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Comparison of spine motion in elite golfers with and without low back pain

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Low back pain is a common musculoskeletal disorder affecting golfers, yet little is known of the specific mechanisms responsible for this injury. The aim of this study was to compare golf swing spinal motion in three movement planes between six male professional golfers with low back pain (age 29.2 ± 6.4 years; height 1.79 ± 0.04 m; body mass 78.2 ± 12.2 kg; mean $\pm s$) and six without low back pain (age 32.7 ± 4.8 years; height 1.75 ± 0.03 m; body mass 85.8 ± 10.9 kg) using a lightweight triaxial electrogoniometer. We found that golfers with low back pain tended to flex their spines more when addressing the ball and used significantly greater left side bending on the backswing. Golfers with low back pain also had less trunk rotation (obtained from a neutral posture), which resulted in a relative 'supramaximal' rotation of their spines when swinging. Pain-free golfers demonstrated over twice as much trunk flexion velocity on the downswing, which could relate to increased abdominal muscle activity in this group. This study is the first to show distinct differences in the swing mechanics between golfers with and without low back pain and provides valuable guidance for clinicians and teachers to improve technique to facilitate recovery from golf-related low back pain.

Keywords: golf, injury, posture, technique.

Introduction

Low back pain is the most common musculoskeletal disorder affecting amateur and professional golfers (McCarroll *et al.*, 1990; McCarroll, 1996; Thériault *et al.*, 1996; Sugaya *et al.*, 1999). Although the incidence of back problems among golfers is fairly well documented, less is known of the specific mechanisms responsible for these injuries.

Hosea *et al.* (1990) calculated the compressive, shear, lateral bending and rotational loads on the L3–L4 segment of the lumbar spine during golf swings using a five iron. Kinetic, kinematic and surface electromyographic (EMG) data were collected from four professional (mean age 37 years) and four amateur (mean age 34 years) golfers. The authors concluded that, except for compressive load, professional golfers produced less spinal loads than amateur players. Compressive loads for both groups peaked at about eight times body mass. The complex, rapid and intense nature of the spinal loads associated with the golf swing led Hosea *et al.* to conclude that pre-participation conditioning, reasonable practice habits and a proper warm-up are important for preventing low back pain from golf.

Morgan *et al.* (1997) analysed spinal motions and velocities in Japanese collegiate golfers using a three-dimensional motion analysis system. They reported 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. Morgan *et al.* used the term 'crunch factor' to describe the instantaneous product of lumbar side bend angle and axial rotation velocity. They postulated a high crunch factor was damaging to the lumbar spine (i.e. during the impact phase), resulting in injury and pain. In a follow-up study, Morgan *et al.* (1999) examined lumbar spine mechanics in healthy golfers of different age categories. College-age golfers (age 18–21 years) exhibited a significantly greater 'crunch factor' than senior golfers (over 50 years). The authors commented that low back pain and the 'crunch factor' were probably interrelated, in that both parameters exhibit a consistent (and significant) decrease with increasing age.

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Sugaya *et al.* (1999) conducted a two-part study examining low back pain among elite Japanese golfers. In the first part of their study, they surveyed Japanese tour professionals at four different tournaments. The authors reported that 55% of the players who responded to the survey had a history of chronic low back pain. Of those suffering from low back pain, 51% identified trail (i.e. right) side low back symptoms, compared with 28% left side and 21% central or no laterality. The second part of the study involved radiographic investigation of 10 elite male amateur, 14 male professional and two female professional right-handed golfers, all presenting with low back symptoms. The results revealed a significantly greater change in right side vertebral body and facet joint arthritis than age-matched controls. Sugaya *et al.* concluded that both the repetitive and asymmetric nature of the golf swing contributed to low back pain and injury in elite golfers.

Although the above studies have presented valuable information regarding the relationship between the golf swing and low back pain, none has specifically compared swing characteristics between golfers with and without low back pain. Documentation of spinal motion from golfers with and without low back pain would allow a better understanding of the stresses associated with the golf swing and could lead to technique modifications that would minimize low back stress and injury risk. The aim of the present study was to compare maximum spine angles and velocities in three movement planes during the execution of full golf swings between professional golfers with and without low back pain. Demographic and golf activity profiles between the same two groups were also determined.

