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Research article

Hip rotational velocities during the full golf swing

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Abstract
Since labral pathology in professional golfers has been reported, and such pathology has been associated with internal/external hip rotation, quantifying the rotational velocity of the hips during the golf swing may be helpful in understanding the mechanism involved in labral injury. Thus, the purpose of this study was to determine the peak internal/external rotational velocities of the thigh relative to the pelvis during the golf swing. Fifteen female, collegiate golfers participated in the study. Data were acquired through high-speed three dimensional (3-D) videography using a multi-segment bilateral marker set to define the segments, while the subjects completed multiple repetitions of a drive. The results indicated that the lead hip peak internal rotational velocity was significantly greater than that of the trail hip external rotational velocity ($p = 0.003$). It appears that the lead hip of a golfer experiences much higher rotational velocities during the downswing than that of the trail hip. In other structures, such as the shoulder, an increased risk of soft tissue injury has been associated with high levels of rotational velocity. This may indicate that, in golfers, the lead hip may be more susceptible to injury such as labral tears than that of the trailing hip.

Key words: Golf, hip, injury.

Introduction

During most sport skills, the goal of the movement is to increase angular velocity of a body segment to impart the optimum linear velocity to an object being released or hit. However, these angular (rotational) velocities may reach levels of sufficient magnitude to induce injury to the soft-tissue that is involved in producing or controlling these high velocities. For example high rotational velocities experienced at the shoulder during the baseball pitch and overhead tennis serve have been associated with labral tears of the glenohumeral joint (Andrews et al., 1991). Thus, it appears that motions such as these, which involve high rotational velocities, have the potential to induce injury.

Recently, the occurrence of acetabular labral tears has been documented in a number of elite athletes, including professional golfers (McCarthy et al., 2003; Philipon, 2001). One suggested mechanism for these tears involves the hip experiencing torsion during combined hip external rotation (ER) and extension (Mason, 2001). Since the velocity of joint motion contributes to the overall stress on the joint, knowledge of the hip rotational velocities during the golf swing may provide meaningful insight into this issue.

Just as there have been studies on upper extremity rotational velocities during the throwing motion (Dillman et al, 1993; Fleisig and Andrews, 1995), there have also been studies that have quantified lower extremity rotational velocities in several sports (Aprianton et al, 2006; Kellis et al., 2006; Nunome et al., 2002; 2006). However, these studies have addressed a lower limb moving in an open kinetic chain, typically involving the kicking leg. Very few studies have examined the rotational velocities achieved at the hip joint during athletic activities while the foot is fixed (closed kinetic chain). One such study that examined lower extremity rotational velocities in baseball batting found that the rotational velocity at the hip reached a maximum speed of 714 deg·sec^{-1} at 0.075 seconds prior to ball contact (Welch et al., 1995). However, it should be noted that the investigators described hip motion as a vector from the right to the left hip, which is more indicative of the entire pelvic movement, and not separate hip (pelvic-on-femoral) rotation.

Like the baseball hitter, whose foot is fixed during the weight transfer onto the front foot during the bat swing, golfers also experience rotational velocities at the hip in a closed kinetic chain. Currently, we are not aware of data describing the actual pelvis-on-femoral rotational velocities of the hips during the golf swing, or where in the golf swing these reach their peak. Therefore, the purpose of the study was to determine the peak internal/external rotational (IR/ER) velocities of each hip during the downswing phase of the golf swing.

Methods

Fifteen healthy, female Division I collegiate golfers (mean age 19.6 ± 1.4 yrs; ht. 1.63 ± 0.1 m; wt. 59.5 ± 6.6 kg, USGA handicap 5.2 ± 3.3) free from hip, back, or lower extremity injury in the past six months participated in the study. All subjects were right-handed players, and subsequently utilized their left leg as the lead leg during the golf swing. Prior to participation, subjects signed a written consent form as approved by the University of Toledo Human Subjects Research Review Committee.

Data were acquired through a high-speed videography motion capture system (Motion Analysis Corporation, Santa Rosa, CA) and a multi-segment bilateral marker set (Figure 1). This system involved EVa 7.0 software (Motion Analysis Corporation, Santa Rosa, CA) for video and analog data acquisition and processing. Eight electronically synchronized Falcon High Resolution cameras (Motion Analysis Corporation, Santa Rosa, CA), sampling at 120 Hz were used for capturing the movement of the retroflective markers on each subject and

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generating a three-dimensional reconstruction of the trajectories of each marker.

