ORIGINAL RESEARCH

TRUNK ROTATION STRENGTH AND ENDURANCE IN HEALTHY NORMALS AND ELITE MALE GOLFERS WITH AND WITHOUT LOW BACK PAIN

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ABSTRACT

Background. The relative importance and asymmetric loading of the trunk muscles in golf (slow rotation backswing followed by high velocity downswing) may cause side-to-side imbalances in axial rotation strength and endurance characteristics amongst elite players who frequently play and practice. Such imbalances may further be compounded by the presence of low back pain.

Objective. To establish and compare trunk rotation strength and endurance of healthy individuals who do not play golf and those that are highly skilled at the sport. Additionally, a smaller group of elite golfers with non-debilitating low back pain (LBP) were also evaluated and compared to their healthy counterparts.

Methods. Forty healthy non-golfing control subjects, 32 healthy elite golfers, and 7 golfers with LBP participated in this study. Bilateral trunk rotation strength and endurance was assessed using the Biodex System III Isokinetic Dynamometer with torso rotation attachment. Strength and endurance data was analyzed using 2-way ANOVA.

Results. No significant differences in peak torque were found within or between groups. However, golfers with LBP demonstrated significantly less endurance in the non-dominant direction (the follow-through of the golf swing) than either healthy group. No significant difference in endurance was found between the non-golfing controls and the healthy elite golfers.

Conclusions. Trunk rotation endurance in golfers with LBP might be more important than strength alone in the prevention and treatment of LBP. The results from this study provide useful information on possible risk factors associated with low back pain in golfers (decreased endurance) and allow for sport-specific clinical intervention strategies to be developed.

Key Words: spinal rotation, injury, golf

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INTRODUCTION

The effective execution of the golf swing not only requires rapid movement of the extremities but also substantial strength and power of the trunk muscles. The torso rotates away from the target (to the right for a right handed player) at approximately 85 deg/sec on the backswing while the powerful downswing involves trunk velocities approaching 200 deg/sec.[1] Pink et al[2] demonstrated relatively high and constant activity in the abdominal oblique muscles throughout most parts of the golf swing of skilled amateur players. In a similar study using professional golfers, Watkins et al[3] measured muscle activity in the erector spinae, abdominal oblique, and rectus abdominis. These authors established that all trunk muscles were relatively active during the acceleration phase of the golf swing with the trail-side abdominal oblique muscles showing the highest level of activity.

Given the relative importance of the trunk muscles in golf, particularly in terms of generating powerful axial rotation on the downswing, repetitive play and practice might contribute to enhanced rotational strength and endurance amongst these athletes. Furthermore, this asymmetric pattern of trunk rotation during the golf swing (slow rotation backswing followed by high velocity downswing) may cause side-to-side imbalances in rotational strength and endurance characteristics amongst elite players who frequently play and practice. These potential imbalances may contribute to an increased susceptibility of developing low back pain. Lindsey and Horton[4] have shown side-to-side maximum trunk rotation flexibility imbalances in elite golfers with and without low back pain (LBP).

The authors of this study are aware of only six peer-reviewed, non golf-related research studies that have evaluated strength and endurance characteristics of the trunk muscles during axial rotation movements.[5-10] Three of these studies[5,6,9] have reported isokinetic trunk rotation strength measures, while the others attempted to assess trunk muscle characteristics with electromyography (EMG) during repeated trunk rotations. Five different studies have investigated strength and or endurance parameters during trunk flexion and extension motions.[11-15] A limitation of most of these studies was they used custom made equipment to collect data. Kumar[5] reported that the scarcity of data for trunk rotation is directly attributable to the lack of suitable, accurate, standardized, and affordable devices to permit such measurement. Consequently, gaps in the literature exist regarding trunk rotation strength and endurance capabilities in the general population. Furthermore, no previous studies have investigated trunk rotation strength and endurance in golfers.