Materials and methods

Participants

Altogether, 54 male professional golfers belonging to the Alberta Professional Golf Association completed a questionnaire asking how often they experienced low back pain when playing or practising during the past golf season and whether they felt the pain was related specifically to golf. Six response categories were provided: 'Always', 'Frequently', 'Occasionally', 'Rarely', 'Never', 'Don't know/Not Applicable'. Six golfers each indicated that they either 'always' or 'never' experienced low back pain from golf. These 12 golfers were interviewed further by one of the investigators to ensure their interpretation of the questionnaire response categories matched those of the investigator. The six participants who 'never' experienced low back pain after playing or practising were classified as controls (age 32.7 ± 4.8 years; height 1.75 ± 0.03 m; body mass 85.8 ± 10.9 kg; mean $\pm s$). The six participants who 'always' experienced low back pain after playing or practising were classified as low back pain individuals (age 29.2 ± 6.4 years; height 1.79 ± 0.04 m; body mass 78.2 ± 12.2 kg). No attempt was made to diagnose or categorize the nature of the low back pain. However, all of the participants with low back pain felt that golf was a direct cause of their pain and all continued to play and practise despite the discomfort.

Apparatus

Spinal motion characteristics during the golf swing were assessed using a lightweight device known as a Lumbar Motion Monitor (Wellness Design™, Chattanooga Group Inc., Hixson, TN). The Lumbar Motion Monitor is a triaxial electrogoniometer capable of assessing the instantaneous three-dimensional motion of the thoracolumbar spine. Measurements recorded by the monitor include flexion, extension, side bending and axial rotation ranges of motion, as well as the velocity and acceleration of these motions. The monitor is attached to the back by a chest harness and pelvic strap (Fig. 1) and measures the movement occurring between the mid (thoracic spine) and lower (pelvic) parts of the back. The outputs from the sensors are transmitted to an analog-to-digital board in a portable computer, in which instantaneous position, velocity and acceleration of the lumbar spine were calculated. The position accuracy of the Lumbar Motion Monitor compared with a three-dimensional reference frame has been reported as being over 98%, while the correlation coefficients for velocity using high-speed motion analysis for comparison also show very high agreement ($r > 0.95$, $P < 0.0001$) (Marras and Fattalah, 1992). Pilot trials and interviews using the Lumbar Motion Monitor indicated that the apparatus did not restrict a player's normal movements during the golf swing.

Test procedures

The test procedures were consistent for all participants. The field tests, which lasted about 30 min, were carried out at a local driving range; the participants used their own golf club. The test session began with an explanation of the procedures, followed by a warm-up consisting of stretching exercises and several practice swings. The Lumbar Motion Monitor was then attached and the participants were instructed to strike golf balls until they felt comfortable. These practice swings allowed the participants to become familiar with the apparatus and permitted the investigator to check the operation of the monitor.

After the warm-up, the monitor was calibrated with the participant standing in an upright, anatomically

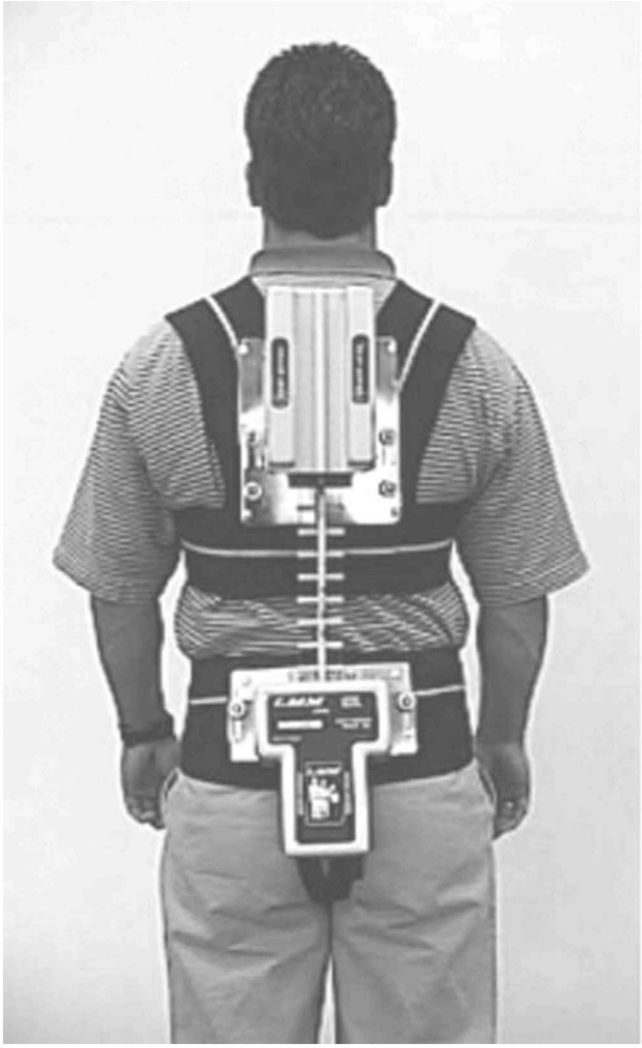

Fig. 1. The Lumbar Motion Monitor (Wellness Design™, Chattanooga Group, Inc., Hixson, TN).