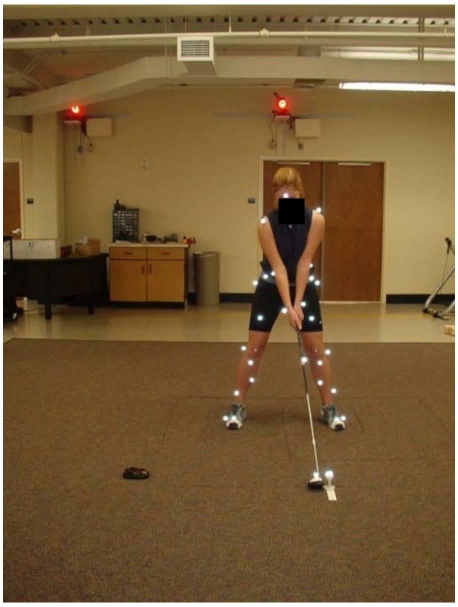

Figure 1. Retroflective marker setup.

Following this initial data collection and processing, KinTrak 4.0 software (Motion Analysis Corporation, Santa Rosa, CA) was used to calculate range of motion and angular velocities for the involved segments and joints in all three planes. The pelvic segment was defined by markers on the right anterior superior iliac spine (ASIS), left ASIS, and sacrum. The femoral segment was defined by markers on the greater trochanter, lateral femoral condyle, and anterior thigh (for left and right sides respectively). Segment axes and joint centers were calculated from these marker locations using conventional techniques incorporated in the KinTrak software. Thus, the internal/external hip rotation was based on the transverse plane motion of the femoral segment relative to the pelvic segment, and hip rotational velocity was calculated as the first derivative of this motion.

Each subject hit ten shots toward a target (into a net) with a driver (45” standard weight, shaft flex, and design), during which data was collected. A single driver was used by all subjects to minimize the effects of variations in driver design on the variables of interest. Practice swings were allowed for warm-up, as well as to allow the subject to feel comfortable making a golf swing with the marker set in place. The golfers hit a wiffle ball with a retroflective marker on top, and during all trials the swing speed was measured using the Swing Mate (Beltronics, West Chester, OH) device (placed approximately three feet behind the tee).

Three representative swings for each subject were then selected, tracked, processed, analyzed and ensemble averaged, and used to examine the hip velocity characteristics associated with the swing. For analysis, the downswing phase was defined as the time period between the top of the swing and impact. Both of those events (top of swing and impact) were identified within the data, based on acceleration patterns of the club. Two different hip rotational velocities were compared during the downswing. Since the lead hip is undergoing IR and the trail hip is undergoing ER, these were the rotational velocities of interest.

Statistical data analysis was performed using Statistical package SPSS version 12.0 (SPSS Inc., Chicago, IL). Data was tested using a paired t-test comparing the right and left hip velocities during the downswing. The significance level was set at an alpha level of 0.05.

Table 1. Subject Demographics.

Golfers (n = 15)	Mean (±SD)
Age (yrs)	19.7 (1.4)
Height (m)	1.63 (.07)
Weight (kg)	59.6 (6.6)
Clubhead velocity (km·hr$^{-1)}$	134.4 (12.6)

Results

Subject demographics are found in Table 1. The clubhead velocities (Table 1), as measured with the Swing Mate were consistent and characteristic of elite female golfers (Egret et al., 2005). Table 2 reports the hip rotational velocities for each hip during the golf swing. The lead hip peak IR velocity was significantly greater than the trail hip ER velocity (p = 0.003, t-value = 3.65). Furthermore, the lead hip peak IR velocity and trail hip peak ER occurs at 89.1% and 85.2% of the downswing time respectively (Table 2).

Table 2. Means (±SD) for Hip Rotational Velocities (n =15).

Golf Swing Variable	Mean (±SD)
Trail Hip Peak ER vel (deg·sec^{-1})	-145.3 (68.0)
Peak L hip IR vel (deg·sec^{-1})	-227.8 (96.6) *

* t = 3.655, p = 0.033.

Discussion

The results of our study demonstrated that the lead hip experiences a significantly higher IR velocity during the downswing, compared to the trail hip ERvelocity. Although the rotational velocities of the hip are lower than those that have been reported for the shoulder during the throwing motion (Dillman et al., 1993; Fleisig and Andrews, 1995), the fact that these are experienced in a closed kinetic chain, may produce sufficient torsion on the hip to predispose the joint to injury. In particular, the rotational velocity contributing to the stress at the hip joint, may expose the acetabular labrum to risk for tear.

Although golf is typically considered a non-contact sport, injuries related to golfing do occur. The leading area of injury in both professionals and amateurs appears to be the back (Gosheger et al., 2003; Grimshaw et al., 2002; Lindsay et al., 2000; McCarroll, 1996; Mc Carroll et al., 1990). Interestingly, these surveys have reported almost no hip injuries in golfers (Batt, 1992; Grimshaw et al., 2002; Lindsay et al., 2000; McCarroll, 1996; McCarroll et al., 1990; Theriault and Lachance, 1998). However, one orthopedic surgeon has reported on treatments of professional golfers for a particular pathology, hip labral tears (Philipon, 2001).

