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Tuck Jump Assessment for Reducing Anterior Cruciate Ligament Injury Risk

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FEMALE ATHLETES demonstrate a 4 to 6 times higher incidence of non-contact anterior cruciate ligament (ACL) injury than male athletes participating in the same landing and pivoting sports.[1-3] This greater risk of ACL injury, coupled with a dramatic increase in participation (doubling each decade), has led to a significant rise in the number of ACL injuries in female athletes. This gender disparity in non-contact ACL injury risk, combined with evidence that the primary cause may be neuromuscular in nature, have lead to the development of neuromuscular interventions designed to prevent injury.[4-9] Initial interventions aimed at reducing the incidence of ACL injuries in female athletes were developed based on empirical evidence from coaching and training female athletes and from performance enhancement research.[4,10] More current techniques, developed from identified injury mechanism (dynamic knee valgus[11]) and objective analysis of training methods,[12-19] may further reduce traumatic ACL injuries in female athletes.[5-7] The programs that have demonstrated ACL injury reduction are comprehensive, and include multiple training components that may induce the neuromuscular changes. The purpose of this report is to discuss the current evidence related to modifiable ACL injury mechanisms during landing and to present a novel "clinician-friendly" assessment and training technique that can be used to identify these mechanisms in high-risk female athletes.

Key Points

Use of the tuck jump assessment to identify neuromuscular imbalances may provide direction for targeted treatment for those at high risk for ACL injury.

Improvement in neuromuscular techniques may be assessed and continually monitored with repeated measurement using the tuck jump assessment.

Multiple factors may underlie the differences in ACL injury risk in male and females, neuromuscular control may be the most important and modifiable factor that can be addressed with plyometric training.

Identification of Modifiable ACL Injury Mechanisms Associated With Landing Techniques

Hewett et al.[10] tested the hypothesis that insufficient neuromuscular control of lower limb biomechanics, particularly the knee joint, lead to high risk patterns in female athletes during execution of common (albeit potentially hazardous) movements. The results of this study demonstrated that peak landing forces were significantly predicted by valgus torque at the knee in females, females developed decreased relative knee flexor torque during landing compared to males, and females had greater side to side differences in normalized hamstrings peak torque. Ford et al.[20] demonstrated similar gender differences during the performance of a drop vertical jump from a drop height of 31 cm. This study determined that female athletes landed with a greater maximum valgus knee angle and greater total valgus knee motion than male athletes.

Female athletes also had significant differences between dominant and non-dominant side in maximum valgus knee angle. These differences in valgus measures and limb-to-limb asymmetries reflect neuromuscular deficits that may be indicative of decreased dynamic knee joint control in female athletes.[20] Kernozek and colleagues also reported similar coronal plane gender differences in their investigation of drop landing from a greater height (60 cm).[21]

Subsequent studies evaluated more proximal neuromuscular control at the hip and trunk to help determine a potential contributing mechanism to high risk knee mechanics during landing.[22,23] When performing single-leg landing tasks, female athletes demonstrated increased trunk flexion and lateral tilt. This decreased proximal control was hypothesized to be a potential contributor to high-risk mechanics at the knee.[24] Further evidence from multiple, potentially high-risk landing movements indicated that variables at the hip contributed to dynamic valgus while electromyographic (EMG) data demonstrated female to male differences in firing patterns of the hip musculature.[22] The purpose of these studies was to identify gender differences in hip motion, kinetics, and muscle firing patterns during single-leg agility and landing maneuvers. The hypothesis was that female athletes would display increased hip adduction angles and external adduction moments during this multicomponent dynamic maneuver that may contribute to lower extremity valgus. The results demonstrated that female athletes had greater hip adduction angles and torques than males during multidirectional single-leg landing. These differences were limited to the frontal plane and were not observed in the sagittal plane. EMG patterns showed increased quadriceps firing and decreased gluteal firing in females.[22] Another study examined gender differences during single-leg landings from either a medial or lateral direction.[25] In addition to greater knee abduction angles (valgus displacement), female athletes had increased hip coronal plane excursion compared to males during both types of landings.[25] The increased hip adduction (hip varus) motion seen in the coronal plane during athletic activities likely contributes to the dynamic valgus knee position that may place the athlete at increased risk for ACL injury.[23,25]

Potential to Modify Landing Techniques and Reduce ACI Injury Risk

There is strong evidence that neuromuscular training decreases ACL injury incidence,[4-9,19] and that it alters a biomechanical risk factor (knee abduction) for ACL injury[13,16,17] and improves the performance capabilities of female athletes.[10,13,15] Effective neuromuscular training programs utilize plyometric power training, biomechanical technique training, strength training, balance training, and core stability training to induce neuromuscular changes.[5,7,10,13,15-17,26,27] A systematic review[18] of the published literature yielded six interventions that targeted ACL injury prevention in female athletes.[4,7-9,26,28] Out of these six studies, four significantly reduced knee injury incidence in both genders and three significantly reduced ACL injury incidence in females. A meta-analysis[19] of these six studies demonstrated a significant effect of neuromuscular training programs on ACL injury incidence in female athletes ($Z = 4.31$, $P < .001$). Examination of the similarities and differences between the training regimens may provide insight into the development of more effective and efficient interventions.[18]