neutral position. The angles measured during testing were therefore a representation of movement from this anatomically neutral position. After the monitor was calibrated, the participants were asked to assume their normal address position (Fig. 2). Spine angles in the address position were then recorded.

After the measurement of the address position, the participants were required to perform three maximal effort shots with a driver. Spinal position and velocity were recorded during each of the three shots. After recording the golf swing spinal measurements, the participants were asked to move their torso through maximal range of motion (without a golf club), from an upright neutral posture, in a total of four different directions (right and left side bending and right and left rotation). This allowed the investigators to make comparisons between the maximum spinal angles recorded during the golf swing and the maximal available neutral posture

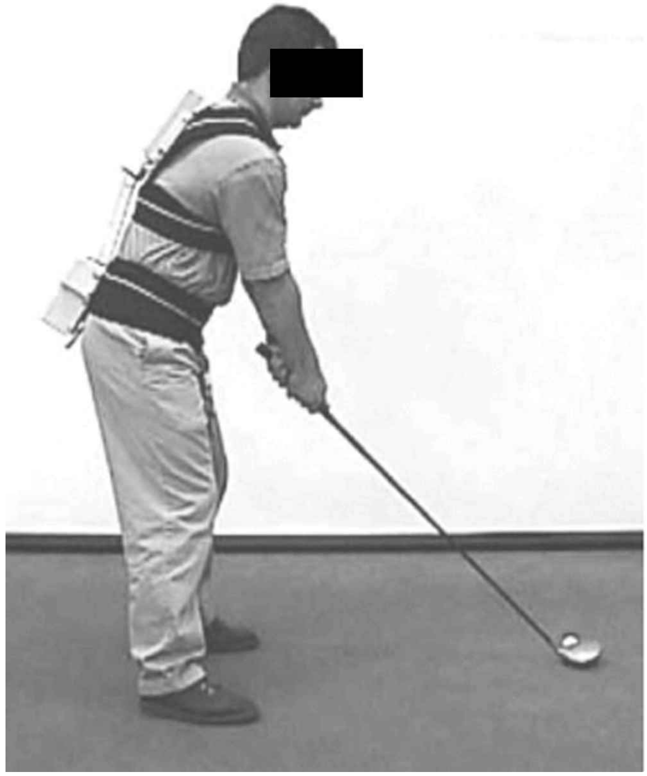

Fig. 2. Typical address position.

range of motion. Maximum neutral posture motion was measured using a relatively slow (in comparison to a golf swing) and steady movement speed. Maximum neutral posture flexion and extension ranges of motions were not recorded, as these directions were not expected to approach maximum during the golf swing.

Statistical analysis

Non-parametric statistical methods were used because of the small sample size in each group. Statistically significant differences in maximum spinal angles and velocities between professional golfers with and without low back pain were determined using the Mann–Whitney *U*-test. The statistical analyses were performed using SPSS.

Ethical considerations

Since the activities performed in this study were neither excessive nor any different from normal golf swings, the risk of injury during the test procedure was considered to be low. All participants completed a Physical Activity Readiness Questionnaire and a sport-specific activity profile questionnaire and gave their informed consent before testing. Ethics approval was granted by the University of Calgary Conjoint Faculties Research Ethics Committee.

Results

No significant differences in address position, flexion, right side bending or left rotation were noted between the golfers with and without low back pain ($P > 0.05$) (Table 1). The maximum spinal angles recorded in the different movement directions during swings with the driver are shown in Table 2. The only significant difference between the controls and those with low back pain was for maximum left side bending. Table 3 compares the average maximum side bend and rotation angles recorded during the golf swing and expressed as a percentage of the respective maximum neutral posture range of motion. No significant differences were observed, although golf swing axial rotation consistently exceeded the neutral posture maximum voluntary rotation among the low back pain participants. The spinal velocity results are shown in Table 4. Significant differences in flexion velocity ($P = 0.01$) and left side bend velocity ($P = 0.04$) were noted between golfers with and without low back pain. Table 5 compares the golf activity profiles of the two groups. The participants were asked to report the average rounds played per month as well as the time spent practising full golf shots