Labral pathology of the hip is a more recent diagnosis in athletes. The occurrences of tears in the athlete's acetabular labrum have been reported in sports that place rotational demands on the hip (such as tennis, golf, and hockey) (Binningsley, 2003; Mason, 2001; McCarthy et al., 2003). Although kinematic data on the throwing motion in baseball may illustrate mechanisms of a labral tear in the shoulder (Andrews et al., 1991), there is currently no evidence of the velocities of the lead and trail hips during a full golf swing to determine if the same potential exists for labral pathology in the hip.

Past studies that have examined lower extremity rotational velocities have measured the hip in an open kinetic chain movement (Kellis et al., 2006; Nunome et al., 2002; 2006), but the lower extremity is a closed kinetic chain during the golf swing. For example, during the soccer kick, Kellis et al. (2006) found the angular velocity of the hip was between 125.9 and 151.4 deg·sec^{-1} depending on the time measured during a fatiguing protocol. It should be noted that the angular velocity of the hip in this skill movement would primarily be in the sagittal plane, and not a transverse plane rotational velocity as seen during the golf swing.. The study by Nunome et al. (2002) found much higher hip external rotational velocities of 636.0 deg·sec^{-1} during a side-foot soccer kick, but a lower rotational velocity of 343.8 deg·sec^{-1} during an instep soccer kick. The only study to measure "hip" rotational velocity in a closed kinetic chain was Welch et al., 1995. They found the peak pelvis rotational velocity to be 714 deg·sec^{-1} just prior to impact of hitting a baseball. In our study peak hip rotational velocities were much lower at -227.8 ± 96.6 and -145.3 ± 68.0 deg·sec^{-1} respectively, occuring at 89.1% and 85.2% of the total downswing time (Table 2). This may reflect inherent differences in the mechanics of the baseball swing versus that of the golf swing. Additionally, our study was completed on female athletes who may have less capacity to generate high velocities than the male athletes in the baseball research. Furthermore, the "hip" rotational velocity in the Welch study actually measured pelvis velocity relative to a stationary global coordinate system, which could produce inflated velocities as it does not account for the simultaneous movement of the adjacent segments as was done in our study.

The golf swing is a very rapid movement, with the typical backswing taking 0.8-1.0 seconds, and the downswing lasting only 0.1-0.3 seconds for a total swing time ranging from 1.09-1.28 seconds among professionals and amateurs (McTeigue, 1994). Although the trail hip had a significantly lower rotational velocity than the lead hip, this type of quick movement during the downswing may place golfers at risk for labral pathology when the trail hip experiences ER and extension. Mason (2001) suggested this combined position of hip ER and extension may be the "danger zone" for labral tears to occur. Interestingly,, a golfer may not even have to exceed their normal joint range of motion (ROM) at the hip for this injury to occur, as long as the overall torsion on the joint surpasses threshold .

Not only could injury occur to the acetabular labrum, but the repetitive rotational velocities may also be contributing to joint ROM adaptations. Vad et al. (2004) and Gulgin et al. (2008) have both found decreased IR in the lead hip of elite golfers. Thus, the significantly higher rotational velocities on the lead hip may be contributing to the surrounding soft-tissue adaptation. Vad et al. (2004) suggested that the rotational movement may be producing micro-trauma that leads to capsular contracture and ROM deficits, such as seen in shoulders of throwing athletes.

Although the previous studies have found IR ROM deficits on the lead hip, both of those studies measured joint ROM in a non-weightbearing position. Future studies related to a more functional measurement, such as the golfer's weight-bearing ROM would provide additional insight as to whether a golfer exceeds their available joint ROM at any point during the golf swing, thus stressing the surrounding soft tissue, and possibly adding to the injury risk. In addition, reports about the frequency of acetabular labral tears, and which hip the pathology occurs (for athletes) would also be beneficial for understanding the mechanism of this pathology.

One limitation to our study was that all golfers were asked to swing the same custom-built driver provided by our lab. We wanted to control the length and mass of the club so that rotational velocities of the hip would not be the result of swinging a heavier or lighter club with respect to the other golfers. Although this length or mass may not have been what all participants were used to, they were allowed adequate practice swings in order to gain a level or comfort with the driver.

Conclusion

In conclusion, it appears that the lead hip of a golfer experiences higher rotational velocities than the trail hip during the full golf swing. The higher rotational velocity is likely to influence the overall stress acting on the hip, which may influence the risk for hip pathology. Additional attention is needed on the forces acting on the hip during the sport of golf as we observe the possible increase in hip pathology in those that play the sport professionally and recreationally.

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Key points

- Lead hip of golfer experiences significantly higher rotational velocities than the trail hip.
- Golfers may be more susceptible to injuries on the lead hip.
- Clubhead velocities were consistent with elite female golfers.

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