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Research article

Frontal plane knee moments in golf: Effect of target side foot position at address

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Abstract
Golf has the potential to keep people active well into their later years. Injuries to the target side knee have been reported in golfers, yet no mechanisms for these injuries have been proposed. The loads on the knee during the golf swing may be insufficient to cause acute injury, yet they may be a factor in the progression of overuse/degenerative conditions; therefore, research developing swing modifications that may alter loading of the knee is warranted. It has been suggested that the proper golf set-up position has the target-side foot externally rotated but no reasoning for this modification has been provided. Frontal plane knee moments have been implicated in many knee pathologies. Therefore, this study used a 3-dimensional link segment model to quantify the frontal plane knee moments during the golf swing in a straight (STR) and externally rotated (EXT) target-side foot position. Subjects were 7 collegiate golfers and knee moments were compared between conditions using repeated measures T-tests. The golf swing knee moment magnitudes were also descriptively compared to those reported for two athletic maneuvers (drop jump landing, side-step cutting) and activities of daily living (gait, stair ascent). The EXT condition decreased the peak knee adduction moment as compared to the STR condition; however, foot position had no effect on the peak knee abduction moment. Also, the magnitude of the knee adduction moments during the two activities of daily living were 9-33% smaller than those experienced during the two different golfing conditions. The drop jump landing and golf swing knee moments were of similar magnitude (STR= - 5%, EXT= + 8%); however, the moments associated with side-step cutting were 50-71% larger than those on the target side knee during the golf swing. The loading of the target side knee during the golf swing may be a factor in the development and progression of knee pathologies and further research should examine ways of attenuating these loads through exercise and swing modifications.

Key words: Golf, ACL injury, biomechanics, knee abduction (valgus) moment/torque, knee adduction (varus) moment/torque, knee osteoarthritis.

Introduction

Current public health messages are consistent in their emphasis of the value of an active lifestyle across all ages. The game of golf has great potential in keeping people active as it has been called a "lifetime" sport that allows for participation from early childhood until well into our older adult years. With the estimated 55 million golfers world-wide (Farrally et al., 2003), the potential of this game for keeping a large number of individuals active is enormous. Therefore, research aimed at ensuring that golfers can avoid musculoskeletal injury/degenerative disease and remain active much longer is warranted.

Traditionally, golf has been considered a docile and non-strenuous sport; however, recent evidence has shown that there is considerable strain on the musculoskeletal system during the golf swing. Although not as common as injuries to the upper extremity joints (wrist, shoulder, elbow) as well as the lower back, there is evidence that lower body injuries account for anywhere from 15-18% of the total injuries reported by golfers (McCarroll, 1996). The prevalence of upper body and low back injuries are high for both amateur and professional golfers; however, the prevalence of some lower extremity injuries has been shown to differ between these two groups. One difference is that in the professional golfer, the left knee was found to be injured about as frequently (7%) as the left hand (7.1%) and left shoulder (7.1%), and was also injured more commonly than several upper limb joints (left elbow – 3.8%, right wrist – 3.1%, right elbow – 2.8%) (McCarroll, 1996). In amateurs, the knee was not injured as commonly (9.3%) as any of the upper limb joints – elbow (33%), hand and wrist (20%), shoulder (11.9%) (McCarroll, 1996). The subjects in the McCarroll (1996) study were exclusively right handed golfers and their left leg is the target side leg upon which the golfer stands following the shot. These different injury rates would suggest that the loads experienced by the joints during the golf swing differ between professional and amateur golfers.

