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# BIOMECHANICAL MODELLING FOR COMPUTATION OF KNEE JOINT TORQUE IN DIFFERENT STRATEGIES OF STOP-JUMP LANDING

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Knee injuries especially non-contact anterior cruciate ligament injury, is very common in sport activities and often occurs in landing. The purpose of this study was to recognize the risk factors and to recommend better landing strategies using dynamic modeling. For this purpose, the stop-jump landing was modeled using anthropometric, kinematic and kinetic data. The knee torque was calculated for different landing strategies. The result showed that the maximum knee torque for women was 42% more than men. When the knee flexion at the initial foot contact increased, the peak knee torque decreased. Finally, increasing the knee and hip angular displacement, the maximum knee torque decreased at first and then increased again. Therefore the knee flexion angle at initial foot contact and the knee and hip angular displacement are effective factors in reducing knee injuries.

**KEY WORDS:** dynamic modeling, knee injury, inverse dynamic

**INTRODUCTION:** Anterior cruciate ligament injury (ACL) is very common in sport activities. Studies have shown that the main reason of ACL injuries is non-contact mechanism which often occurs in high deceleration, side cutting and inappropriate landing (Arendt and Dick 1995; Boden, Dean et al. 2000; Malinzak, Colby et al. 2001; Chaudhari, Hearn et al. 2005; Alentorn-Geli, Myer et al. 2009). Biomechanical analysis of the knee joint is essential to understand the joint injury mechanisms, to recognize the risk factors and to develop the prevention strategies (Yu and Garrett 2007). Some experimental studies showed that the biomechanical factors of sagittal plane such as decreased knee and hip flexion angle are effective mechanisms of non-contact ACL injury and between these two factors, the knee flexion angle has the highest contribution to knee injury (Sell, Ferris et al. 2007; Yu and Garrett 2007; Alentorn-Geli, Myer et al. 2009). Other results indicated that the landing stage is more prone to injury than take-off stage, for both men and women, however women have shown greater knee extension torque, decreased angular displacement of knee and hip, and greater peak vertical ground reaction force, than men (Chappell, Yu et al. 2002; Yu, Lin et al. 2006; Renstrom, Ljungqvist et al. 2008). The angular velocity of knee and hip flexion and the peak torque of knee extension have significant relationships with the vertical and posterior components of ground reaction force. Also the increased knee flexion, leads to a decrease in vertical ground reaction force and an increase in knee extensor torque. Therefore the main reason of non-contact ACL injury is the increase in ground reaction force and the reduction in knee flexion angles (Yu, Lin et al. 2006; Lin, Gross et al. 2009; Podraza and White 2010). Biomechanical modeling is one of the possible methods to obtain kinematic and kinetic parameters during movement. Using this method, some investigators showed similar results with experimental studies for different types of sport movements ((McLean, Lipfert et al. 2004; Shin, Chaudhari et al. 2007; Shin, Chaudhari et al. 2009). The purpose of this study was to examine the relationship between knee torque and different kinematics of lower extremity during the landing of the stop-jump task that is frequently performed in sports and has been associated with non-contact ACL injuries. Investigating different landing strategies as an experimental experience, does have major problems including, problems that inherently exist in testing, high injury probability in athletes, and the time and the costs the test need. Therefore to recognize the risk factors associated with of knee injuries, a simulation of stop-jump landing using biomechanical modeling seems to be beneficial.

**METHODS:** The stop jump landing was analyzed using the inverse dynamics approach. For this purpose, the segments and joints of the body were modeled as rigid mechanical links and hinge joints respectively in SimMechanics software (MATLAB®, R2010a, The MathWorks). Model properties including the length, mass and inertia moment of the links were obtained from_anthropometric data (Winter 2005). The model that is shown in figure 1 includes four links and three joints in the sagittal plane. The links represent the foot, lower leg, upper leg and HAT (head, arms, and trunk) and joints represent the ankle, knee and hip. The anterior-posterior and vertical components of ground reaction force, the angles of the hip, knee and ankle and landing time for men and women were imported to the model as input (Yu, Lin et al. 2006; Brown, Padua et al. 2008). The input data were the mean values for men and women in order to compare the results of the model with experimental investigations. Using this model, we simulated different strategies including the variation of the knee flexion angle at the instant of initial contact with ground, the knee angular displacement and the hip angular displacement during landing. The values of knee torque were computed at all above mentioned strategies during landing using inverse dynamic approach.

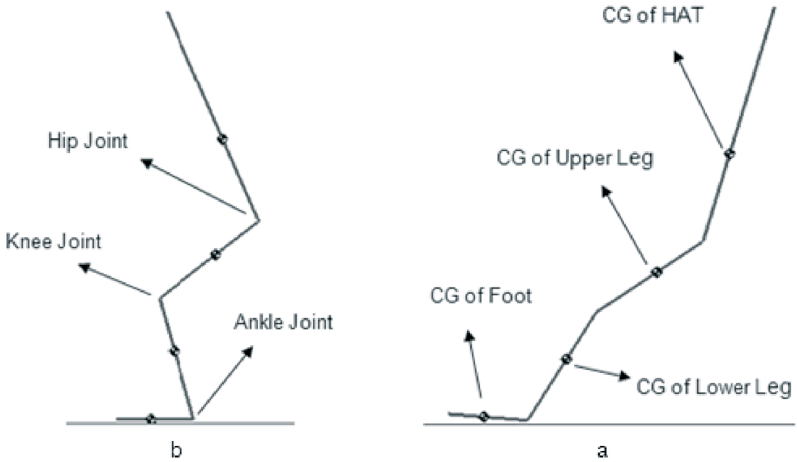


**Figure 1: The model of the proposed for simulation of different stop-jump landing strategies a) The Initial foot contact with the ground, b) Maximum knee and hip angular displacement.**