Table 1. Static spinal angles during address position with a driver (mean ± *s*)

	Flexion	Right side bend	Left rotation
Without low back pain ($n = 6$)	25.3 ± 6.6	8.7 ± 3.4	6.7 ± 1.5
With low back pain ($n = 6$)	37.0 ± 11.4	8.5 ± 4.7	7.7 ± 1.8
	$P = 0.09$	$P = 0.94$	$P = 0.32$

Table 2. Maximum spinal angles recorded during golf swings with the driver (mean ± *s*)

	Flexion	Extension	Left side bend	Right side bend	Right rotation	Left rotation
Without low back pain ($n = 6$)	50.7 ± 7.2	−10.2 ± 8.0[a]	0.5 ± 3.1	29.9 ± 3.2	34.8 ± 7.3	49.2 ± 11.3
With low back pain ($n = 6$)	44.0 ± 5.3	−2.3 ± 8.5[a]	6.7 ± 3.2	28.8 ± 5.8	35.6 ± 4.2	50.3 ± 5.0
	$P = 0.15$	$P = 0.15$	$P = 0.01$	$P = 0.58$	$P = 0.81$	$P = 0.87$

[a] Average maximum extension values were negative, indicating the spine did not reach an extended position at any time during the golf swing.

Table 3. Frontal and transverse plane maximum obtainable neutral posture angles (NPA) and maximum golf swing angles (GSA) expressed as a percentage of NPA (mean ± *s*)

	Left side bending	Right side bending	Right rotation	Left rotation
Without low back pain ($n = 6$)				
NPA (°)	32.7 ± 6.2	38.2 ± 4.2	41.8 ± 12	50.0 ± 5.9
GSA/NPA (%)	0.4 ± 9.8	79.6 ± 15.5	88.0 ± 24.9	99.6 ± 24.6
With low back pain ($n = 6$)				
NPA (°)	29.7 ± 6.2	35.5 ± 6.7	34.8 ± 5.0	44.0 ± 5.2
GSA/NPA (%)	23.4 ± 12.6	82.1 ± 11.0	108.3 ± 20.0	116.4 ± 4.4

Table 4. Maximum spine motion velocities ($rad \cdot s^{-1}$) during golf swings with the driver (mean ± *s*)

	Flexion velocity	Extension velocity	Left side bend velocity	Right side bend velocity	Right rot. velocity	Left rot. velocity
Without low back pain ($n = 6$)	1.56 ± 0.45	2.01 ± 1.05	0.56 ± 0.17	1.86 ± 0.25	1.33 ± 0.26	3.18 ± 1.62
With low back pain ($n = 6$)	0.73 ± 0.33	2.41 ± 0.99	0.78 ± 0.16	1.88 ± 0.43	1.61 ± 0.30	3.25 ± 0.58
	$P = 0.01$	$P = 0.75$	$P = 0.04$	$P = 0.87$	$P = 0.13$	$P = 0.87$

Table 5. Comparison of self-reported golf activity profiles for golfers with and without low back pain (mean ± *s*)

	Average rounds played per month	Average full-swing practice sessions per month	Average balls struck per full-swing practice session	Average putting practice sessions per month	Average time (min) spent per putting practice session
Without low back pain ($n = 6$)	7.3 ± 3.0	6.7 ± 2.3	66.7 ± 66.5	7.2 ± 1.2	29.2 ± 17.4
With low back pain ($n = 6$)	9.4 ± 5.2	12.3 ± 5.4	94.2 ± 64.4	11.5 ± 7.6	17.5 ± 9.9
	$P = 0.50$	$P = 0.10$	$P = 0.48$	$P = 0.31$	$P = 0.18$

and putting. No significant differences in practice and playing habits were noted between professional golfers with and without low back pain.

Discussion

The main aim of this study was to compare the spinal motion (i.e. maximum angles and velocities) of male professional golfers with and without low back pain during golf swings with a driver. No significant differences in address position spinal posture ($P > 0.05$) were noted between the two groups. Although not statistically significant, the golfers with low back pain tended to address the ball with considerably more spinal flexion than the controls (Table 1). The average flexion angle of the healthy controls (25.3 ± 6.6°) was consistent with the results of McTeigue *et al.* (1994), who observed forward flexion of 28 ± 8° among Professional Golf Association (PGA) Tour players. The average address position flexion angle recorded from the golfers with low back pain was 37.0 ± 11.4°. Since increased flexion is associated with increased lumbar disc pressure and risk of injury (Kumar *et al.*, 1998), this difference in set-up posture could contribute to low back pain from golf.