Suter and Lindsay[16] compared static trunk extensor endurance and inhibition of the quadriceps in low handicap golfers with LBP and healthy age-matched controls who did not golf. The authors were unable to show any significant differences in static holding times or decline in the EMG median frequency between groups. However, golfers with the lowest trunk extensor endurance were found to have significant quadriceps muscle inhibition compared to golfers with higher trunk endurance. It was postulated the inhibition of the quadriceps might be a direct result of abnormal afferent input to the muscle due to irritation of the spinal structures which innervate that specific region. No such association was observed for the normal subjects.

Considering the role of trunk rotation during the golf swing and the possible relationship between trunk muscle strength and endurance and low back pain, the purposes of the proposed exploratory research project were the following: 1) To establish normative data by measuring trunk rotational strength and endurance in healthy individuals who do not play golf. 2) To measure trunk rotation strength and endurance in age-matched elite golfers without LBP. (Collection of this data would permit comparisons between non-golfing control subjects and healthy golfers. This would also establish whether the repetitive and asymmetric nature of the golf swing leads to side-to-side differences in trunk rotation strength and endurance.) 3) To measure trunk rotation strength and endurance in elite golfers with non-debilitating LBP to determine if these individuals have less rotation strength and endurance compared to healthy elite golfers.

Owing to the scarcity of data associated with isokinetic trunk rotation testing, a number of secondary purposes were also investigated. In particular, whether subjects' torque and work results were influenced by trunk rotation range of motion (ROM) or body weight. The reliability and technical error associated with isokinetic strength testing was also examined.

METHODS

Subject Recruitment

Healthy male volunteer subjects that did not play golf were recruited via mass e-mail advertisements to University of Calgary faculty, staff, and students. Advertisements were faxed to golf professionals in the Alberta Professional Golf Association to recruit male professional and elite amateur golfers with and without LBP. Advertisements were also faxed to physical therapy clinics in the Calgary area to recruit elite male golfers with LBP.

Potential subjects were initially asked to complete a screening questionnaire regarding history of LBP (location, duration, frequency, and treatment) and the effects of playing golf and practicing on LBP. Those individuals who had not played golf more than twice per year in the past 5 years and had not experienced LBP in the previous 12 months were considered to be *control normals*. Elite golfers were defined as those playing and practicing at least 50 times per year and carrying a sanctioned handicap of 10 or less. Elite golfers who "never" or "rarely" experienced pain in the lumbar region of their back after practicing or playing during the golf season prior to completion of the questionnaire were classified as *control* *golfers*. Those players who "always" or "often" experienced pain in the lumbar region of their back after practicing or playing during the season preceding the questionnaire were classified as *golfers with LBP*.

Individuals were excluded from participating in the study if they were older than 49 years of age or had previously undergone surgery or other medically invasive procedures (nerve blocks or ablation, prolotherapy, cortisone injections) for LBP. Individuals over the age of 49 years were excluded based on published reports that both isometric and dynamic strength declines after age 50.[17] Furthermore, potential *golfers with LBP* were excluded if they had experienced golf-related LBP for less than six months prior to the commencement of the study. Those *golfers with LBP* who met the inclusion criteria were individuals who had experienced LBP for some time and continued to play golf in spite of this pain. These inclusion criteria restrictions made it more difficult to recruit eligible subjects resulting in a lower sample than in the other groups.

