University of Cincinnati

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I, Anne T Grisez M.S., hereby submit this original work as part of the requirements for the degree of Master of Science in Health Education (Exercise & Fitness).

It is entitled:
The investigation of the difference in observed knee valgus displacement during an overhead squat and the box drop landing maneuver in a pre-pubertal adolescent population in males and females.

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This work and its defense approved by:

Committee chair: Bradley Wilson, Ph.D.
The investigation of the difference in observed knee valgus displacement during an overhead squat and the box drops landing maneuver in a pre-pubertal adolescent population in males and females.

A thesis submitted to the Graduate School of the University of Cincinnati
In partial fulfillment of the requirements for the degree of

Master of Science

In the Department of Health Education, Concentration in Exercise Management College of Education, Criminal Justice, and Human Services
by

Anne Grisez 22 July 2014

Bachelor of Science in Athletic Training
2012

Chair: Dr. Bradley Wilson
Faculty Advisor: Dr. Thomas G. Palmer
ABSTRACT

Context: Knee valgus or medial knee displacement during sports with bounding, landing and cutting has been reported as a common risk factor resulting in injury for teenage and adolescent athletic participants. Squatting maneuvers and landing mechanics have been used to evaluate the occurrence of knee valgus displacement. Commonly squat mechanics are used during rapid change in directions and landing from a jump; however, the occurrence of knee valgus in pre-pubertal adolescents has not been evaluated.

Objective: To investigate the difference in observed knee valgus displacement during an overhead squat and the box drop landing maneuver in pre-pubertal adolescent males and females.

Design: Prospective cohort study.

Setting: Laboratory.

Patients or Other Participants: Sixty-two elementary school students, with a mean age= 9.32, height= 54.38cm, and weight= 79.04lbs for males and a mean age= 9.37, height= 53.80cm, and weight= 74.81lbs for females.

Intervention(s): Overhead squat and box drop landing maneuver.

Main Outcome Measure(s): Visual observation of a frontal plane knee valgus displacement of approximately 10 degrees.

Results: A two-tailed independent Student’s t-test indicated females have significantly greater occurrence of observed knee valgus defects when compared to males during the squat ($P = .008$). Overall, females had more than two-times the observed knee valgus defects when compared to males (females= 21, males= 10) and more observed left, right, and bilateral defects; however, a two-tailed independent Student’s t-test indicated no significant difference between sexes during the box drop landing maneuver ($P = .33$).

Conclusions: Observed valgus knee displacement was observed in both male and female pre-adolescents. The greater occurrence of knee valgus displacement in females is unexplained. Further research is needed to explore the differences between sexes and the implementation of early interventions targeting knee valgus displacement.
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INTRODUCTION

It is recognized that excessive frontal plane motion and knee valgus displacement is a widened risk leading to anterior cruciate ligaments (ACL) injuries (23). ACL injuries are presented in a large number of young individuals, and many times are disabling or season-ending (8). Research suggests female athletes sustain non-contact ACL injuries at four to six times of their male counterparts (18). High-risk mechanics can often be evident in the frontal plane during various movements but are most commonly the result of multi-planar kinematics including internal rotation and adduction at the hip, external rotation and abduction of the knee, and navicular drop of the ankle (23). Landing components in sports that exhibit cutting have a high-risk of injuries to the ACL. Padua et al (23), reported knee valgus displacement in healthy 18 and 25 year old athletes; however, there is little research evaluating valgus displacement in younger populations (21).

The prospective link of valgus moments and ACL injury risk has been proposed previously (13,22). During sport the act of landing and/or cutting with abnormal body position causes valgus moments at the knee. The multifactorial contributors of poor landing mechanics appear to increase the risk of injury to the lower extremity (13,24). The overhead squat and box drop landing maneuver are valued screening techniques for detecting knee valgus motions (5,8,9,13). Recent literature has reported these screening techniques are effective in identifying potential injury risks in the lower extremity (9). It has been suggested that landing in dynamic valgus is harmful to the knee (6,10,12,13); however, to our knowledge the overhead squat and box drop landing techniques have not been used to assess knee valgus moments in healthy pre-pubertal adolescent populations.