Exercise Modes and Techniques Used to Reduce ACL Injury Risk

When comparing the data extracted from the intervention studies, one might generate a few potentially valuable generalizations. Plyometric training combined with biomechanical analysis and technique training were the two common components of all 4 studies that effectively reduced ACL injury incidence.[4-7] In addition, balance training alone is probably not as effective for injury prevention as when it is combined with other types of training.[18] One needs to consider whether the teams' or athletes' primary goal is injury prevention, performance enhancement or both. In-season training alone is probably the most cost-effective

and efficient method for achieving beneficial injury prevention effects,[5,19] though the absence of high-intensity overload in these programs may preclude measurable performance enhancement effects. High-intensity pre-season neuromuscular training programs are effective to increase performance and reduce injury risk.[10,13,17,27] Probably the most important finding, however, is that all four studies[4-7] that incorporated high-intensity plyometrics reduced incidence of ACL injuries, while the studies that did not incorporate high-intensity plyometrics[8,9] had no reduction in incidence of ACL injuries.[19]

The plyometric component of these interventions, which trains the muscles, connective tissue, and nervous system to effectively carry out the stretch-shortening cycle[29] and that focuses on proper technique and body mechanics, appears to reduce ACL injuries.[4-7] Injury prevention programs that combine techniques demonstrated to enhance performance capabilities have positive preventive and biomechanical effects;[13,18] however, training programs that utilized more single-faceted training approaches that did not incorporate plyometric training have demonstrated limited success in reducing knee injury incidence or risk factors in female athletes.[9,30-32]

"Clinician-Friendly" Plyometric Assessment and Technique Training

The tuck jump exercise (Figure 1) may be useful to the clinician for the identification of lower extremity landing technique flaws during a plyometric activity.[12] The tuck jump requires a high-level effort from the athlete. Initially, the athlete may place most of his or her cognitive efforts solely on the performance of this difficult jump. The clinician may readily identify potential performance deficiencies (Figure 2), especially during the first few repetitions.[12] In addition, the tuck jump exercise may be used to assess improvement in lower extremity biomechanics as the athletes progress through their training.[12]

Figure 2 provides the "clinician friendly" landing technique assessment clinicians may use to monitor an athlete's performance of the tuck jump before, during, and after training. Specifically, the athletes perform repeated tuck jumps for 10 seconds, which allows the clinician to visually grade the outlined criteria. To further improve accuracy of the assessment, standard 2D camera photos acquired in the frontal and sagittal planes may be utilized to assist the clinician. The athletes' techniques (Figure 2) are subjectively rated as either having an apparent deficit (checked) or not. The deficits are then tallied for the final assessment score. Indicators of flawed techniques should be noted for each athlete and should be the focus of feedback during subsequent training sessions. The athletes' baseline performances can be compared to repeated assessments performed at the mid-point and conclusion of a training program, to objectively track improvement with jumping and landing technique (Figure 2). Empirical evidence from our laboratory suggests that athletes who do not improve their scores, or who demonstrate 6 or more flawed techniques, should be targeted for further technique training. Pilot work in our laboratory has indicated that the intrarater reliability is high; R = 0.84 (range 0.72-0.97). These data indicate that the tuck jump assessment may be adequate for a single clinician to reassess athletes to determine changes in technical performance of the tuck jump exercise.[33] Additional investigation between clinicians is currently being performed.

One specific area that the clinician should focus on when training to reduce incidence of ACL injury is the correction of lower extremity valgus at landing and equalization of side-to-side differences in lower extremity movements, which are both emphasized in the tuck jump assessment (Figure 2). The link between valgus knee loading and resultant increases in ACL strain has been demonstrated through cadaver, in vivo, and computer modeling experiments.[34-37] Valgus torque on the knee can significantly increase tibial subluxation and load on the ACL.[36] A prospective combined biomechanical-epidemiologic study showed that knee abduction moments (valgus torque) and angles measured during a plyometric activity were

significant predictors of future ACL injury.[11] The tuck jump assessment can be utilized to improve these high-risk deficiencies during an exercise that requires a high-level effort from the athlete. Athletes may place most of their cognitive efforts on the performance of this difficult jump and demonstrate many technical flaws that are indicative of increased risk for injury; however, if they can improve neuromuscular control during this difficult jump and landing sequence, they may gain skill that can be transferred to competitive play.

Conclusion

The authors acknowledge that more research is needed to determine the validity and between-rater reliability of the proposed assessment method. However, the use of the tuck jump assessment may provide a clinician-friendly means to identify high-risk landing mechanics and may provide direction for a targeted intervention to reduce risk of ACL injury.[17] In addition, improvement in neuromuscular control may be assessed and continually monitored with repeated testing of the athlete. Although multiple factors may underlie the differences in ACL injury risk between males and females, neuromuscular control may be the most important and modifiable factor.

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Biography

Gregory D. Myer is the sports biomechanist at the Cincinnati Children's Hospital Sports Medicine Biodynamics Center. His work in the Human Performance Laboratory allows him to incorporate the most advanced research findings into athletic development and injury prevention training protocols.