Although the prevalence of target side knee injury is much more common in the professional golfer relative to injuries of other joints, it has been found that there is no difference in the knee joint kinetics between skilled and unskilled golfers (Gatt et al., 1998). If it is assumed that on average a group of professional golfers would be more skilled than a group of amateurs, it may be hypothesized that the different target side knee injury rates in these two groups of golfers are due to the cumulative loading of the knee, as professionals would most likely be performing this motion much more often. Bechler et al. (1995) also tested the EMG activity of various muscles during the golf swing in extremely skilled golfers (handicaps less than 5), and findings indicated that the activity in these target side leg muscles reached up to 83% of peak muscle contraction. Therefore, the combination of these muscular contractions and the external forces resulting from the powerful transfer of the entire body mass onto the target side leg during the swing could place large loads on the knee joint.

Since abnormal loading of the knee joint can be detrimental to many of the soft tissues in the joint (Hewett et al. 2005; Lynn et al., 2007), it is important to attempt to quantify these loads during golf in order to determine the relative risk for acute/chronic injury and/or degenerative

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disease. The three-dimensional knee joint kinetics during the golf swing have been previously reported (Gatt et al., 1998) and it was concluded that these forces and moments are not large enough for golf to be considered a high risk sport for acute knee injury; however, the knee joint kinetics during the golf swing have not been previously compared to the loads associated with activities of daily living (gait, stair climbing) or simple athletic movements (jump landing and cutting maneuvers). These comparisons would be important in determining the risk of golf in the development of overuse/degenerative pathologies of the knee.

The frontal plane knee moment has been linked to the development and progression of various knee pathologies. The external knee adduction moment during gait has been linked with the development and progression of medial knee osteoarthritis (OA) (Lynn et al., 2007; Miyazaki et al., 2002), while the external knee abduction moment has been linked to non-contact ACL injury during a cutting and jump-landing tasks (Hewett et al., 2005, Sigward and Powers, 2007) and lateral compartment knee OA during gait (Lynn et al., 2007). Therefore, comparisons of the moments associated with these various activities and the golf swing moments are warranted.

A common golf set-up position has the target side foot externally rotated 30^o into a toe-out position at address (Hogan, 1957; Leadbetter, 1990). Although this external foot rotation is advocated as one of the basic fundamentals of golf, to our knowledge there is no scientific reasoning currently supporting it. Also, it is not currently known what effect altering the position of the target side foot at address has on knee loads during the golf swing.

Therefore, this study has two main goals: (1) to quantify the peak abduction and adduction moments on the target side knee during the golf swing with a 30^0 externally rotated target side foot stance position and a square or neutral foot position, (2) to descriptively compare the magnitude of these peak moments with those presented in the literature for other activities of daily living (gait, stair climbing) and athletic maneuvers (cutting and drop-landing tasks). It is hypothesized that the external rotation of the foot will decrease the frontal plane knee moments and that the golf swing loads will be greater than those for basic activities of daily living, but not as large as those for other athletic maneuvers.

Methods

Participants

Subjects were recruited from the members of the men's and women's college golf teams at Queen's University (Kingston, ON, Canada). Participants were seven healthy subjects (5M) without history or complaint of chronic pain, major injury, or surgery to the lower limbs or low back. This study was approved by the Queen's University General Research Ethics Board and each subject provided written informed consent prior to participation. Subjects had self reported Royal Canadian Golf Association (RCGA) handicap indexes ranging from +2.7 to 8.1, with a mean of 2.9 (SD 3.6). Subjects were 21.3 (SD 3.1) years of age, 181.4 cm (SD 6.2) tall, and had a mass of 80.2 kg (SD 11.6). All subjects were also right handed golfers and therefore the left leg was the target side leg for all subjects.

Data collection

Subjects had marker arrays containing infrared light emitting diodes (LEDs) from an Optotrak® 3020 three-dimensional motion tracking system (NDI, Waterloo, Ontario, Canada) strapped securely to their target side foot/shoe, and the distal/lateral aspect of the left shank and left thigh using Velcro straps and surgical tape in an attempt to minimize soft tissue motion artifact (Manal et al., 2000). This motion tracking system gives the three dimensional coordinates of these LEDs accurate to within 0.1 mm for the x and y coordinates and 0.15 mm for the z coordinate.