The multi-factorial contributions of knee valgus displacement are often apparent during visual observation of squatting or landing mechanics, which incorporate squatting movements. Excessive hip adduction and internal rotation with weight bearing has the possibility to influence the kinematics of the entire lower extremity (22). As a result of the foot being fixed to the ground, the inward motion of the knee joint occurs creating the tibia to abduct and the foot to pronate, resulting in knee valgus displacement (15,22). Literature has shown knee valgus displacement and diminished hip muscle strength relations (1,8,12,19,22); however, we are unaware of this analysis in pre-puberty
adolescent population.

In addition to gait, the squat is the second most routinely researched motor task and common exercise used to examine knee kinematics; however, there appears to be a lack of knowledge regarding the effect age can have on squatting or landing maneuvers (9). Fukagawa et al (9) described age-related tendencies during activities that necessitate a squat maneuver in volunteers (range 21-75 years). The main finding was increased age was correlated ($r = -0.559, P=0.007$) with larger maximal knee abduction throughout the squat (9). Therefore, older individuals revealed more valgus alignment during a squatting maneuver. It is unclear if the propagation of knee valgus moments exist at a younger age and potentially contribute to future knee valgus episodes and possible injury. Training proper squat technique and related landing mechanisms have been reported to correct mal-alignments at the knee (13,14). Squatting and box drops have been used as interventions for post-puberty populations but not as a field assessment or a training intervention for the pre-puberty adolescent population.

Recently, a large amount of attention has focused on ACL injuries in female athletes. Numerous studies have found that females participating in equivalent activities as males are at elevated risk for ACL injuries. The higher prevalence of ACL tears among females has been theorized to result from neuromuscular deficits, hormonal factors and/or anatomical structure (8,9,13). Targeting female athletes with intervention training programs in high school with high-risk knee abduction loads throughout dynamic actions has been studied. Ford et al (8) reported “high-risk” high school female athletes have a decrease in ACL injury risk factors as a result of neuromuscular training 3x/week over a 7-week period (8). Others have reported there is a small difference in the individual risk of an ACL injury among men and women (8). Mountcastel et al (16), reported collegiate male and female students have little difference in the overall risk of an anterior cruciate ligament tear; however, their research displays gender differences with injury rates with specific sports (16). Knee valgus displacement is an apparent occurrence for all activities; however, more research is needed to discern the development of knee valgus moments in pre-pubertal adolescents. Therefore, the purpose of this study was to investigate the prevalence of an observed knee valgus displacement during an overhead squat and a box drop landing maneuver in a pre-pubertal adolescent
population. We hypothesized that there would not be a sex difference in the knee valgus displacement angles in this population.

METHODS

Participants

Participants included were from a cohort in a prospective study. Sixty-two healthy elementary school-aged students with a mean of age = 9.32, height = 54.38 cm, and weight = 79.04 lbs for males and a mean of age = 9.37, height = 53.80 cm, and weight = 74.81 lbs for females participated in the study. There were right-handed = 48, left-handed = 6, ambidextrous = 3 elementary school students in the 4-week testing period.

Procedure

The testing consisted of a two-dimensional (field-based) observational analysis and video capture of the frontal and sagittal plane to capture knee kinematic data. An initial live observation was performed, and a second observation was performed using observational analysis of the video for confirmation purposes. Before data collection, testing procedures were approved by the University of Cincinnati’s Institutional Review Board and informed written consent was obtained from the parents or legal guardian of each participant. Consent was also acquired from each participant prior to involvement in the study. Cameras were located at 5ft height level and 8ft distance from participants. Cameras were perpendicular to each other in the frontal and sagittal planes. Each participant was recorded performing the squat maneuver at one given time. The overhead squat is a simple exercise that requires no specialized equipment and is performed without resistance. With the feet shoulder-width apart, hands interlocked behind the head, the participant is asked to squat down by flexing at the knees (90°). Participants had their feet placed on the horizontal tape on the floor. The box drop task began with participants standing on top of a 31-cm box with their feet shoulder-width apart and arms held at their sides. The participants dropped down off the box onto the floor surface into a squat depth previously demonstrated in overhead squat. During the initial drop, the participants were instructed to leave the box, drop straight down, and at the same time
have the feet land. Two certified professionals clinically observed the anterior/frontal plane of the knee. They reviewed and agreed upon the knee valgus displacement illustrated in the scale shown in Table 1.