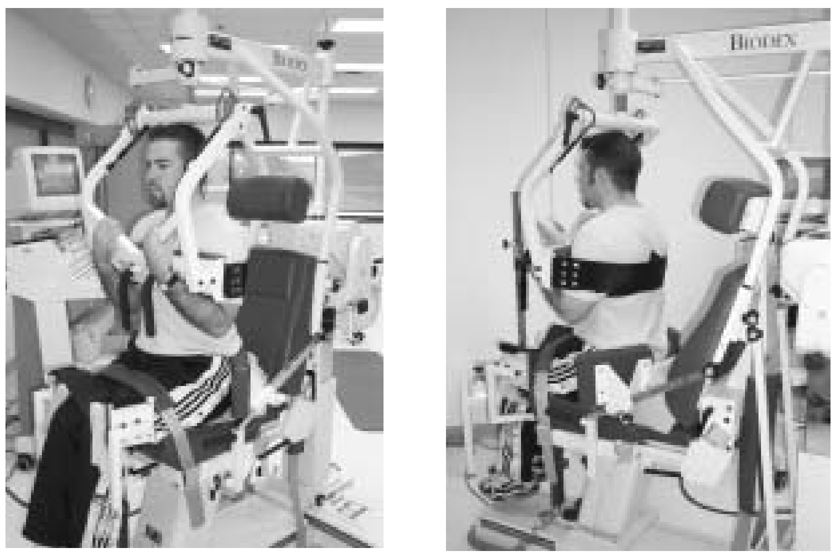

Figure 1. Subject positioning in the Biodex Torso Rotation Attachment.

Subjects

Forty healthy *control normals* (27.9 ± 4.8 yrs; 78.1 ± 8.2 kg; 176.5 ± 5.4 cm), 32 *control golfers* (30.0 ± 6.0 yrs; 79.1 ± 8.8 kg; 176.0 ± 5.7 cm), and 7 *golfers with LBP* (33.3 ± 9.6 yrs; 83.4 ± 10.9 kg; 178.7 ± 5.4 cm) participated in this study. All subjects completed a physical activity readiness questionnaire (PAR-Q) and signed an informed consent form prior to any testing procedures. Ethical approval was granted by the University of Calgary's Faculty of Medicine Conjoint Health Research Ethics Board.

Testing Procedures

Subjects were required to visit the University of Calgary Sport Medicine Centre on one occasion for testing. Prior to any testing procedures, subjects completed a low back pain and disability questionnaire (Oswestery Pain Questionnaire). Height and weight measurements were made followed by a short five-minute warm-up on a stationary bicycle. Following the warm-up, subjects were required to perform a series of standard stretches for the abdominal, back, hip, and leg muscles. An explanation of the testing procedures was then given verbally. Subjects were asked to sit in the chair of the Biodex System III Isokinetic Torso Rotation Attachment (Biodex Medical Systems, Inc., Shirley, New York) in an upright position so that the axis of rotation of the Torso Rotation Attachment was aligned with the long axis of the subject's spine *(Figure 1).* Once adjustments to the Torso Rotation Attachment were made to suit each individual, leg straps and hip pads were tightened to restrict lower body movement. A strap was then tightened around the back so the upper body was as tight as possible against the chest pad without causing discomfort. Once the apparatus was properly adjusted, subjects were given an opportunity to perform slow practice repetitions of trunk rotation to become familiar with the desired movement. All subjects were experiencing minimal or no low back pain on the day of testing. Subjects then underwent isokinetic axial rotation strength and endurance testing as per the following consistent protocol:

Strength Testing

Subjects were initially asked to turn as far as possible (without discomfort) in both directions to determine total ROM and to set limits in right and left rotation. After setting the ROM limits, subjects were required to perform practice repetitions at 90 deg/sec at a moderate intensity to become accustomed to the required speed of movement for the strength test. Shortly after this, subjects performed five bilateral concentric trunk rotations at 90 deg/sec. Ninety degrees per second has been shown to be highly reliable for strength testing using the Biodex Isokinetic Dynamometer.[18] Subjects were instructed to concentrate on using the trunk muscles rather than the arms or shoulders to perform the axial rotation movements; to start with moderate effort rotations; to gradually increase their effort so the last three repetitions were of maximal effort; to give equal effort in both directions of rotation; to keep breathing throughout the test (each subject determined their own pattern of breathing); and to stop the test if they felt any discomfort. All subjects were given verbal encouragement during the test.