Once outfitted with the marker arrays, the subjects stood with the target side foot on a force plate (AMTI, Newton, Mass, USA) with all LEDs in view of the position sensor cameras. Subjects wore standard athletic footwear and their regular athletic shoes (it was not possible for subjects to wear golf cleats as the force plates were not covered with artificial turf). An indoor golf training aid was used for the data collection. This training aid had a golf ball attached by a short rope to a small metal frame so that it spun around after it was struck. This training aid was placed on a second force plate which produced a force spike when the ball was struck; this allowed for the instance of ball contact to be identified much more accurately than was previously done using hand height kinematics (Gatt et al., 1998). Figure 1 shows a sample of the data collection protocol with the subject outfitted with all the markers and the golf specific training aid shown.

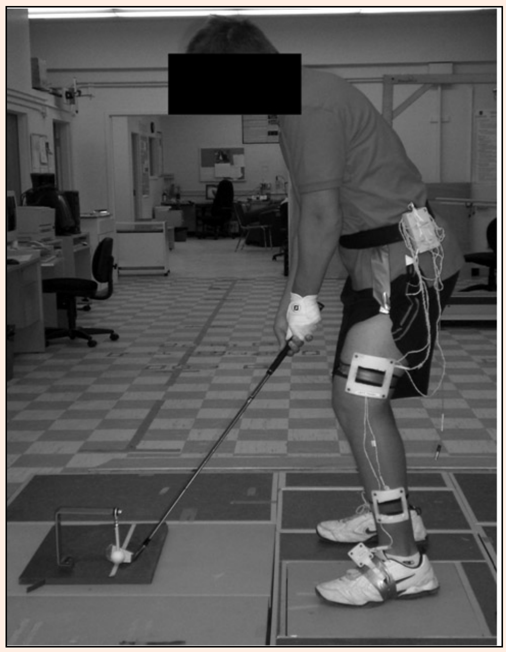

Figure 1. Experimental set-up showing one subject standing with his left foot on a force plate while outfitted with the marker arrays on the left foot, shank and thigh. The specific golf training aid used for this study is also located on separate force plate to allow for the accurate determination of ball contact.

Tape lines were placed on the force plate with one perpendicular to the direction of the golf shot and another at an angle of 30 degrees to this first piece of tape. This was done so that the subjects could reposition their foot consistently for both the square foot position and external rotation/toe-out trials. Subjects were asked to estimate that their 2nd toe was placed on top of the appropriate piece of tape before each trial. The angle of the foot segment in the global coordinate system was calculated to ensure each subject achieved the desired foot angles during each trial. Subjects were then given warm-up time and as many practice trials as they felt were needed to become accustomed to hitting the ball attached to the indoor golf training aid and to be comfortable swinging with the foot in the two different rotation positions. Five trials of regular full golf swings (a 5 iron club was used as this club is approximately the median length club in most golf club sets) for both the straight (STR) and externally rotated (EXT) foot position condition were then performed and the order of the trials was randomized. Subjects were asked to inform researchers if any swings were not representative of their normal golf swing for any reason (i.e. foot slipped, lost balance, etc.) and these trials were repeated. During all golf swing trials, raw marker (100 Hz) and force plate data (2000 Hz) were collected simultaneously.

Following all golf swing trials the participant stood in view of the cameras in normal standing posture and a series of one second reference position trials were collected to identify anatomical landmarks in the local coordinate system of each segment and so that segment axes and joint centers could be approximated during processing. A specially designed probe was used to point at the following specific bony landmarks on the target side lower limb: base of the first and fifth metatarsal, medial and lateral malleoli, medial and lateral femoral condyles, and both the right and left hip greater trochanters.

