of swings was counterbalanced so that some participants began with the full backswing and others with the shortened backswing. Participants used their own 7-iron club for all swings to ensure consistency (Bulbulian et al., 2001).

Data collection occurred indoors in a motion analysis laboratory. Eight infrared cameras (Vicon MX, Denver, CO, USA) captured data at 240 Hz while the participant produced the swings on two force plates (1,000 Hz) mounted within the floor (Bertec, Columbus, OH, USA).

Three-dimension (3D) motion data were captured and processed using a full-body inverse dynamic model with Vicon Nexus (Vicon, Denver, CO, USA). We utilised the Vicon Golf model, which is based on the full-body Vicon Dynamic Gait model utilising 39 markers for the body and four markers for the golf club (Najafi, Lee-Eng, Wrobel, & Goebel, 2015). Reflective markers were placed on the participants body in the following locations: Four markers were placed on the head with two in the front and two on the back of the head; four markers were placed on the pelvis with a marker on each anterior and posterior superior iliac spines; and single markers were placed upon the landmarks of C7, T10, right scapula, jugular notch, xiphoid process, acromion processes, lateral humeral epicondyle, radial and ulnar styloid processes, second metacarpal head, lateral femoral condyle, lateral malleolus, calcaneus, and second metatarsal head. These were arranged in bilateral fashion in the extremities and segmental markers were placed midpoint between these bony landmarks on the shafts of the humerus, radius, femur, and fibula. A static calibration trial preceded dynamic trials of the full and shortened golf swing. Data were post-processed using a Woltring low-pass, cross-validity quintic spline filter and exported for later analysis (Woltring, 1986). The Woltring filter smoothed the data using a Mean Square Error of 20 mm (Joyce, Burnett, & Ball, 2010; Molloy, Salazar-Torres, Kerr, McDowell, & Cosgrove, 2008).

Each swing was also recorded with a standard 30 Hz digital camcorder (model PV-GS70D, Panasonic, Secaucus, NJ, USA) that was placed six metres away from the participant, which provided the two-dimensional data. This camera was placed at the level of the umbilicus within the frontal plane facing the participant with the camera's field of view centred on the participants' hands. The commercial P3 ProSwing (Sports Vision Technologies™, Bethel, ME, USA) optical sensor was used to report golf shot performance data (see performance-related dependent variables in the following section).

The videotaped swings were subsequently analysed with Image J software to measure the 2D backswing angle (°) (Abramoff, Magelhaes, & Ram, 2004). For calculation of backswing angle, zero degrees was defined at ball address position with the club shaft angle being perpendicular to the horizontal. A shortened backswing was operationally defined for an arc of motion occurring from 210 to 240°. A full backswing was defined as an arc of motion up to 255–285° (Bulbulian et al., 2001).

Dependent variables

Spine kinematic and kinetic variables described the various peak forces and their respective timings relative to impact (time 0). The kinematic variables were the *X*-Factor and the time points describing when kinetic variables occurred relative to impact. The *X*-Factor was computed as the difference between maximal thoracic rotation and maximal pelvic rotation using the Cardan sequence previously described by Joyce et al. (2010), e.g. lateral bend–flexion/extension–axial rotation. The other dependent kinematic variables were reported as the time of peak compression (Tc), time of peak lateral shear (Tls), and time of peak anteroposterior shear (Tap) of the lumbar spine. The kinetic variables were computed via inverse dynamic algorithms derived from force plate and kinematic data. Kinetic variables

Table 1. Peak spinal forces (normalised to body mass) and the respective timing (T, seconds) relative to impact (means ± SEM).