Endurance Testing

Subjects were given a five-minute rest period between the strength and endurance tests. Five minutes is regarded as adequate time for replenishment of ATP and phosphocreatine stores in muscle following short-term maximal exercise.[19] Range of motion limits were again set in the same manner as the strength testing protocol. Subjects were then required to perform moderate effort practice trunk rotations at a speed of 180 deg/sec. Following the practice repetitions and a brief rest, subjects performed 25 bilateral maximal trunk rotations at the 180 deg/sec speed. This velocity approximates the trunk rotation velocities reported for adult golfers[20] and is an accepted velocity for endurance testing with isokinetic dynamometers.[21] Subjects were instructed to perform the endurance test beginning with maximal effort and to maintain that intensity as long as possible throughout the duration of the test until 25 repetitions were completed. Subjects were given verbal encouragement throughout the test.

Strength Test Reliability

In addition to the strength and endurance testing for this research study, reliability of the strength test was assessed with a sub-group of 12 *control normal* subjects. These subjects performed the strength test three times with a 5-minute rest between tests. These same subjects repeated the same testing procedure 3-5 days following the initial testing session.

Data Analysis

To allow data from both left and right-handed subjects to be collected and interpreted in a consistent manner, right and left rotation values were categorized as "dominant" or "non-dominant." Right torso rotation for a right-handed subject was categorized as "dominant" rotation while left rotation was referred to as "non-dominant" rotation. Right rotation for a left handed subject was categorized as "non-dominant" rotation.

Strength Test Reliability

Repeated measures analysis of variance (ANOVA) was used to determine significant differences between the six strength tests, while test-retest reliability was assessed by intraclass correlation coefficients (ICCs) as described by Baumgartner.[22] A Technical Error Measurement (TEM) was also used to determine error of method due to biological and technical factors as per the following equation:

$$Absolute\ TEM = \sqrt{\frac{\sum di^2}{2n}}$$

Where d = The difference of one measure to the next; i = Number of individuals; 2n = number of samples x 2.

Rotational Strength Data

The peak torque of dominant and non-dominant trunk rotation during any of the test repetitions was used to represent trunk rotation strength. Peak torque (Nm) was calculated by the Biodex System III software and provided in a printout format. A 2-way ANOVA (groups X sides) was used to determine significant differences in strength measures between groups and between dominant and non-dominant sides.

Rotational Endurance Data

The total work (Joules) performed by subjects in both dominant and non-dominant trunk rotation over 25 repetitions was calculated by the Biodex System III software and provided in a printout format. A 2-way ANOVA (groups X sides) was used to determine significant differences in endurance measures between groups and between dominant and non-dominant sides.

Range of Motion of Torso Rotation

Total ROM (from dominant to non-dominant limit) was calculated by the Biodex System III software and provided in a printout format. An ASCI file for each subject was imported into Microsoft Excel to determine dominant ROM and non-dominant ROM.

Correlation Analyses

The ROM and strength data from control normals and control golfers were combined (n = 72) to determine a potential association between the ROM achieved during the test procedure and peak torque (Nm) (whether individuals with higher ROM were able to generate more trunk rotation torque). A Pearson Product Correlation was performed to investigate an association between ROM and peak torque. This calculation was done independently for dominant and non-dominant rotation data. The ROM and endurance data were also treated in this same manner to determine a potential association between the ROM achieved during the test procedure and work performed (Joules) (i.e. whether individual's with higher ROM were able to perform more work in rotation).

Body weight data and rotational strength data from *control normals* and *control golfers* were combined (n = 72) and a Pearson Product Correlation performed to determine if there was an association between body weight (kg) and peak torque (Nm). This calculation was done independently for dominant and non-dominant data. The body weight and endurance data was also treated in this same manner to investigate a potential association between subject weight and the work performed (Joules).

Table 1. Strength test reliability data (mean ± SD).

	Axial Rotation Torque (Nm)					
	Initial Test Session			Follow-up Test Session		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Dominant Rotation (n=12)	135.5 ±26.1	135.1 ±29.6	128.7 ±26.5	132.1 ±27.1	130.4 ±25.8	132.3 ±26.6
Non-Dominant Rotation (n=12)	139.7 ±25.9	140.0 ±23.9	132.2 ±23.3	133.0 ±31.3	134.1 ±27.0	130.5 ±25.1

RESULTS

Strength Test Reliability

Mean values (± SD) of the 12 subjects for each of the six strength tests are presented in Table 1. No significant differences in peak torque were found between the six strength tests for left or right rotation ($p > 0.05$). Intraclass correlation coefficients for both dominant and non-dominant rotation were found to be 0.93. The Technical Error of Measurement was found to be 7.70 (5.82%) for dominant rotation and 8.12 (6.01%) for non-dominant rotation.