**RESULTS:** The results showed that the female-to-male knee joint torque ratio was 1.43. Increasing the knee flexion at the instant of initial contact with the ground resulted in a decrease in the maximum knee torque for both males and females. When the knee angular displacement increased, the maximum knee torque decreased at first. However, there was an optimum value for this angular displacement, and when the angular displacement exceeded this optimum value, the knee torque increased again. The maximum knee flexion angles during landing obtained 51.36° and 40.54° for males and females respectively. Similar result also was obtained for a third strategy. Increasing hip angular displacement, the maximum knee torque decreased at first and then increased again. The maximum hip flexion angles obtained were 107.33° and 101.26° for males and females respectively.

**DISCUSSION:** The stop-jump landing was modeled to predict ACL injury probability. This task was frequently performed in basketball and volleyball, in which ACL injuries often occur. From elasticity theory, we know that the injury probability is related to the value of joint torque. The gender differences in lower extremity kinetics observed in this study were consistent with those in experimental studies. The results showed that the female-male knee

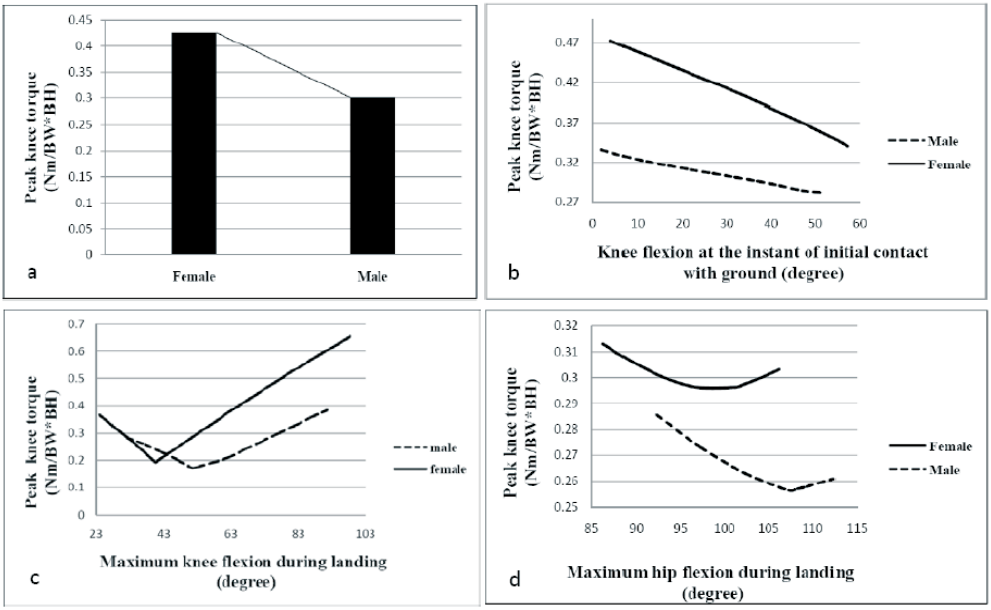


**Figure 2: Peak knee torque for different stop-jump landing strategies a) The comparison of knee torque for female and male b) The variation of knee flexion angle at the instant of initial foot contact with the ground c) The variation of knee angular displacement d) The variation of hip angular displacement.**

joint torque ratio was 1.43. This means that the knee injury probability in women is 42% more than men which was similar to other studies (Arendt and Dick 1995; Arendt, Agel et al. 1999; Pollard, Sigward et al. 2007; Prodromos, Han et al. 2007). In these studies, the probability of ACL tears for female athletes have been reported two to six times greater than male athletes. Also using a stochastic biomechanical model has been shown that the female-to-male non-contact ACL injury rate ratio was 4.96 (Lin, Gross et al. 2009). The results of this study also support the validity of this dynamic model for the peak ACL loading. According to our results, we showed that the maximum of knee torque is affected by the knee flexion angle at the instant of initial contact with the ground. Our results are in agreement with experimental investigations (Salci, Kentel et al. 2004; Yu, Lin et al. 2006; Pollard, Sigward et al. 2007; Yu and Garrett 2007; Renstrom, Ljungqvist et al. 2008; Alentorn-Geli, Myer et al. 2009). This result demonstrates that the knee flexion angle at the instant of initial contact is an effective factor in knee injuries. In second and third strategies when the maximum of knee and hip flexion angle increased, the maximum of knee torque decreased first and then increased again. Yu and his co-workers (2006) reported that “the large hip and knee flexion angles at the initial foot contact with the ground do not necessarily reduce the impact forces during the landing of the stop-jump task, but active hip and knee flexion motions do”. Our model not only supports the results of Yu, but also discovered the optimum angles for maximum knee and hip flexion. Therefore, to decrease joint torque and increase shock absorption during landing, the proper value for knee and hip angular displacement are recommended.

**CONCLUSIONS:** Comparison of this model and previous investigations in the field of sport injuries shows that this approach is a useful tool to predict the conditions which probably lead to injuries. The advantage of modeling is its ability to simulate any condition for each person while this is difficult by experimental studies.

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