Data processing

Visual 3D (C-Motion Inc., Rockville, MD, USA) was then used to filter and process the data. A standard ground-up three-dimensional link segment model combined the kinematics and force plate data with anatomical landmark locations and subject specific anthropometrics data; this calculated the net external moments and forces on the target side knee in the tibial coordinate system during the golf swing trials. Although forces in all three directions and moments about all three axes were calculated, for this current study, only the frontal plane knee moment (the moment about the anterior-posterior (A-P) axis) was examined. Knee moments were also normalized to body mass (Nm/kg) as this allowed for comparison with values reported for ADLs and side step cutting maneuvers (Costigan et al., 2002; Sigward and Power, 2007). The moments reported for drop jump landing (Hewett et al., 2005) were divided by the mean group mass for which they were calculated to convert them into the same unit ($Nm \cdot kg^{-1}$). Data from the second force plate, upon which the swing trainer was sitting, were then used to identify the instant of ball contact and this instant in time was set to zero. Therefore, negative time corresponds to 'before impact' and positive time periods correspond to 'after impact'. Key outcome measures were the peak external varus (positive or adduction) and external valgus (negative or abduction) knee moments. Peaks moments for all trials were identified and averaged together for each subject in both foot positions.

Statistical analysis

Data were assessed for parametric assumptions and then paired sample T-tests were used to determine if there were differences in peak external knee varus and valgus moment between foot rotation conditions (significance level = 0.05). The effect size (r) of the change in the knee moment with external foot rotation was also calculated.

Descriptive moment magnitude comparison

The magnitude of the mean peak knee moments during the two golf swing conditions (EXT, STR) were also compared to values reported in the literature for other activities of daily living - gait, stair ascent (Costigan et al., 2002); and athletic maneuvers – side-step cutting (Sigward and Powers, 2007) and drop-jump landing tasks (Hewett et al., 2005). Differences between these values were not tested statistically but simply compared descriptively based on their relative magnitudes.

Results

Figure 2 shows the mean curve profile of the frontal plane knee moment during the golf swing of all subjects. All subjects had a similar pattern of peak external valgus/abduction moment (negative peak) just before ball contact and a knee varus/adduction moment peak (positive peak) just after ball contact.

The external foot rotation position was measured for each subject/trial and the mean external rotation was 27.9° (SD = 5.3°). The individual standard deviations between trials for each subject were also relatively small as they ranged from 1.0° to 4.1°. Table 1 presents the pooled mean peak values taken from the frontal plane moment curves during the golf swings in both the straight and externally rotated foot set-up position. It should be noted that external foot rotation decreased the post ball contact peak varus/adduction moment at the knee for all subjects (paired samples t-test, t stat = -3.51, $p = 0.01$, effect size (r) = 0.19) as compared to the straight foot rotation condition. However, the effects of foot rotation were inconsistent for the pre-ball contact valgus/abduction moment peak, and therefore foot rotation had no effect on it (paired samples t-test, t stat = -2.14, $p = 0.07$, effect size (r) = 0.39).

Also, the magnitudes of the varus/adduction moments at the knee during the two activities of daily living are 9-33% smaller than those experienced by the target side knee during the two golf swing conditions (Table 1). In comparing the golf knee loads to those experienced during the two athletic maneuvers, it was discovered that the drop jump landing produced similar valgus/abduction moment magnitudes to golf (STR = 5%, EXT = + 8% greater), while the valgus/abduction knee moment during side-step cutting was 50-71% greater than those experienced by the target side leg during the golf swing.