Table 1. Scoring for Observed Medial Knee Valgus Displacement

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&lt;10º valgus displacement</td>
</tr>
<tr>
<td>1</td>
<td>&gt;10º valgus displacement with left knee</td>
</tr>
<tr>
<td>2</td>
<td>&gt;10º valgus displacement with right knee</td>
</tr>
<tr>
<td>3</td>
<td>&gt;10º valgus displacement with both knees</td>
</tr>
</tbody>
</table>

All participants were familiarized with how to perform the squat and box drop test. This period was designed to instruct and manage the overhead squat and box drop. Corrections were made when there was incorrect form. There were two familiarization periods prior to testing one week apart. The investigation team monitored and corrected the overhead squat and box drop technique. The data were collected one week following the second familiarization week. It was the same squat and drop box protocol as shown during the familiarization periods. Each participant has a general participation warm-up. They had the opportunity to perform three overhead squats and drop box landings while being filmed. If the squat and box drop requirements were not fulfilled, the trial was repeated. During testing, film data and observations of the knee moment by the team were made.

RESULTS

Medial knee displacement in the pre-puberty adolescent population was evident in both male and female participants. The percentage of valgus defects observed between males and females during the squat and drop box landing were less in males, Table 2 and Table 3. Nearly 50% of all the males had a noted defect during the squat maneuver (left=14.3, right=11.4%, bilateral=22%). Eighteen and a half percent of males had an observed knee valgus deficit (left=7.4, bilateral=11.1) in the box drop. A two-tailed independent Student’s t-test indicated females have a significantly greater occurrence of observed knee valgus defects when compared to males during the squat ($P=.008$).
Multiple independent Student’s t-test and Pearson Product Moment were used to evaluate group differences between male and female for both the squat and the box drop. Secondary analyses listed in Table 4 included a Pearson Product Moment correlation to evaluate the relationships of observed knee valgus, male and female, and the squat and box drop. The squat and box drop were significantly correlated ($r=0.412$) which explains 16% of the variation.

Overall, the box drop resulted in a greater number of observed knee valgus defects in both sexes when compared with the squat. Females had more than two-times the observed knee valgus defects when compared to males (females= 21, males= 10) and more observed left, right, and bilateral defects; however, a two-tailed independent Student’s t-test indicated no significant difference between sexes during the box drop ($P=0.33$). A Dependent pair-wise comparison of the males showed a significantly higher number of valgus episodes occurred during the box drop than with the squat ($P=0.033$). Overall, the females had more box drop knee valgus displacements when compared to males, but a dependent pair-wise comparison did not show a difference of valgus episodes among females when comparing squats to box drops ($P=0.814$).

Table 2: Observed Medial Knee Valgus Displacement Percentile by Sex during Squat

<table>
<thead>
<tr>
<th>Sex</th>
<th>Squat</th>
<th>No Defect</th>
<th>Left Leg Defect</th>
<th>Right leg Defect</th>
<th>Bilateral Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>18</td>
<td>5</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Females</td>
<td>Row N %</td>
<td>51.4%</td>
<td>14.3%</td>
<td>11.4%</td>
<td>22.9%</td>
</tr>
<tr>
<td>Males</td>
<td>N</td>
<td>22</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Row N %</td>
<td>81.5%</td>
<td>7.4%</td>
<td>0.0%</td>
<td>11.1%</td>
</tr>
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</table>
Table 3. Observed Medial Knee Valgus Displacement Percentile by Sex during Box Drop