	Compression (Fc and Tc)	Lateral Shear (Fls and Tls)	Anteroposterior shear (Fap and Tap)
Shortened Backswing	7.0 ± 0.5 N*	3.3 ± 0.3 N	1.9 ± 0.2 N
Time	−0.02 ± 0.01 s	−0.03 ± 0.02 s**	−0.09 ± 0.02 s
Full Backswing	7.6 ± 0.4 N	3.2 ± 0.2 N	2.0 ± 0.2 N
Time	−0.02 ± 0.01 s	−0.05 ± 0.02 s	−0.08 ± 0.02 s

Notes: Time: Instant of ball impact = 0; Fc: Peak compression force; Fls: Peak lateral shear force; Fap: Peak anteroposterior force; Tc: Timing of peak compression force relative to impact; Tls: Timing of peak lateral shear force relative to impact; Tap: Timing of peak anteroposterior shear force relative to impact.
*Shortened Fc < full backswing Fc ($p < 0.05$).
**Shortened Tls < full backswing Tls ($p < 0.05$).

Table 2. Pooled means (***n*** = ten swings for each swing type) of the dependent variables (means ± SEM) and $ICC_{3,1}$ data between the two sets of five swings.

	Club head Velocity (m/s); $ICC_{3,1}$	2D Backswing angle(°); $ICC_{3,1}$	Shot distance (m); $ICC_{3,1}$	Shot accuracy (distance from target, m); $ICC_{3,1}$
Mean Shortened Backswing	31.3 ± 0.7*; 0.80	231.0 ± 2.2*; 0.38	139.3 ± 2.4*; 0.80	3.3 ± 0.4; 0.68
Mean Full Backswing	33.2 ± 0.6; 0.69	265.6 ± 3.4; 0.64	149.7 ± 3.3; 0.73	4.9 ± 1.2; 0.39

*Shortened swing was significantly different than the full swing ($p < 0.05$).

included peak forces of vertical compression (Fc), lateral shear (Fls), and anteroposterior shear (Fap) of the lumbar spine.

Performance-related dependent variables included CHV (m/s), shot accuracy determined by distance from intended target line (m), shot distance (m), and backswing angle (°). The P3 ProSwing golf simulation software reported these variables.

Statistical analysis was performed with repeated-measures ANOVA (SPSS 17.0, IBM, Armonk, NY, USA) using a priori alpha values of 0.05. Post-hoc analyses were performed with paired t-tests corrected for alpha inflation by the Bonferroni procedure. Two-way mixed-effects intraclass coefficients ($ICC_{3,1}$) were used to determine shot consistency. The $ICC_{3,1}$ was chosen because the data are quantitative while the rater was fixed (P3 ProSwing) and the values were considered random (two-way mixed model). Effect size (Cohen's D) was calculated *post hoc* for findings that were statistically significant and interpreted as small, medium, or large effects with the respective values of 0.2, 0.5, or 0.8 (Cohen, 1977).

Results

All dependent variables met the required assumptions for repeated measures ANOVA including independence (Box's M > 0.05), normality (Shapiro–Wilk > 0.05), and homogeneity (Levine's statistic > 0.05). Testing for sphericity was not needed given that there were only two comparisons. Paired t-tests revealed no differences between the separate sets of five swings for each swing type ($p > 0.05$). Data were then pooled to yield a total of ten swings for each swing type. Data are reported as means ± SEM.

The 2D analysis of the backswing showed a backswing club angle of 231 ± 2° and 265 ± 3° for the shortened and full swings, respectively ($p < 0.001$, Cohen's D > 0.8). The *X*-Factor was found to be significantly reduced from 49.9 ± 3.0° to 45.4 ± 3.0° in the full to shortened swing, respectively ($p < 0.001$, Cohen's D = 0.42). The reductions of backswing swing and *X*-Factor were considered large and medium effect sizes, respectively (Cohen, 1977).

The kinetic data analysis showed that peak Fc forces were significantly reduced in the modified shortened golf swing ($p < 0.05$, Table 1). This was associated with a Cohen's D of .37 (medium effect). The other forces, Fls and Fap, were not significantly different between the swing types ($p > 0.05$).

