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Human Kinetics
CRITICALLY APPRAISED TOPIC

A Critically Appraised Topic on the Tuck Jump Assessment: Does the Tuck Jump Assessment Demonstrate Interrater and Intrarater Reliability in Healthy Individuals?

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Clinical Scenario: Lower-extremity injuries in the United States costs millions of dollars each year. Athletes should be screened for neuromuscular deficits and trained to correct them. The tuck jump assessment (TJA) is a plyometric tool that can be used with athletes. ***Clinical Question:*** Does the TJA demonstrate both interrater and intrarater reliability in healthy individuals? ***Summary of Key Findings:*** Four of the 5 articles included in this critically appraised topic showed good to excellent reliability; however, caution should be taken in interpreting these results. Although composite scores of the TJA were found to be reliable, individual flaws do not demonstrate reliability on their own, with the exception of knee valgus at landing. Aspects of the TJA itself, including rater training, scoring system, playback speed, volume, and number of views allotted, need to be standardized before the reliability of this clinical assessment can be further researched. ***Clinical Bottom Line:*** The TJA has shown varying levels of reliability, from poor to excellent, for both interrater and intrarater reliability, given current research. ***Strength of Recommendation:*** According to the Centre for Evidence Based Medicine levels of evidence, there is level 2b evidence for research into the reliability of the TJA. This evidence has been demonstrated in elite, adolescent, and college-level athletics in the United Kingdom, Spain, and the United States. The recommendation of level 2b was chosen because these studies utilized cohort design for interrater and intrarater reliability across populations. An overall grade of B was recommended because there were consistent level 2 studies.

Keywords: rehabilitation, sport management, sports physiotherapist, tuck jump assessment, testing and measurement

Clinical Scenario

Lower-extremity (LE) injuries are common in the athletic population, especially injuries to the anterior cruciate ligament (ACL).[1] These injuries can be career ending for athletes and result in costs in the United States of approximately 1 billion dollars annually.[2] The large number of LE injuries and ACL injuries in particular may be able to be reduced with proper screening, which could reduce costs to the US health care system.[2] Currently, plyometric screening tests include the landing error scoring system,[3] the drop jump video screening test,[4] and the tuck jump assessment (TJA).[5–7] The TJA is a clinician-friendly tool that requires minimal equipment, is time efficient (it only takes 10 s to administer), and evaluates jumping performance for 10 flaws. Two-dimensional video (frontal and sagittal) is taken of an individual performing repeated tuck jumps for 10 seconds, and the rater watches the videos to retrospectively score the TJA for the presence or absence of each flaw. If a flaw is present one or more times, a score of 1 is given, and if a flaw is absent during the 10 seconds, a score of 0 is given. An athlete may earn a score between 0 and 10; a score of 10 represents the poorest neuromuscular performance, with all flaws present, and a score of 0 represents the best performance, with no flaws present.[5–7]

Focused Clinical Question

Does the TJA demonstrate both interrater and intrarater reliability in healthy individuals?

Summary of Search, Best Evidence Appraised, and Key Findings:

- Five cohort studies[8–12] were found in the literature review that met the inclusion criteria for this critically appraised topic.
- Three studies[8–10] involved participants who were healthy, college-aged athletes, and 2 studies[11,12] involved healthy youth athletes.
- Two of the studies[9,10] provided a full description of the raters. Dudley et al[9] included 5 raters: a physical therapist with a Doctor of Physical Therapy and 4 years of clinical experience, a certified strength and conditioning coach with 7 years of clinical experience, a certified athletic trainer with 17 years of clinical experience, a third-year Doctor of Physical Therapy student, and a first-year Doctor of Physical Therapy student. Mayhew et al[10] included 4 raters: 2 physical therapists with 10 and 11 years of experience, respectively, and 2 strength and conditioning coaches with 1 and 11 years of experience, respectively. Another study stated that the raters were certified strength and conditioning coaches with more than 5 years of experience each.[12] In addition, 2 of the studies did not mention any education of the raters or related clinical experience.[8,11]
- Interrater reliability was determined in 4 of the studies,[8–10,12] and intrarater reliability was also determined in 4 studies.[8,9,11,12]

Clinical Bottom Line

There is insufficient evidence to determine the reliability of the TJA in healthy individuals. According to Centre for Evidence Based Medicine levels of evidence, there is level 2b evidence for research

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into the reliability of the TJA. This evidence has been demonstrated in elite, adolescent, and college-level athletics in the United Kingdom, Spain, and the United States.