Left side bend was the only maximum spinal angle found to be significantly different between the two groups during the golf swing (Table 2). Left side bend, which occurs on the backswing (right-handed golfer), was significantly greater ($P = 0.01$) for the golfers with low back pain. It is not known whether the increased left side bend observed in this study is an important contributing factor to low back pain, since the maximum amount of left side bend during the swing was relatively small (6.7 ± 3.2°). Also, other researchers have identified the downswing, rather than the backswing, as the key part of the swing during which most stress and injuries occur (Hosea *et al.*, 1990; Sugaya *et al.*, 1999).

A comparison of the results in Tables 1 and 2 shows that, although flexion in the static address position was greater among the golfers with low back pain (37.0 ± 11.4 *vs* 25.3 ± 6.6°), maximum flexion angle during the swing was higher for the golfers without low back pain (50.7 ± 7.2 *vs* 44.0 ± 5.3°). Peak flexion occurred on the downswing (i.e. before the club contacted the ball). By subtracting the start (address position) flexion from the maximum (downswing) flexion, it would appear that spinal flexion of the golfers without low back pain increased by just over 25° on the downswing compared with just 7° for the golfers with low back pain. However, empirical observations of both groups of professional golfers showed that the trunk maintained a consistent angle with the ground throughout the entire backswing and downswing (golf teachers often refer to this as maintenance of a consistent 'spine angle'). McTeigue *et al.* (1994) also observed considerable changes in spinal flexion during the downswings of elite professional golfers, although they did not comment on the cause. One possible explanation for the apparent disparity between the instrumented spinal flexion results and empirical observations may relate to localized movement created by the anterior trunk muscles. Powerful anterior trunk muscle contractions on the downswing may cause an initial posterior tilting of the pelvis and an apparent increase in localized spinal flexion rather than true flexion of the entire trunk. If this is the case, it is possible that golfers without low back pain may use their anterior trunk muscles more on the downswing than golfers with low back pain. Watkins *et al.* (1996) speculated that abdominal muscle activity might be different in golfers suffering with low back pain. Evans and Oldreive (2000) reported that golfers with low back pain have a reduced ability to maintain a static contraction of the transverse abdominal muscle, although it is unclear whether this translates to differences in golf swing activity patterns. Recently, Horton *et al.* (2001) used oblique abdominal muscle activity collected during a standardized movement (double leg raise in supine) as the reference signal for comparing electromyograms (EMG) from the same muscles during golf swings in players with and without low back pain. No significant differences were found for the golf swing and standard movement EMG ratio between groups; however, the onset times were delayed in the group with low back pain. Clearly, additional research is required to examine differences in abdominal muscle recruitment patterns between golfers with and without low back pain.

Although no significant differences in the maximum axial rotation angles were observed between groups during the golf swing (Table 2), we noted that the golfers with low back pain tended to use considerably more rotation in their swings than the maximum rotation range they were able to obtain from a neutral posture and controlled speed (Table 3). This resulted in the golf swing producing 'supramaximal' rotation in the golfers with low back pain. Sugaya *et al.* (1999) have suggested that spinal injury and pain are partly related to the extreme ranges of motion placed on the spine while performing the golf swing. In a case study of a professional golfer, Grimshaw and Burden (2000) reported that decreasing the amount of spinal rotation during the swing was beneficial for reducing his low back pain. The results in Table 3 would appear to lend support to the observations of Sugaya *et al.* (1999) and Grimshaw and Burden (2000). In addition to controlling spinal rotation during golf swings, players with low back pain should work on improving their general trunk rotation flexibility. Furthermore, all golfers should stretch and warm-up properly before swinging aggressively.

Spinal velocity was also significantly different between the two groups in the present study. Golfers with low back pain demonstrated significantly lower flexion and higher left side bend velocities than golfers without low back pain. (Table 4). As already mentioned, left side bending occurs on the backswing and may not be an important factor in the aetiology of low back pain from golf. The very large difference in flexion velocity between the two groups may again be related to differences in anterior trunk muscle contractions. Pink *et al.* (1993) and Watkins *et al.* (1996) have shown that the oblique abdominal muscles on both sides of the trunk are very active in golf swings of healthy elite players. It is possible that the considerably lower flexion velocity observed for the golfers with low back pain in this study was due to differences in the force of contraction of the abdominal muscles.