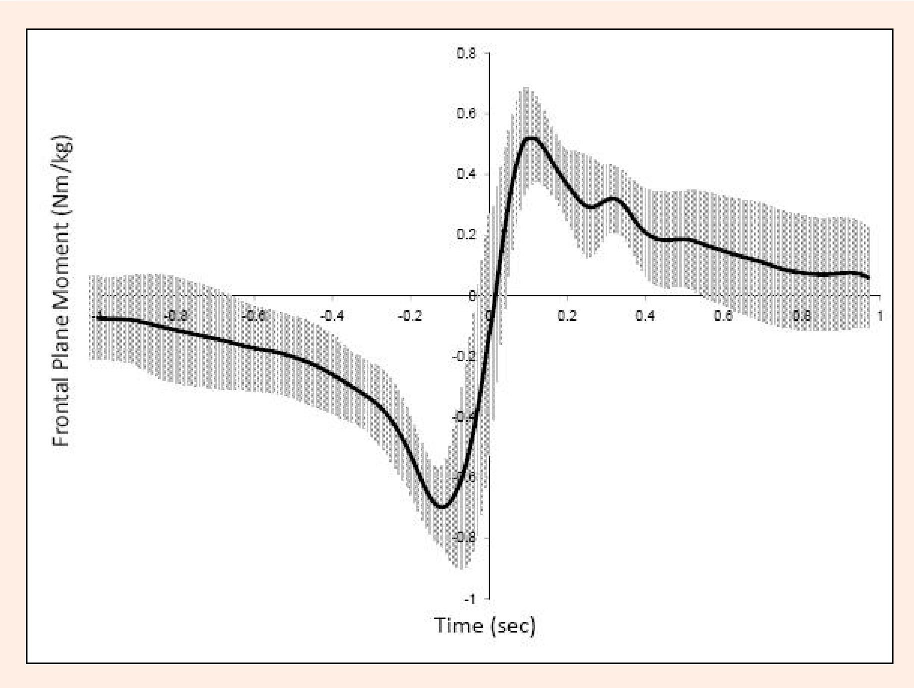

Figure 2. The lead knee average external frontal plane moment profile during the golf swing (7 subjects). Note: Positive y- values correspond to an external knee adduction/varus moment. Negative y- values correspond to an external knee abduction/valgus moment. Time zero (x-axis) = ball contact.

Table 1. Comparison between mean peak external adduction (varus) and abduction (valgus) knee moments experienced by the lead leg during golf (in both straight and externally rotated set-up foot position), gait, stair ascent, drop jump landing, and a side-step cutting maneuver.

	Frontal Plane External Knee Moment (Nm/kg)	
	Adduction Moment	Abduction Moment
Golf STR	.63 (.23) †	-.70 (.12)
Golf EXT	.54 (.25) †	-.80 (.19)
Gait [a]	.49 (.19)	n/a
Stair Ascent [a]	.42 (.15)	n/a
Drop Jump Landing [b]	n/a	-.74 (.46)
Side-step cut [c]	n/a	-1.20 (.40)

a = taken from Costigan et al. (2002). b = calculated from Hewett et al. (2005). c = taken from Sigward and Powers (2007). STR = straight golf set-up foot position. EXT = externally rotated golf set-up foot position. † = Statistical difference between the STR & EXT foot rotation conditions at $p < 0.05$.

Discussion

The main findings in this study are: (a) the peak external knee varus/adduction moment reported for the two activities of daily living (gait and stair climbing) (Costigan et al., 2002) are smaller than those on the target side limb during the golf swing; however, comfortable external rotation of the foot at set-up does decrease the magnitude of this peak. (b) The peak external knee valgus/abduction moment during the golf swing on the target side limb is not affected by set-up foot position. Also, the magnitude of this knee valgus/abduction peak during golf is similar to jump-landing loads (Hewett et al., 2005) but not as large as during side step cutting maneuvers (Sigward and Powers, 2007). This study has demonstrated that the magnitude of external knee varus/adduction moment on the target side leg created just after ball contact during the golf swing is larger than those normally experienced by the knee during gait and stair ascent (Table 1). This would suggest that during this phase of the golf swing, additional loads are shifted onto the knee's medial compartment as this moment has been shown to relate to the ratio of loading between the knees medial and lateral compartment (Hurwitz et al., 1998). This is supported by a study that examined the results of total knee arthroplasty (TKA) in patients who were active right handed golfers (Mallon and Callaghan, 1993). These results revealed that those with left (target side leg) total knee arthroplastys (TKAs) had significantly more pain during and after playing golf than did those with right side TKAs. This may be due to this varus/adduction moment on the knee that occurs just after ball contact with every swing (Figure 3). Although the cumulative loading of the knee's medial compartment caused by the golf swing adduction moment may not be large enough to be implicated in the development of medial compartment disease, as the number of loading cycles on the medial compartment during golf swings would be much less than the number of gait cycles. Also, the knee's medial compartment has a large surface area and is better able to decrease the stress on the cartilage. However, this adduction moment on the target side knee during the swing may make golf extremely uncomfortable/painful for those already presenting with medial compartment knee pathology.