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Figure 1.
Tuck jumps are an example of an exercise used to train athletes to increase lower body power. The tuck jump can also be used as an assessment to grade improvement in technique. to perform the tuck jump, athletes start in the athletic position with feet shoulder-width apart. They initiate the jump with a slight crouch downward while extending their arms behind them. They then swing their arms forward as they simultaneously jump straight up and pull their knees up as high as possible. At the highest point of the jump, the athletes are in the air with thighs parallel to the ground. When landing, the athletes should immediately begin the next tuck jump. Encourage the athletes to land softly, using a toe to mid-foot rocker landing. The athletes should not continue this jump if they cannot control the high landing force or if they demonstrate a knock-kneed landing.

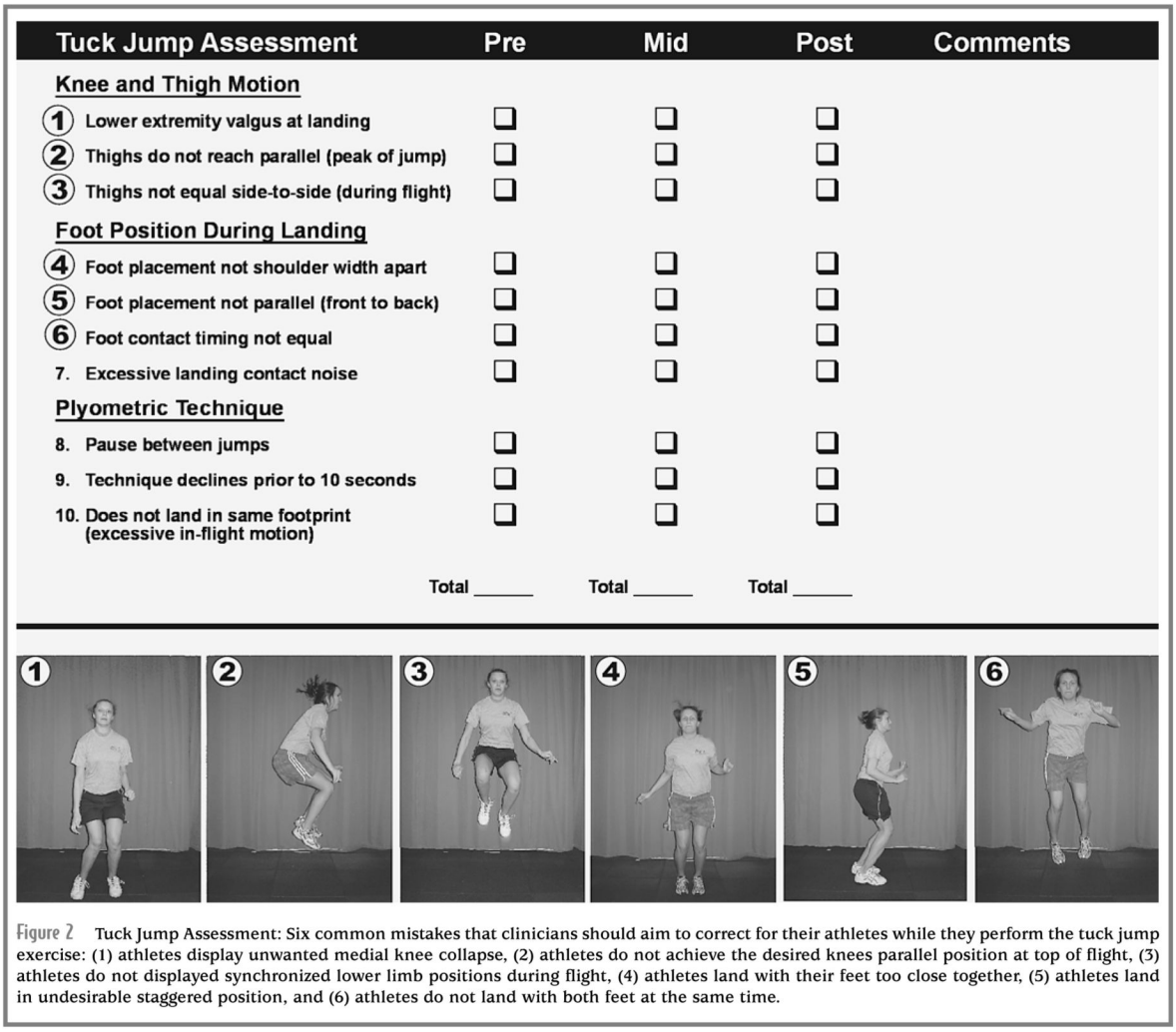

Figure 2 Tuck Jump Assessment: Six common mistakes that clinicians should aim to correct for their athletes while they perform the tuck jump exercise: (1) athletes display unwanted medial knee collapse, (2) athletes do not achieve the desired knees parallel position at top of flight, (3) athletes do not displayed synchronized lower limb positions during flight, (4) athletes land with their feet too close together, (5) athletes land in undesirable staggered position, and (6) athletes do not land with both feet at the same time.

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