The timing of the peak forces was not different between the full and shortened swings for Tc and Tap; however, Tls occurred significantly closer to impact in the shortened swing ($p < 0.05$, Cohen's D = 0.29). The peak *X*-Factor occurred at the top of the backswing in both the full and shortened swings ($p > 0.05$).

Performance findings are summarised in Table 2. We found that CHV was reduced from 33.2 ± 0.6 to 31.3 ± 0.7 m/s ($p < 0$ .05 and Cohen's D = 0.81). Shot distance also diminished from 149.7 ± 3.3 m in the full swing to 139.3 ± 2.4 m in the shortened swing ($p < 0.05$ and Cohen's D = 0.80). Shot accuracy, in terms of distance from target, was not significantly different between the two swings ($p > 0.05$). Intraclass coefficients ($ICC_{3,1}$) are also reported in Table 2 from the set of ten swings for each swing type as an indication of the relative consistencies for the reported variables.

Discussion and implications

Lumbar spine pathologies are often associated with time-loss injuries in golf and reducing trunk rotation during the backswing is thought to reduce torsional stress to the vertebral spine (Evans et al., 2005; Gluck et al., 2008; Gosheger et al., 2003). To our knowledge, only one other paper has previously examined the effects of the shortened backswing upon golf performance (Bulbulian et al., 2001). Bulbulian et al. (2001) compared performance-only variables between the full and shortened backswings of seven golfers, and did not find any significant difference between the two swing types. A criticism of the previous study, however, is that 7 participants with a mean handicap of 16 strokes participated, which suggests increased relative inter- and intra-participant variability compared to participants with lower golf handicaps (Langdown, Bridge, & Francois-Xavier, 2013).

We found that a significant 2D backswing angle reduction (~34°) was associated with a significant reduction of the *X*-Factor by about four degrees (3D). Reducing the *X*-Factor would likely ameliorate torsion within the stabilising tissues of the thoracolumbar spine, and this could potentially reduce repetitive lumbar stress by subsequently diminishing Fc magnitude (next section).

Hosea and Gatt found that peak compressive forces of ~8 times body mass occurred during the full modern golf swing (Hosea & Gatt, 1996). That study compared four amateurs to four professional golfers and did not find a difference between those skill levels and the peak Fc. Similarly, the present study found that Fc peaked at 7.6 times body mass during the full swing at approximately .02 s prior to impact. There are no other studies that quantify spine compressive force and its timing relative to impact.

A reduction of Fc might ameliorate stress to the spine given that compressive injuries may cause or contribute to spine injury (Gluck et al., 2008). We found that shortening the swing significantly reduced Fc. However, one must realise that the reduction of .6 normalised Newtons, though statistically significant, still resulted in Fc values around 7.0 times body mass, and the calculated effect size was a medium effect of 0.37. This mean change of 0.6 normalised Newtons equates to a reduction of 50 kg in vertical compression force to the spine. Provided that the mean body mass of the participants was 83.6 kg, we speculate that a 50-kg reduction could be meaningful, especially when this reduction is consistently applied to all full-swings during a full round of golf (at least 36 swings for a golfer with zero handicap on a par 72 course). The assumption is that mild stress reduction experienced within each swing would benefit the spine by reducing cumulative stress over the entire round. We concede that further research is necessary to support this assumption with a population of golfers experiencing LBP.

The present study found that a shortened backswing reduced the *X*-Factor by 4° (3D data) and ~34° (2D), and this significantly reduced CHV and shot distance (Table 2). These reductions were equivalent to a decrease of about 2 m/s for CHV and about ten metres for shot distance.

The findings reported by Bulbulian et al. (2001) relating to a 2 m/s reduction in CHV were not statistically different; whereas the present study found statistical significance for a comparable reduction of CHV (~2 m/s). Perhaps the reason that the former study's findings were not significantly different was because of the relatively lower number of participants and possibly greater variability within the study. The SEM of Bulbulian's study was 2.2 m/s compared to 0.7 m/s in this study. Also, the former study also included seven participants with a higher average handicap (16.3) compared to the present study's 13 participants with a handicap of 7.1.