Search Strategy

Terms Used to Guide Search Strategy

- **P**atient/Client group: healthy subjects OR athletes OR collegiate athletes
- **I**ntervention: tuck jump assessment OR TJA
- **C**omparison: no comparison
- **O**utcomes: reliability OR interrater reliability OR intrarater reliability OR like term

Sources of Evidence Searched

- PubMed
- MEDLINE
- CINAHL
- SPORTDiscus

Inclusion and Exclusion Criteria

Inclusion Criteria

- Studies with healthy participants
- English language studies published from May 2012 to October 2018
- Oxford Centre for Evidence-Based Medicine rating of 2b or higher
- Articles that have been peer reviewed

Exclusion Criteria

- Studies that did not evaluate interrater and/or intrarater reliability

Results of Search

Five relevant studies were found and are presented in Table 1. Interrater reliability was determined in 4 of the studies,[8–10,12] and intrarater reliability was also determined in 4 of the studies.[8,9,11,12]

Best Evidence

The 5 studies chosen for this critically appraised topic were identified as the best match when considering the inclusion and exclusion criteria. These 5 studies investigated interrater and intrarater reliability (Table 2).

Table 1 Summary of Study Designs of Articles

Level of evidence	Study design	Reference
2b	Cohort study	Herrington et al[8]
2b	Cohort study	Dudley et al[9]
2b	Cohort study	Mayhew et al[10]
2b	Cohort study	Read et al[11]
2b	Cohort study	Fort-Vanmeerhaeghe et al[12]

Implications for Practice, Education, and Future Research

Musculoskeletal conditions were ranked as the third-highest expenditure in health care spending in 2013, accounting for 190 billion health care dollars spent that year.[13] A large portion of musculoskeletal care involves treatment of LE injuries. Of all sports-related injuries, 66% are LE injury injuries, with knee injuries being most common.[14] A study conducted by Herzog et al[15] found that between 2005 and 2013 the immediate cost for 229,446 ACL surgeries was over 2 billion dollars. This statistic does not account for the rehabilitation process following the surgery. ACL injuries can be career-ending injuries for many athletes. Therefore, athletes' risk for LE injury should be recognized, treated, and prevented via clinical assessment tools and strength and endurance training programs. This will not only prevent devastating consequences to athletic careers but also assist in reducing health care costs in our nation.

To reduce the risk of career-ending ACL injuries, several plyometric screening tools been developed, including the landing error scoring system,[3] the drop jump video screening test,[4] and the TJA.[5–7] Tools like the landing error scoring system and the drop jump video screening are more time consuming than the TJA, which only takes 10 seconds to conduct. The TJA has been deemed clinician friendly by researchers of the tool because it requires minimal equipment.[9,15]

The TJA starts with camera set up in both the frontal and sagittal planes.[7] Two pieces of tape on the ground, 35 cm apart, indicate the starting and finishing point for the athlete's feet. Myers et al[7] described that the athlete should jump straight up and at the highest point of the jump bring the knees as high as possible. The jumper should land with the same foot placement after each jump and land softly each time. The effort of the athlete should not decline prior to the completion of the 10 seconds. The instructions to raters differ between studies. However, all 5 raters in the study by Dudley et al[9] received the same instructions, videos, and original Myer et al[7] article that describes the scoring. The raters in the study by Dudley et al[9] were allowed to watch the videos as many times as necessary. The raters scored each video independently, with no discussion allowed.