Combinations of lumbar right side bend spinal angle and left axial rotation velocity (right-handed golfers) have been identified as important contributors to low back pain and injury among elite golfers (Morgan *et al.*, 1997). The term 'crunch factor' has been used to describe the asymmetric forces arising from these localized side bend and rotation motions about the lumbar spine (Morgan *et al.*, 1997; Sugaya *et al.*, 1999). Morgan *et al.* (1999) reported the average maximum crunch factor of eight elite collegiate golfers (age 19 ± 1 years) to be 45.1 ± 21.7 rad $\cdot$ s^{-1}. We are unaware of any previous study that has compared the simultaneous product of axial rotation velocity and side bending angle in golfers with and without low back pain. Although the methods used in the present study did not allow lumbar motion to be isolated from thoracic motions, an overall trunk 'crunch factor' could be measured. Peak trunk 'crunch factors' for participants with and without low back pain were calculated as 82.4 ± 21.9 and 87.7 ± 28.4 rad $\cdot$ s^{-1}, respectively. If one assumes that the combination of thoracic and lumbar motions provides a representation of the lumbar 'crunch factor', then it would appear that factors other than the 'crunch factor' must be responsible for the differences in low back pain perception identified by the two groups in this study.

Another difference between the two groups of golfers (although not statistically significant) was the time spent playing and practising. Golfers with low back pain practised full-swing shots, on average, almost twice as often and hit more balls per practice session than the golfers without low back pain. (Table 4). Combining data from these two categories shows that golfers with low back pain tended to hit 2.5 times more balls per month than the golfers without low back pain. Golfers with low back pain also tended to play more rounds per month. Both groups spent about the same total time practising their putting (sessions per month multiplied by putting time per session). Obviously, the more time spent performing the asymmetrical golf swing motion, the greater the likelihood of suffering an overuse injury to the lower back. The results from this study lend support to the empirical observations of others who have identified overuse as a risk factor for low back pain, especially among professional golfers (Batt, 1992; McCarroll, 1996).

Although the results of the present study offer valuable insight into the relationship between low back pain and golf, there are several limitations. Because spinal motion measurements were made on participants who had existing chronic low back pain, we cannot conclude whether the position or velocity differences between the professional golfers with and without low back pain were a cause of, or a result of, the pain. Also, numbers were relatively low, making true associations less clear than would have been seen with a larger pool of participants. In light of these limitations, this study is one of the first to make direct comparisons between the swing mechanics of elite golfers with and without low back pain and provides interesting findings that may offer solutions to a widespread problem in a highly popular sport. Recommendations for future research, in addition to addressing the limitations outlined above, would be to compare abdominal muscle forces of contraction during the swings of golfers with and without low back pain to determine if differences exist in the ability to protect the lower back between these groups. The influence of fatigue (i.e. repetitive ball striking) on spinal motion should also be investigated. Prospective long-term studies are needed to determine if spinal motion characteristics or abdominal muscle activity are affected by, or contribute to, the onset of golf-related low back pain.

Conclusions

In this study, golfers with low back pain tended to flex their spines more when addressing the ball than golfers without low back pain. Golfers with low back pain also used significantly more left side bending on the back-swing than those without. Although the golf swing maximum rotation angles did not vary between the two groups, maximum rotation range of motion (obtained from a neutral posture and at controlled speed) was more restricted in the group with low back pain. This resulted in these players using relative 'supramaximal' rotation of their spines when swinging, which, in turn, could contribute to ongoing irritation of the spinal structures. Pain-free golfers demonstrated over twice as much trunk flexion velocity on the downswing, which could relate to increased abdominal muscle activity in this group. No differences in peak 'crunch factor' were observed for the trunk region between the golfers with and without low back pain. Other researchers have speculated that the lumbar 'crunch factor', which is the instantaneous product of side bend angle and axial rotation velocity, contributes to the degenerative changes seen in the lumbar spines of elite golfers. A further risk factor for low back pain observed in this study may be the increased golf-specific activity patterns demonstrated by the injured golfers. The results of this study suggest that golfers with low back pain should: warm-up properly before playing as well as engage in regular stretching exercises to improve their maximum available trunk range of motion; improve their posture when addressing the ball; develop better abdominal muscle function during the downswing; and reduce the overall time they spend playing and practising.

Acknowledgements

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