Although participants were able to place the club within the accepted arc of 210–240 degrees from the address position (Angle 0) for all 10 swings, the novelty of the shortened swing was evident with the reproduction of a specific backswing angle (ICC of 0.38). Despite its novelty to the participants; however, the shortened swing produced ICC values > 0.68 and similar or lower SEM values with respect to CHV, shot distance, and accuracy (see Table 2). Not surprisingly, the ICC of the 10 full swings was .64, which demonstrates a modest level of consistency with replication of the full backswing angle.

Accuracy, as defined in the distance from target line, was not statistically significant between the full and shortened swings. However, the ICC values for the recorded distances from the target line were higher (0.68) in the shortened swing compared to the full swing. This demonstrates a consistent clustering of the shots around the target line during the shortened swing that is likely associated with the reduction of CHV and shot distance.

Shortening the backswing, and therefore reducing compressive forces, may benefit golfers with a history of LBP by reducing the magnitude of lumbar stress during the golf swing. If the stress is ameliorated during golf swing multiplied times the number of golf swings encountered during practice and playing rounds of golf, then it stands to reason that the volume of stress would be ameliorated. More research is necessary with golfers having a history of LBP.

A golfer may initially be resistant to adopting a shortened swing because of CHV reduction (Fradkin, Sherman, & Finch, 2004). However, one could argue that consistency improves with shortening the swing (Table 2). Another suggestion would be to use the next longer club in the bag to compensate for potential ball flight reduction in the shortened swing. There is usually around a 10-m separation in ball flight distance between each golf club (Newell, 2001). Therefore, given that there was about a 10-m reduction in flight distance between the full and shortened swing, a golfer could theoretically switch to a 6-iron when they would normally choose their 7-iron, and not lose any ball flight distance during the shortened swing. The potential problem that arises with this suggestion is that left to right deviation of ball flight is larger in off-centre hits when using the lower lofted angle clubs. This means that one may hit the ball farther with the lower lofted clubs, but the left to right deviation from the target can also increase if the ball is not struck squarely. Higher USGA handicap golfers typically have difficulty with consistently striking the ball squarely within the clubface, and may not benefit from the suggestion of using the next longer club in all circumstances on the golf course.

The present study found that the participants were able to produce the shortened swing relatively easily with practice repetitions and feedback from the golf professional. One could surmise that this was likely due to the participants shortening their own swing, and not having to adopt a novel swing.

These data are limited to swing analyses with a 7-iron, and the present study did not have electromyographic data to describe activity of various muscle groups during the swing. Follow-up studies using surface electromyographic equipment would provide more information about muscle activity alteration during the shortened swing. This information would be valuable since there are limited data describing electromyographical information during the shortened and full modern (one-plane) golf swings (Bulbulian et al., 2001).

The present data are also limited to golfers without a history of LBP. Subsequent studies that assess one-plane swing modification in patient populations with LBP would further substantiate the relevance of the present findings. Moreover, additional information is needed to ascertain long-term ramifications of this swing modification.

Could the cumulative stress encountered during a round of golf present as delayed soreness incurred during or following the bout? If so, spine damage would be insidious, and more research is needed in this area.

Conclusion

The findings of this study offer insight into modification of the modern golf swing. We found that the shortened golf swing modestly decreases spinal compressive loads, *X*-Factor, and CHV. The shortened swing also improved relative consistency (ICC data) with respect to CHV, shot distance, and accuracy when compared to the full swing.

The practical implications apply to individuals that might benefit from amelioration of cumulative spine stress from a round of golf. This is most likely in individuals with chronic mild to moderate LBP that is exacerbated after playing golf. However, it would be premature to recommend swing modifications before these results can be validated in individuals with LBP. Therefore, more research is needed to determine the effect of swing modification and spinal load amelioration in an actual round of golf and with individuals that would potentially benefit from reduced spinal loads.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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