This study also demonstrated that it is possible to decrease this external knee varus/adduction moment by addressing the ball with the foot in an externally rotated position. This foot position most likely allows the golfer to move the ground reaction force vector more laterally and thus keep it closer to the axis of rotation of the knee in the frontal plane and decreasing the varus/adduction moment (Figure 3). Foot external rotation has been examined in several gait analysis studies and it has been suggested that this foot positioning can decrease the knee adduction moment (Lynn et al., 2008) and slow the progression of medial compartment knee OA (Chang et al., 2007); therefore, this may be useful for those with medial compartment knee OA as it would take some of the loads off of the diseased compartment of their knee. Since a large positive varus/adduction moment during gait is known to increase the loading (bone density) in the knee's medial compartment (Hurwitz et al., 1998), decreasing it during the golf swing may help decrease the loads on the medial compartment and help alleviate some of the pain associated with the golf swing motion.

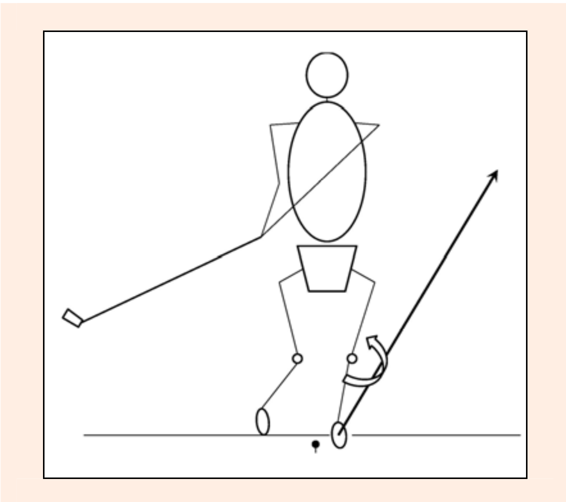

Figure 3. The position of the ground reaction force relative to the frontal plane axis of rotation of the lead knee just prior to ball contact in the golf swing. This creates an external valgus/abduction moment on the knee.

The magnitude of the peak knee valgus/abduction moment on the target side leg just before ball contact also has important clinical implications. During most activities of daily living, such as gait and stair climbing, the ground reaction vector is directed medially to the knee joint axis rotation, creating a varus/adduction moment on the knee throughout the time the foot is in contact with the ground (Costigan et al., 2002). However, the knee is built to handle large varus/adduction loads, as the larger surface area of the knee's medial compartment can help to decrease the stress on the joint. Although this is the case, even in the presence of an external knee adduction moment, there is still some force being transmitted through the relatively smaller lateral compartment (Hurwitz et al., 1998). It has also been demonstrated that those with a frontal plane moment close to zero (ground reaction force vector passing almost directly through the axis of rotation of the knee in the frontal plane) during gait are actually at increased risk of developing lateral compartment knee OA (Lynn et al., 2007). Therefore, it can be hypothesized that the large abduction moment experienced by the knee just before ball contact would be shifting the loads onto the much smaller lateral compartment cartilage (Figure 4). It can then be hypothesized that those who perform this motion hundreds of times a day over many years could be putting themselves at risk for lateral compartment degenerative disease in their knee. Since the majority of knee OA cases in the general population affect the medial compartment (Felson, 1998), future studies could examine whether professional and avid golfers have increased signs of lateral compartment degenerative changes in their knee as compared to the general public. If this is the case, then interventions aimed at decreasing this load would need to be developed, as the simple set up modification tested in this study (external rotation of the foot) did not decrease the magnitude of this valgus knee load (Table 1). Further examination of our data reveals that with more subjects, we may have seen an increased magnitude of valgus moment with external rotation as the foot would move the ground reaction force laterally – further away from the axis of rotation just before ball contact (Figure 4).