<table>
<thead>
<tr>
<th>Sex</th>
<th>Box Drop</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No Defect</td>
<td>Left Leg Defect</td>
<td>Right leg Defect</td>
<td>Bilateral Defect</td>
</tr>
<tr>
<td>Females</td>
<td>N</td>
<td>14</td>
<td>3</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Row N %</td>
<td>40.0%</td>
<td>8.6%</td>
<td>14.3%</td>
<td>37.1%</td>
</tr>
<tr>
<td>Males</td>
<td>N</td>
<td>17</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Row N %</td>
<td>63.0%</td>
<td>7.4%</td>
<td>7.4%</td>
<td>22.2%</td>
</tr>
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</table>

Table 4. Pearson Product Correlation Coefficients for Observed Knee Valgus Displacements During the Squat and Drop Box Landing Maneuvers with Height and Weight: N= 62

<table>
<thead>
<tr>
<th></th>
<th>BDV</th>
<th>SV</th>
<th>Wt</th>
<th>Ht</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDV</td>
<td>1.000</td>
<td>0.412**</td>
<td>-0.030</td>
<td>-0.034</td>
</tr>
<tr>
<td>Sig.(2-tailed)</td>
<td>0.001</td>
<td>0.818</td>
<td>0.792</td>
<td></td>
</tr>
<tr>
<td>SV</td>
<td>1.000</td>
<td>-0.015</td>
<td>-0.203</td>
<td></td>
</tr>
<tr>
<td>Sig.(2-tailed)</td>
<td></td>
<td>0.910</td>
<td>0.114</td>
<td></td>
</tr>
<tr>
<td>Wt</td>
<td>1.000</td>
<td>0.464**</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Sig.(2-tailed)</td>
<td></td>
<td></td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Ht</td>
<td></td>
<td></td>
<td></td>
<td>1.000</td>
</tr>
</tbody>
</table>

BDV= Visual observation of box drop valgus displacement
SV= Visual observation of squat valgus displacement
Wt= Subjects weight in lbs
Ht= Subjects height in cm

** Correlation is significant at the 0.001 level (2-tailed).
DISCUSSION

We hypothesized that there would not be a sex difference in the knee valgus displacement angles in the pre-puberty adolescent population; however, our data showed there were knee valgus displacements and sex differences. This valgus displacement in pre-puberty adolescents population data is compelling because now we have data to support the potential of using interventions for the pre-puberty adolescent population. The overhead squat and box drop appear to be a valid screening technique to detect potential knee valgus displacement, which may decrease knee valgus moments and potential injury for both pre-puberty and in later years. It is still uncertain when and how risk factors develop; however, our data indicate the use of these field assessment techniques for this specific population may be a useful tool. The significant positive correlation between the box drop and squat indicates these tests may measure some similar components related to the knee valgus occurrence; however, the weak correlation (.423) suggests the tests are predominately measuring different components of ground reaction force and knee moments as only 16% of the variance for each test explained.

The occurrence of knee valgus displacement in males compared to females in this study is consistent with previous literature findings. Ford et al (8) revealed sex differences evident in high school basketball players with females displaying a significantly greater maximum knee valgus displacement when landing (8). Overall, our findings were similar with the box drop resulting in a greater number of observed knee valgus defects in both sexes; however, females had more than two-times the observed knee valgus defects when compared to males. It is important to determine if the younger female population, pre-puberty adolescents, shows knee valgus displacement. Overall, the impact of injury in females makes knee valgus displacement a concern.

Our data mimic the corresponding knee valgus displacement literature for the post-puberty population (1,8,12,19,22). Knee valgus displacement is more predominant in the female population; however, additional research is necessary as the current study followed one cohort of sixty-two elementary students from the same region. Based on the current literature regarding post-puberty populations it appears the knee valgus displacement that occurs in the older populations may be partially established at a younger age (pre-puberty). The observed knee valgus displacement in males and females
during the squat and box drop was greatest in the box drop; however, when we looked at the dependent pair-wise comparison the males showed a significant difference during the squat ($P = .033$). The females overall had more box drop occurrences compared to males, but with a dependent pair-wise comparison, the results did not show a difference when comparing squats to box drops ($P = .814$). We can recognize that neuromuscular control on body position is important during an open chain movement, as well as important in knee valgus displacement.

