A BIOMECHANICAL ANALYSIS OF THE KNEE DURING JUMP LANDING

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This paper discussed jump landing activity that is a frequently performed task in volleyball, badminton smash and basketball game that may lead to injury if the wrong landing techniques have been used. The Qualysis Track Manager software, Oqus camera system and Delsys were used to record and analyze the performance. Eight male and eight female, aged 20 to 25 years, were selected in the study. The result shows that the female subjects have a greater GRF than the male subjects for these three sports. In addition, female subjects landed with lesser knee flexion angles. It is concluded that the male subjects have better strategies in jump landing that prevent them from having serious ACL injuries when compared to female subjects.

KEY WORDS: kinetic analysis, knee flexion angle, muscle activation.

INTRODUCTION: The anterior cruciate ligament (ACL) injuries are common in sports that involve sudden changes of direction or when landing from a jump (Yu & Garrett, 2006; Withrow, Huston, Wojtys & Ashton-Miller, 2006). One of the major findings is that women are nearly three times more likely to have ACL injuries than men. Researchers believe this may be due to differences in hormone levels on ligament strength and stiffness, neuromuscular control and lower limb biomechanics. However, gender differences in regards during-jump landing have been inadequately researched and the results of these studies are contradictory.
In order to discover the initial cause that the female athletes are more likely to have ACL injuries than male athletes, a study was conducted on jump landing for three different sports (badminton, volleyball and basketball). These three sports have been chosen because it requires the athletes to do the jump landing during spiking in volleyball, badminton smash and shooting in basketball. The jump landing technique for different genders for every sport will be analysed.

METHODS: Sixteen subjects without joint and muscular pathology (eight male and eight female) were selected among the UniMAP students. The subjects were required to have basic knowledge in volleyball, basketball and badminton sports in order to make them qualified to participate in the study.
Each subject was requested to perform a vertical jump and landing with both legs depending on the actual sports activity such as jump landing during smashing for badminton, shooting the ball for basketball and spiking the ball for volleyball. The jumping and landing trial was performed in triplicate by each subject.
Five Oqus cameras (Qualysis, Gothenburg, Sweden, 70 Hz) have been placed surrounding the subject dominant leg in order to measure the knee flexion angle (kinematic), and ground reaction force (kinetic). The reflective markers (Ø19mm) were placed at the key locations on the subject's dominant leg to observe the knee movement during jump landing. The position of the markers on the subject is shown in Figure 1. The capture rate was set at 70 Hz and the duration of the capture was set to 10 s. These capture rates are shown better while executing one data (jump landing) for particular analysis.

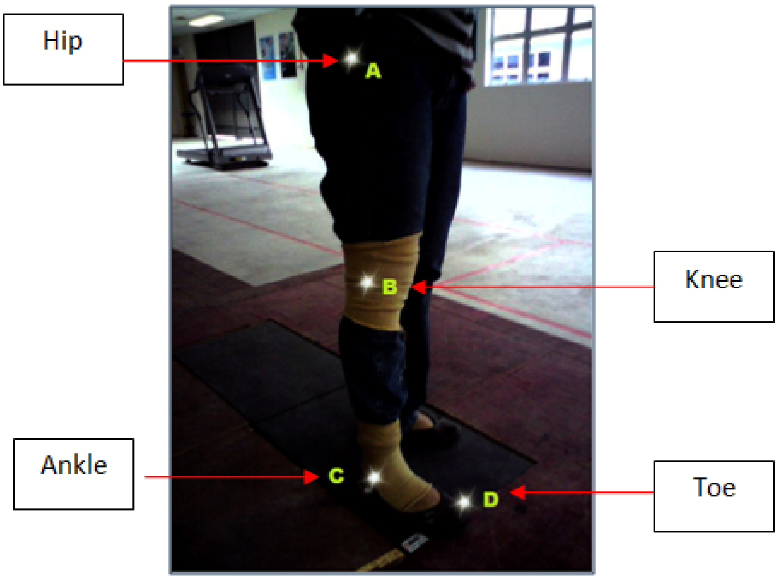

Figure 1: The position of markers (side view).

Data were collected at vastus medialis (VM), vastus lateralis (VL), rectus femoris (RF) and biceps femoris (BF) using electrode sensor of EMG (Delsys system). The midpoint of the top patella was used as reference point to the Delsys system which was used to detect muscular activity at dominant leg. The EMG data were taken simultaneously with data kinetic and kinematic recording while the subject made the jump landing. EMG data collection has a standardization procedure for all subjects involved.
Kinetic and kinematic data were analyzed using Qualysis Track Manager (QTM) while EMG data was analyzed using Delsys software. The raw EMG data were converted into mean values. The mean value of EMG was calculated during vertical Ground Reaction Force (vGRF) at higher values of means of knee flexion angle during each jump landing.
The independent T-test was used to compare mean of vGRF, knee flexion angles and muscle activation in different types of sports during jump landing between genders. A significant different was considered when *P* value is less than 0.05. In addition, the Pearson's correlation analysis was used to examine the correlation relationship for each parameter in men and women. The value of a Pearson's can fall between 0.00 (no correlation) and 1.00 (perfect correlation).