Rotational Strength Testing

No significant differences in peak torque for non-dominant rotation were found between groups (df = 2,76; F = 0.51; p = 0.6) *(Table 2)*. A significant difference between groups was found for dominant rotation (df = 2,76; F = 3.15; p = 0.048). However, using a Sheffé post hoc test, there was evidence that the *control normals* and *golfers with LBP* were different though this fell just outside statistical significance (p = 0.056). No significant differences in peak torque between dominant and non-dominant rotation were found within any group (*control normals*: df = 1,78; F = 0.30; p = 0.59; *control golfers*: df = 1,62; F = 1.30; p = 0.26; *golfers with LBP*: df = 1,12; F = 1.46; p = 0.25).

Table 2. Peak rotational torque (mean ± SD) of subjects in dominant and non-dominant rotation at 90 deg/sec.

	Peak Torque (Nm)	
	Non-Dominant Rotation*	Dominant Rotation
Control Normals (n=40)	141.4 ± 27.5	138.2 ± 24.8
Control Golfers (n=33)	138.8 ± 28.6	130.7 ± 28.4
Golfers with LBP (n=7)	129.8 ± 28.8	111.6 ± 27.7

** left trunk rotation in a right-hand dominant subject*

Rotational Endurance Testing

Significant differences in total work performed were found between groups for non-dominant ($df = 2,76$; $F = 5.49$; $p = 0.006$) but not dominant rotation ($df = 2,76$; $F = 2.78$; $p = 0.07$) *(Table 3)*. Using a Sheffé post hoc test, it was found that there were significant differences for non-dominant rotation between *control normals* and *golfers with LBP* ($p = 0.009$), and between *control golfers* and *golfers with LBP* ($p = 0.009$). No significant differences in total work were found between *control normals* and *control golfers* ($p = 0.99$). No significant differences in total work were found between dominant and non-dominant rotation in any group (*control normals*: $df = 1,78$; $F = 0.79$; $p = 0.38$; *control golfers*: $df = 1,62$; $F = 0.57$; $p = 0.45$; *golfers with LBP*: $df = 1,12$; $F = 0.2$; $p = 0.66$).

Table 3. Rotational endurance (mean ± SD) of subjects in dominant and non-dominant rotation at 180 deg/sec.

	Work (Joules)	
	Non-Dominant Rotation†	Dominant Rotation
Control Normals (n=40)	2908.1 ± 219.5	2797.0 ± 561.1
Control Golfers (n=33)	2922.6 ± 550.6	2817.2 ± 563.2
Golfers with LBP (n=7)	2203.1 ± 407.2	2294.9 ± 358.6

† *left trunk rotation in a right-hand dominant subject*

Association Between ROM and Torque and Work

A poor correlation was found between the amount of ROM and the amount of torque produced in both dominant ($r = -0.29$) and non-dominant rotation ($r = -0.17$). A poor correlation was also found between the amount of ROM and the amount of work performed in both dominant ($r = 0.16$) and non-dominant rotation ($r = 0.36$).

Association Between Body Weight and Torque and Work

A moderate correlation existed between bodyweight and the amount of torque produced in both dominant ($r = 0.44$) and non-dominant rotation ($r = 0.44$). A poor correlation was found between body weight and the amount of work performed in both dominant ($r = 0.34$) and non-dominant rotation ($r = 0.28$).

DISCUSSION

The resultant ICC of greater than 0.90 for the test-retest data collected from 12 control normals on two different days indicated that the strength and endurance test protocol used in the present study were reliable measures of peak torque. The Technical Error of Measurement indicates that approximately 6% of the measured values obtained from this method of data collection were potentially due to apparatus error (technical error) or other biological factors. This finding means that if the same device were used in a future intervention study, more than 10% change in performance would be necessary to determine a significant effect from the intervention.

