The Reliability and Discriminative Ability of the Overhead Squat Test for Observational Screening of Medial Knee Displacement

Eric G. Post, Matthew Olson, Stephanie Trigsted, Scott Hetzel, and David R. Bell

Context: The overhead squat test (OHS) is a functional screening exam that is used to identify high-risk movement profiles such as medial knee displacement (MKD). The reliability and discriminative ability of observational screening during the OHS to identify MKD have yet to be established. Objectives: To investigate the reliability and discriminative ability of observational screening for MKD during the OHS. Study Design: Clinical measurement, cross-sectional. Participants: 100 college students were video-recorded performing the OHS. Three certified athletic trainers classified the knee posture of each subject during the OHS on 2 different occasions using screening guidelines. Main Outcome Measures: Ratings were evaluated by calculating kappa coefficients for intra- and interrater levels of agreements. MKD was measured using motion analysis. Results: Intrarater reliability range was .60–.76 with an average value of .70. Interrater reliability was substantial (kappa > .60) for both observation sessions (Fleiss kappa session 1 = .69, session 2 = .70). Sensitivity range was .58–.83, while specificity range was .70–.88. The MKD group displayed significantly more displacement than the no-MKD group (P < .001). There was a moderate positive correlation (r = .48, P < .001) between knee-posture group and MKD assessed using motion analysis. Conclusion: The OHS has substantial reliability and is able to assess the presence of MKD. The OHS should be used as part of a comprehensive examination that evaluates multiple movement patterns and risk levels.

Keywords: movement screening, preparticipation physical exam, OHS, MKD

The overhead squat test (OHS) is a popular screening exam used to assess the overall quality of an individual’s movement.1,2 It assesses multiple joints and muscle groups and is a functional task commonly performed during athletic activity, as well as activities of daily living. Poor movement patterns such as dynamic knee valgus or medial knee displacement (MKD) are believed to be linked to increased injury risk and are among the most common movement dysfunctions observed during the OHS.1,3 Common injuries linked with MKD include patellofemoral pain and anterior cruciate ligament (ACL) injuries, due to the tension placed on the ACL and medial structures of the knee during knee abduction.3 Muscle imbalances at the hip coupled with decreased flexibility at the ankle, especially in males, can lead to abduction and internal rotation of the hip, which can present as MKD during a weight-bearing activity.1,2 Since the OHS is a commonly used preseason screening test, it is important to demonstrate its discriminative ability to identify MKD so that clinicians can develop interventions to prevent injury. The OHS is a useful exam for several reasons: It requires no equipment and only a small space to perform, so it can be used in almost any setting; the low intensity of the OHS allows for screening of populations where the single-leg squat or jump-landing task is not feasible; and the OHS only takes a short time to both coach and perform, allowing for the screening of many athletes in a short amount of time.

The purpose of this study was to investigate the reliability and discriminative ability of the OHS test in identifying high-risk movement patterns such as MKD. We hypothesized that raters would achieve substantial interrater and intrarater agreement identifying MKD with the OHS (kappa > .60) and that observational screening for MKD would yield results similar to those of motion-capture analysis.

Methods

Participants

One hundred participants volunteered for this study. Participants had no history of injury to the knee, back, hips, or ankles in the 3 months before testing; had no history of lower-extremity surgery; and were age 18 to 25 years of age. All subjects signed a consent form approved by the University of Wisconsin–Madison institutional review board. Seven subjects were excluded because of corrupt...
data files that resulted in loss of video footage, leaving 93 subjects for final analysis (age 20.29 ± 1.51 y, mass 69.21 ± 12.34, height 170.97 ± 8.89, 66 women, 26 men).

Procedures

An electromagnetic tracking system (Ascension Technologies, Inc, Burlington, VT) controlled by MotionMonitor software (Innovative Sports Training, Inc, Chicago, IL) was used to quantify lower-extremity 3-dimensional kinematics (sampling rate: 144 Hz) of the dominant limb during the overhead squat. The electromagnetic sensor placement used in this study has been previously described. Two practice trials were performed to ensure accurate kinematic data and proper sensor alignment. It has been demonstrated that ability to perform the OHS can differ based on testing position. We chose to use the standardized OHS testing position from the Functional Movement Screen due to its familiarity to clinicians. Subjects began from a standardized position with the feet shoulder width apart, toes straight ahead, and hands over the head with the elbows locked. Subjects were instructed to perform 5 continuous squats as if sitting down on a chair. Front and side videos were captured using standard video cameras (Panasonic HDC-SD80, Newark, NJ), and each session was downloaded, edited, and copied to compact discs that were given to each rater.

The sensor setup and global reference system definition have been previously described, but briefly, MKD was calculated as frontal-plane displacement of the knee-joint center in the y-axis. Custom MATLAB (Version 2013a, The MathWorks; Natick, MA) software was used to filter (fourth-order low-pass Butterworth filter with a cutoff frequency of 14.5 Hz) and identify the peak values of the dependent variables of interest during each squat (averaged over 5 trials).

Rating Protocol

Three certified athletic trainers with 2 to 4 years of experience working as clinicians in the college setting served as raters. The athletic trainers were instructed to grade subjects using a binary system to classify each subject’s knee posture with either the presence or absence of MKD (Figure 1). A single 2-hour training session with all reviewers present and led by the senior author was held before the first grading session, where example videos from other research studies were viewed and operational definitions of MKD were provided. MKD-present knee posture was defined as the center of the patella moving medial to the second toe. If the foot began in a turned-out position and the knee began positioned medial to the second toe, visible movement of the patella medially was classified as MKD-present posture. MKD had to be viewed in at least 3 out of 5 trials to be classified with the dysfunction. The raters were allowed to watch the trials as many times and for as long as necessary to make their decision.