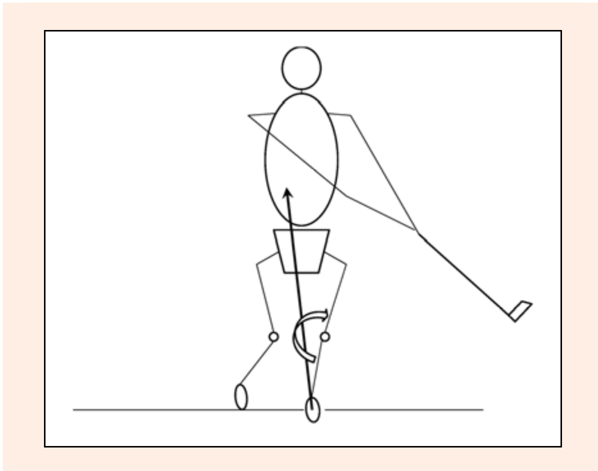

Figure 4. The position of the ground reaction force relative to the frontal plane axis of rotation of the lead knee just following ball contact in the golf swing. This creates an external varus/adduction moment on the knee.

There has also been a strong link established between valgus/abduction loading of the knee and ACL stress (Fukuda et al., 2003). Therefore, the current finding of a knee valgus/abduction moment just prior to ball contact in the golf swing may suggest that the target side knee ACL is put under tensile stress with every swing. The magnitudes of these valgus/abduction golf swing loads are similar to those experienced during a drop jump landing for athletes who went on to injure their ACL in a subsequent season (Hewett et al., 2005), but less than those experienced during a side-step cutting maneuver in athletes who were considered to have excessive valgus/abduction moments (Sigward and Powers, 2007). The magnitude of these loads demonstrate how side-step cutting has the potential to cause a non-contact ACL injury; however, how is it possible that non-contact ACL tears occur during drop jump landing but not during golf, when the loads are of similar magnitude? It should be noted that in the drop jump landing study (Hewett et al., 2005), valgus/abduction moments were collected in a controlled laboratory situation where there were no other external factors (other athletes, ball, etc.) for the athlete to consider, as there would be in sports where jump-landing is required. Also, although the peak abduction moments may be similar between these two activities, the rate of loading would no doubt be different between the golf swing and jump-landing. It is most likely the combination of the motor pattern that creates these valgus/abduction moments in the laboratory, the increased loading rate, and these external factors that would cause the acute ACL tears seen in sports requiring jump landing. Golfers, on the other hand would reach this peak moment much more slowly and do not have these external factors to contend with, so the valgus/abduction loads in golf are not likely to cause an acute ACL tear. However, the cumulative exposure of this valgus/abduction moment applied to the knee with every swing could build up over many years and may be able to compromise the integrity of the ligament in those who take thousands of swings a year, such as the professional golfer. Therefore, developing exercises and/or swing modifications that can reduce this valgus/abduction moment on the knee during golf are warranted.

One potential methods of decreasing the external abduction moment on the knee during the golf swing may involve training the proximal control of the femur. There is evidence that frontal plane knee loads can be controlled through proper activation of the hip musculature during single limb stance (Chang et al., 2005), as this is thought to control the position of the trunk on top of the stance limb. Since the golf swing involves the rapid transfer of close to 100% of body weight to the target side leg and finishes with the golfer standing almost exclusively on that limb, exercises aimed at strengthening the hip musculature in single limb stance by learning to control the position of the trunk on top of the stance limb may allow golfers to decrease the external knee abduction moment. Further research should examine the effectiveness of these exercise interventions at controlling these moments in the golf swing and hence reducing the loads on the knee.