One of the purposes of this study was to establish normative trunk rotation strength and endurance data in healthy individuals who do not play golf. This was necessary as there is very limited data available pertaining to axial rotation.[5-7,9] The studies by Kumar et al[5-7] investigating trunk rotation are difficult to reproduce since the measuring device used was developed in their laboratory. In comparison to other published trunk rotation strength data using commercially available equipment (Cybex II), the *control normal* values from the present study *(Table 2)* were slightly higher than the control values reported by Newton et al[9] *(Table 4)*. The *control normals* in the present study were predominantly obtained from an active University population and, therefore, may have had a more athletic background than the control subjects in the study by Newton et al.[9]

The results from Table 2 showed there were no significant differences in trunk rotation torque either between or within the *control normals* and *control golfers* groups. Although the original hypothesis that elite golfers would exhibit greater side-to-side differences than control subjects was not statistically supported, it was interesting to note that a slight and consistent trend in asymmetry was

Table 4. Strength testing data reprinted from Newton et al[9]

	Axial Rotation Torque (Nm)					
	Left Rotation			Right Rotation		
	60 deg/s	120 deg/s	150 deg/s	60 deg/s	120 deg/s	150 deg/s
Control Subjects (n=35)	127.4±42.0	117.9±39.3	115.2±35.3	127.4±35.3	119.3±37.9	117.9±36.6
Subjects with LBP (n=47)	89.5±39.3	85.4±40.7	86.8±37.9	87.6±36.6	82.7±39.3	86.8±39.3

noticed in both *control normals* and *control golfers*. In both groups, the non-dominant direction produced the higher values. A possible reason for slightly higher non-dominant rotation strength in *control normals* might be related to the many recreational activities that involve rotation to the non-dominant side (left trunk rotation for right-handed throw/swing in baseball or racquet sports). It was expected that the golfers would demonstrate an overall higher amount of trunk rotation strength as well as a more pronounced side-to-side difference than *control normals* due to the power and frequency that a highly skilled golfer would perform asymmetrical axial rotation motions. However, since powerful eccentric contractions on the dominant side are also required to decelerate the torso during the follow-through of a golf swing, it is possible these eccentric forces help facilitate concentric strength development of the same muscles.

An additional finding from Table 2 was that trunk rotation strength in *golfers with LBP* was lower, but not to a significant degree, than the values recorded from the *control normals* and *control golfers*. Although statistical significance was not observed, the lower strength values recorded from *golfers with LBP* might have clinical significance which could be related to LBP. It is not clear whether trunk muscle weakness causes LBP or whether LBP leads to muscle dysfunction and hence weakness. However, results from the back pain questionnaire administered prior to testing indicated that *golfers with LBP* were typically only affected by LBP after and not before golfing. Golf has been shown to create considerable shear and compressive loads on the lumbar spine.[23] It seems reasonable to suggest that golfers lacking trunk muscle strength may not be able to control these stresses as well as healthy golfers and thus be more likely to experience LBP when swinging the golf club.

The authors of this study were unable to locate any previously published normative data on isokinetic trunk rotation endurance. The findings from the current study showed no significant side-to-side differences in trunk rotation endurance between any of the groups *(Table 3)*. However, significant differences in rotational endurance were found between *control normals* and *golfers with LBP* and between *control golfers* and *golfers with LBP* in the non-dominant direction. Non-dominant rotation for a golfer (left rotation for a right handed player) occurs at great velocity as the player attempts to accelerate their body towards the target to create maximum clubhead speed. Since this powerful movement is repeated throughout the game or practice session, decreased endurance could lead to premature fatigue and increased injury risk to the trunk region The importance of trunk endurance in preventing LBP has been discussed by McGill[24] and appears to be supported by the results of this study. Furthermore Suter and Lindsay[16] found associations in a population of golfers between poor static trunk extensor endurance and increased quadriceps inhibition. Quadriceps inhibition was postulated to be reflective of irritation to the lumbar structures. Clinical ramifications from the present study suggest that muscular endurance exercises focusing on rotation of the trunk should be an important component of rehabilitation programs targeting golfers with LBP.