The raters graded the videos a second time 2 weeks later to reduce memory of initial viewings, with no additional training sessions before the first and second viewings. R statistical software was used to calculate percentage agreement, intrarater kappa, multirater Fleiss kappa, independent t tests, and Spearman rank correlations.

Statistical Analysis

Rater Agreement. Percentage agreement and kappa coefficients were used for intrarater reliability. Percentage agreement and a multirater Fleiss kappa statistic were used for interrater reliability. A kappa coefficient ≤0 is considered poor agreement, .01 to .20 is slight agreement, .21 to .40 is fair agreement, .41 to .60 is moderate agreement, .61 to .80 is substantial agreement, and .81 to 1.00 is almost-perfect agreement.

Discriminative Ability. A Mann-Whitney U test was used to test differences in the amount of MKD measured using motion analysis between the MKD-present knee-posture group and those who were classified as not having MKD. MKD was collected using the reference-standard electromagnetic motion-analysis system. In addition, a Spearman rank correlation was used to determine the
association between observational knee-posture group and MKD assessed using motion analysis.

Results

Rater Agreement

Intrarater Agreement. Rater 1 achieved 89% agreement by successfully classifying 83 out of 93 cases between the first and second sessions (Table 1). Rater 2 achieved 91% agreement by successfully classifying 85 out of 93 cases, while rater 3 had the lowest percentage agreement (84%) and classified 79 out of 93 cases. Two of the 3 raters achieved a substantial level of agreement (kappa > .60), while 1 rater had moderate agreement, which fell just below the substantial threshold. However, the average level of agreement was substantial (kappa > .60).

Interrater Agreement. Rating sessions 1 and 2 had identical percentage agreement, with all raters agreeing on 82.80% (77 of 93) of the cases. Fleiss kappa values agreed with our hypothesis and achieved substantial agreement during both sessions (kappa > .60).

Discriminative Ability

Subjects classified in the MKD-present knee-posture group displayed greater displacement than subjects classified as not having MKD knee posture (P < .001) (Figure 2). There was a moderate positive correlation (r = .48, P < .001) between the MKD knee-posture group and MKD measured using motion analysis.

Discussion

The most important finding of this study was that the OHS is a reliable screening tool that is able to identify movement patterns associated with knee injury, specifically, MKD. Valid and reliable methods of assessing faulty movement patterns are a crucial step in reducing injuries associated with MKD, such as ACL ruptures.3,6 Previous research has established the reliability and validity of other observational screens for identifying the presence of dynamic knee valgus, such as the single-leg squat and the drop-jump landing.7–10 The OHS is a slower movement than many other commonly used clinical screens such

<table>
<thead>
<tr>
<th>Table 1 Reliability Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
</tr>
<tr>
<td>Intrarater</td>
</tr>
<tr>
<td>time 1</td>
</tr>
<tr>
<td>time 2</td>
</tr>
<tr>
<td>Intrarater</td>
</tr>
<tr>
<td>rater 1</td>
</tr>
<tr>
<td>rater 2</td>
</tr>
<tr>
<td>rater 3</td>
</tr>
<tr>
<td>combined</td>
</tr>
</tbody>
</table>

Figure 2 — Differences in medial knee displacement (MKD) assessed using motion analysis between the groups rated as not having MKD and those rated as displaying MKD. The box represents the interquartile range, with the median and the range of displacement values.
as a jump-landing or cutting task, making it potentially easier for clinicians to identify MKD during the OHS. We therefore believe that the OHS should be part of a holistic approach that incorporates many clinical tests to determine where movement-pattern improvement can be made. To our knowledge the reliability and discriminative ability of the OHS has not been previously examined.

Previous research has established several potential causes of MKD, including musculoskeletal limitations in range of motion and strength and sex differences. Bell et al observed that subjects who displayed MKD exhibited decreased plantar-flexion strength and showed a trend toward decreased dorsiflexion range of motion. Furthermore, recent research demonstrated differences in performance on the OHS based on sex. Males demonstrated increased knee valgus during the OHS and had limitations in both ankle dorsiflexion and hip-rotation range of motion. MKD, as a proxy for knee valgus, is believed to increase the risk of knee injury by increasing lateral compressive and medial tensile forces on the knee and by increasing the strain on the ACL, with multiple studies linking knee valgus and MKD to a potential increased risk of ACL injury. Therefore, it is important for clinicians to take into account the sex of the individual when performing the OHS and to consider injury-prevention interventions that target the strength and mobility of the hip and ankle.

Even with the strong clinical relevance, this study had several limitations. First, our subjects were presumed healthy with no history of injury in the previous 3 months, so it is possible that subjects were included who were exhibiting movement compensations from injuries slightly older than 3 months. The subjects rated the OHS using video instead of scoring it in real time, as would be done in a clinical setting. More research is needed to determine the level of agreement between video and real-world scoring of screening tasks.

On completion of the study we were able to show that the OHS test is a reliable test for clinicians to use and that it has the ability to assess MKD, which has not been previously shown. However, the OHS test should not be a stand-alone test and should be used as part of a comprehensive movement-screening examination that includes both low- and high-intensity movements such as the OHS, single-leg squat, and jump landing. Subjects who were rated as displaying MKD-present knee posture displayed significantly more motion-analysis-assessed displacement, indicating that observational screening of the OHS test has the ability to correctly identify MKD.

Acknowledgments

Supported by the Virginia Horne Henry Fund for Women’s Physical Education, the Wisconsin Athletic Trainers’ Association, and the Mueller Fund for Athletic Training Excellence. The authors would like to acknowledge Tyler Ballentine, Tylee Snafigel, Lisa Vanhoose, and Nick Spacio for assistance with data collection.

References


JSR Technical Reports, 2017