The results of this study also lead to several future research questions in order to further understand the loading of the knee joint during the golf swing. With the experimental set-up used in this investigation, tracking of markers on the club was impossible and therefore no information on swing speed was obtained. Since swing speed would most likely affect the rate and magnitude of knee loading, future research should examine the effects of swinging at different speeds on the loading at the knee. As people age their swing speed would most likely decrease and the effect this has on the loading of the joints should be investigated. Also, there was no way of tracking ball flight to ascertain the effects of front foot address position on golf performance. Another limitation of this current work was the small number of female participants in the subject pool. It has been shown that the loading of the knee joint differs between male and female populations in other movements (Kernozek et al., 2005; Pollard et al., 2007; Sims et al., 2009) and therefore, research investigating sex differences in golf swing knee kinetics is warranted. Also, subjects could not wear their golf shoes during testing as there was not an artificial turf covering on the force plates. Whether or not these different surface/footwear conditions have an effect on the golf knee moments is not known and would be useful information for future labs investigating golf swing kinetics. In addition, subjects were asked to assume these two front foot positions, neither of which were their natural set-up foot positions; therefore, future research should examine the foot rotation position people would naturally use and whether forcing them into these unnatural positions may change their ability to produce a normal golf swing. Finally, the subjects in this current work were all highly skilled golfers and more work would be needed to determine whether these results hold true for golfers of varying skill levels.

Conclusion

These data suggest that it would be useful to teach an externally rotated front foot address position to most aging recreational golfers as the medial compartment is most commonly affected in knee OA cases (Felson, 1998), and therefore, decreasing the loading of the medial compartment could help slow cartilage wear in healthy golfers and decrease pain levels in those with medial knee pathology. However, in those with lateral compartment disease, an externally rotated front foot position may not be as helpful as this set up modification did not affect the abduction moment of the knee during the golf swing.

The magnitude of the knee varus/adduction moment during the golf swing is larger than those experienced during other ADLs, and therefore may have clinical implications in those with medial compartment knee pathologies. Also, the valgus/abduction load on the knee during the golf swing may have clinical consequences as the magnitude of this moment is comparable to those calculated during drop jump landing. Valgus/abduction loading of the knee joint has also been shown to be associated with lateral compartment cartilage wear (Lynn et al., 2007) and stress on the ACL (Fukuda et al., 2003). Therefore, with many swings over several years, the golf swing may have the potential to lead to lateral compartment degenerative changes in the knee and to ligament attenuation of the ACL. Although golf injury data has reported the prevalence of knee injuries in golfers (McCarroll, 1996), the exact pathologies are unclear and this work would suggest that an examination of the prevalence of lateral compartment cartilage and ACL related pathologies in golfer's knees is warranted. External foot rotation at set-up did not decrease the magnitude of this valgus/abduction load and thus, other ways of controlling the magnitude of this moment need to be developed.

The game of golf is as a lifelong leisure time activity that can keep individuals active and healthy well into their older adult years (Vandervoort, 2009). Therefore, research aimed at making the game less harmful on the musculoskeletal system is necessary. This study has demonstrated that the magnitudes of the frontal plane knee loads on the target side limb during the golf swing have potential clinical consequences for golfers and further research examining knee mechanics during the golf swing is needed.

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Key points

- An externally rotated front foot position at address would be recommended for those with medial knee pathology in the target side limb.
- There is a large valgus moment on the target side knee during the golf swing that is not decreased with external rotation of the foot at address.
- The potential of the knee moments on the target side limb to lead to knee pathologies in golfers needs to be further investigated.

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