RESULTS: All subjects performed jump landing with their dominant leg. Kinematic, kinetic and muscles activation variables were used to define the difference and correlation relationship between the two groups. As an example for the sport of badminton , the female group applied greater vGRF (mean=1090.9 ±243.4 N) than males (mean=703.4 ±192.3 N) during landing and the T-test shows that vertical ground reaction force were significantly different ($P<0.05$) between male and female groups (Table 1).

Table 1: Group statistics of force (vGRF) for three sports.

	Gender	N	Mean (N)	Std. Deviation (N)	Std. Error Mean (N)
Force Badminton	Female	8	1090.9	243.4	86.0
	Male	8	703.4	192.3	68.0
Force Basketball	Female	8	919.e	345.9	122.3
	Male	8	732.4	239.6	84.7
Force Volleyball	Female	8	954.8	362.9	128.3
	Male	8	731.1	231.3	81.8

In the male group, the highest knee flexion angle was found for all three types of sports (above 110°). For example in basketball, male group shows the highest angle of movement on knee flexion (135.89°) while females were observed to have the lower or lesser angle of

knee movement (83.5º). Moreover, the female group shows the lower knee flexion angle in three types of sport at peak vGRF during jump landing.
In the case of muscles activation (Table 2), VL shows the highest value of activation level (μV) when compared to other muscles during jump landing whereas BF shows the lowest value of activation level. The RF, VL, VM are quadriceps muscles while BF is hamstring muscle.

Table 2: Muscle activation in mean values (μV) for three sports.

Muscles activation	(Mean values,μV)		
	Badminton	Basketball	Volleyball
RF	109.68	72.60	125.84
VL	343.04	254.46	578.76
VM	166.05	137.70	360.80
BF	47.41	39.74	45.49

The correlations among biomechanical data such as a kinetics or kinematic and electromyographical activity (Table 3) provide important information for future research that relate to the three types of sports especially during the jump landing activity. However, no significant correlation reported between the kinetic (force) and kinematic (angle) data which is similar for the correlation analysis between kinematic and muscle activation.

Table 3
Correlation relationship between variables.

	Kinetic (Force)	Kinematic (Angle)	Muscles activation
Kinetic (Force)	$r = 1$	$r < 1$, $p > 0.05$	$r \sim 1$, $p < 0.05$
Kinematic (Angle)		$r = 1$	$r < 1$, $p > 0.05$
Muscle activation			$r = 1$

Both correlation analyses shows negative value and lower correlation value which is *r* value not approximately to one. The correlation analysis between kinetic (force) and muscle activation shows a significant value and high correlation ($P<0.05$) for two-tailed. As example r value is 0.513 for correlation between force in badminton sport and RF muscle activation in basketball and r value is 0.511 for correlation between force in badminton sport and VL muscle activation in basketball sport. The same goes to the correlation between RF and VL muscle activation in the three sports.

DISCUSSION: The female group has a greater vGRF during jump landing for the three sports than the male group. The mean value of the knee flexion angle also shows a smaller value when compared to males. However, the study by Fagenbaum & Darling (2003) gave a contradictory result. In their study, women landed with greater knee flexion angles and greater knee flexion accelerations than men. Furthermore, the result is supported by the study by Salci et al. (2004) in a volleyball game, in which females demonstrated significantly lower knee and hip flexion angles compared to their male counterparts. Additionally, female players applied significantly higher normalized ground reaction forces. The maximum voluntary contraction (MVC) of the vastus medialis (VM) at a knee flexion angle of 15-45^{O} was significantly higher in women than in men (Yukio, Sumida, Tanaka, Yoshida, Nishiwaki, Tsutsumi & Ochi, 2005). Quadriceps dominance is an imbalance between the recruitment patterns of the knee flexors and extensors. Females tend to rely on their quadriceps over their hamstrings to produce dynamic knee stability during jumping and landing activities (Ford, Myer & Hewett, 2003). It is assumed that this is the factor that influenced the result obtained from the study.

CONCLUSION: The lower the vGRF the more optimal the landing strategy, while high vGRF can lead to knee injuries (Dufek & Bates, 1991). The straight knee landing theory suggest that females exhibit knee flexion at the time of impact that may lead to hyperextension or anterior tibial translation due to the ineffectiveness of the hamstring to provide a posterior force when the knee is close to full extension (Decker, Torry, Wyland, Sterett & Steadman, 2003; Huston, Vibert, Ashton-Miller & Wojtys, 2001). Therefore, it is concluded that males have a better strategy during jump landing that can prevent them from ACL injury. The results also prove that females are more likely than males to injure the anterior cruciate ligament (ACL) because they applied greater vGRF and smaller knee flexion angles during jump landing.

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Acknowledgement: The researchers thank Universiti Malaysia Perlis, Malaysia for funding this study.