The present study data indicate that pre-puberty adolescent populations lack neuromuscular control during open-chain movements (box drop) when compared to close-chain movements (squat). In males specifically, it is reasonable to assume the closed-chain squat maneuver is the more appropriate field assessment. Chappell et al (4) illustrated a difference in valgus moments at the knee in male and female athletes with females showing greater valgus displacement during the landing phase of a vertical jump maneuver (4). Chappell et al (4) and our data build a case for the vertical jump maneuver being the optimal knee valgus measured technique. The deficiency of dynamic knee joint stability may be accountable for the increased rates of knee injuries in females (8). The prospective advantage of injury prevention training is broad, and overall females would be anticipated to benefit from prevention training (NMC or plyometrics); however, it would seem to benefit more to those who exhibited poor dynamic knee stability (8).

Based on the current literature, neuromuscular control programs intervene via plyometrics, strength training, stretching exercises, as well as training balance and correct techniques to prevent injuries (11). From our data the closed chain exercise (squat) shows less knee valgus than the open chain (box drop) (18,19). Ford et al (8) concluded a greater maximum knee displacement and absence of dynamic knee joint stability may be responsible for higher rates of female knee injuries. More neuromuscular control is needed to perform open chain movements and it appears that these movements are in field tests. Hewett et al (12) found neuromuscular training decreases the landing forces and knee moment torques and increases hamstring power and strength imbalances in a high school female group. Hewett et al (12) analyzed the results of neuromuscular training on knee injuries with a trained high school female athlete group and a non-trained high school female athlete group. They found a decrease in serious knee injuries.
in 62% in the high-risk female athletic population with neuromuscular training (12). Therefore, our findings also support the potential for NMC training as a benefit for the pre-puberty adolescent populations.

Integrative neuromuscular training (INT) programs have shown to be a positive enhancement tool in children and adolescents (20). Myer et al (20) concluded that preplanning of an integrative neuromuscular training early in youth (approximately up to age 11 years in females and 13 years in males) can assist training, which is important for children and adolescents. No minimum age is shown in current literature for participating in INT (20). A child who is viewed as ready for organized sports participation (about age 7 or 8 years) characteristically would be ready for INT (3). The foundation INT begins with age-appropriate movement and exercise education, which includes teaching from qualified professionals with knowledge of exercise science and age appropriate progressions (20). Literature shows notable benefits can be gained from training interventions for age-appropriate individuals (20).

Padua et al (23), reported knee valgus displacement in healthy 18 and 25 year old athletes. Fukagawa et al (7) described age-related tendencies during activities that necessitate a squat maneuver in volunteers (range 21-75 years). Ford et al (8) reported “high-risk” high school female athletes have a decrease in ACL injury risk factors as a result of neuromuscular training; however, unlike the previous literature, the pre-puberty adolescents population has not been analyzed.

There were potential limitations to this investigation. Similar techniques for calculating knee valgus displacement have been previously shown in the box drop followed by a maximum vertical jump (8). Seeing that landing from a rebound is the task most frequently associated with ACL injuries in basketball (22), it is possible the first box drop task does not adequately simulate the biomechanical movement performed when landing from a box drop vertical jump (2). Future research should be analyzed on pre-puberty adolescent population with the second landing in the drop vertical jump (DVJ).
CONCLUSIONS

In conclusion, pre-pubertal female adolescents appear to have more knee valgus deformities than males similar to what has been found in adolescents. With this literature previously presented and the results of our study, we believe it may be important to start NMC training programs in pre-puberty adolescents to decrease the knee valgus displacement, which may contribute to decreasing lower extremity injuries. The greater number of knee valgus deformities occurring in females may influence the occurrence of higher knee injury among adolescent populations. It seems reasonable to assess and train proper squat and landing mechanics in pre-puberty adolescents.

BIBLIOGRAPHY