A secondary purpose of this study was to investigate whether trunk rotation ROM influenced the amount of torque and work produced by subjects. The relatively poor correlations indicate that ROM did not appear to influence the amount of torque and work performed by subjects. These findings may have interesting implications for the golf swing, particularly in terms of the amount of trunk rotation on the backswing and the subsequent clubhead speed developed on the downswing. The results from the present study seem to support findings by Neighbors[25] who was able to demonstrate that golfers could generate just as much clubhead velocity using a shortened backswing involving considerably less trunk rotation. Decreasing the amount of trunk rotation ROM during the golf swing has been suggested as important for reducing LBP in individuals that golf.[4,26]

Another secondary purpose was to investigate whether overall body weight influenced torque and work. Results showed that a moderate correlation existed between body weight and peak torque. These findings support those of Newton et al9 suggesting that rotational strength and endurance data can be presented in absolute terms (not normalized) when making between-subject comparisons.

Limitations

Limitations exist in the interpretation of the results from this study. It has been suggested that isokinetic performance does not provide a valid measure of actual muscle strength or deficit. Rather, isokinetic performance measures what patients are doing with their muscles in a controlled environment at pre-determined constant speeds and in isolated movement directions.[9] It is not known how accurately the test procedure incorporated in this study represents the trunk rotation performance associated with swinging a golf club.

The validity of the extrapolation of results from a cross-sectional study is very dependent on the representativeness of the sample. An inherent limitation of most observational studies is that the sample is not representative of the population. The strict inclusion criteria made it more difficult to recruit elite golfers with LBP. The relatively low number of subjects in the *golfers with LBP* group makes true associations less clear than would have been observed with a larger subject pool. Another limitation of cross-sectional studies is determining cause or effect. This study did not permit conclusions about the cause or effect relationship between trunk rotation strength and endurance and LBP.

Future studies should establish normative data for different samples than 18 to 49 year old males (females, seniors). Eccentric trunk rotation strength and endurance parameters should also be investigated considering the important deceleration role this type of contraction plays in the golf swing. Furthermore, it would be worthwhile to conduct a prospective study with an exercise intervention to improve trunk rotation strength and endurance in golfers with LBP with the goal to decrease pain symptoms. Similarly, an exercise intervention could be implemented to increase trunk rotation strength and endurance in healthy golfers to investigate the effects on performance (clubhead speed).

CONCLUSIONS

Normative trunk rotation strength and endurance measures were established with the Biodex System III Isokinetic Dynamometer. As well, this study was the first to investigate isokinetic trunk rotation of elite male golfers with and without LBP. The hypothesis that elite golfers (*control golfers*) would exhibit greater overall strength and endurance as well as increased side-to-side differences compared to healthy control subjects (*control normals*) was not supported in this case.

The hypothesis that elite golfers with LBP (*golfers with LBP*) would demonstrate less rotational strength than *control golfers* was not supported, however, *golfers with LBP* did display significantly less torso rotation endurance in the non-dominant, or downswing direction, than *control golfers*. Trunk rotation endurance in golfers with LBP might be more important than strength alone in the prevention and treatment of LBP.

Another important finding from this study was that ROM used during the test did not appear to influence the amount of torque or work performed. This finding suggests that golfers may not need to employ maximum trunk rotation ROM on the backswing to generate a powerful downswing. Furthermore, the results support those of Newton et al[9] suggesting that rotational strength and endurance data can be presented in absolute terms (not normalized) when making between-subject comparisons.

The importance of this study in establishing trunk rotation normative data is considerable especially when taking into account the immense popularity of the sport and high incidence of low back problems. The results from this study provide valuable information on possible risk factors associated with low back pain in golfers (decreased endurance) and allow for intervention strategies to be developed. Future studies should prospectively investigate the cause and effect relationships between LBP and trunk muscle function.

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