Scoring of the TJA is quick but not necessarily simple, with 10 flaws to score. The 10 flaws include LE valgus at landing, thighs not reaching parallel, thighs not equal side to side, foot placement not shoulder width apart, foot placement not parallel (front to back), foot contact timing not equal, excessive landing contact noise, pause between jumps, technique declines prior to 10 seconds, and does not land in the same foot placement.[5–7] The different flaws must be viewed from either the frontal or sagittal plane and with the volume on. It can be difficult to discern whether a flaw is present or not, especially when rating videos at full speed. Because of the difficulty of scoring a flaw, scorers are likely to slow down the video replay speed in order to view the flaws unless given specific instructions not to. To maintain consistency between scoring attempts, there is a need for standardization of video playback speed because some flaws may be better viewed—and, therefore, better scored—at different speeds. There is also a need for standardization for the video volume because one of the flaws is excessive contact noise. Currently, there is no recommendation on the video playback speed or volume used when viewing the videos.

Two different scoring systems exist for the TJA, the original version and the modified version.[5–7,12] The original scoring system

Table 2 Characteristics of Included Studies

Article	Herrington et al[8]	Dudley et al[9]	Mayhew et al[10]	Read et al[11]	Fort-Vanmeerhaeghe et al[12]
Design	Cohort study	Cohort study	Cohort study	Cohort study	Cohort study
Participants	Participants: 10 physically active participants including 5 males and 5 females, aged 18–21 y old. The participants were given instructions on the TJA. Raters: 2 raters scored the videos with a third rater, who analyzed the scores. There was no description provided by the authors regarding the experience or training of the raters.	Participants: 40 healthy and injury-free participants (aged 18–24 y old) including 13 men and 27 women participated in the tuck jump. The 40 participants did not have any prior tuck jump training. Raters: There were 5 raters, including a physical therapist with 4 y of clinical experience, a SC coach with 7 y of clinical experience, an athletic trainer with 17 y of clinical experience, a third-year DPT student, and a first-year DPT student.	Participants: 60 elite female football players participated in the study. These females were healthy and had a mean age of 20.27 (3.44) y. Raters: The raters who scored the TJA were a convenience sample of SC coaches and PT. The first PT had 5 y of experience with the women's FA and 10 y of clinical experience. PT 2 had a total of 11 y of clinical experience, including 3 y with the FA. The first SC had a total of 11 y of experience and 8 y of experience with the women's FA. Finally, the second SC had 1 y of experience with football players.	Participants: Participants included a total of 50 elite male soccer players who were split into 2 groups: 25 pre-peak height velocity (PHV) males with an average age of 11.93 y and 25 post-PHV males with an average age of 17.26 y. The groupings were based on the male athletes' PHV, also known as the time of adolescent growth spurt, because it has been concluded that athletes are more susceptible to injuries during and post-PHV than they are pre-PHV.[17] PHV was determined using individuals' maturity offset value, which allowed researchers to predict when an individual would reach PHV based on his gender, date of birth, standing and sitting height, and weight. All participants were healthy and active in soccer training and competitions. Raters: Authors mentioned that there was a single rater who scored the videos, but there was no description provided by the authors regarding the training or experience of the rater.	Participants: 24 elite youth volleyball athletes, 12 males and 12 females. Athletes were excluded if they had overuse or acute injuries at the time of testing. Raters: Both of the raters were certified SC coaches with more than 5 y of experience each.
Intervention	Participants: 10 participants, 5 males and 5 females, were given instructions and a demonstration of the TJA. The instructions to the participants included lifting knees to parallel and landing in the same spot as takeoff. Warm-up: not provided Number of jumps performed: 1 round of 10 seconds Camera setup: 2 video cameras were placed 2 m away from the participant in both the frontal and sagittal planes to view all flaws. Camera speed was not provided. Raters: To determine interrater reliability, the raters watched each video 3 times at normal speed, watching for the 10 flaws to determine interrater reliability. They watched the videos again 1 mo later to assess for intrarater reliability.	Participants: 40 participants were instructed on the purpose and protocol of the TJA. Each participant was instructed to jump continuously for 10 s with high effort, landing in the same spot they started in and then immediately beginning the next jump. Warm-up: not provided Number of jumps performed: 1 round of 10 seconds Camera setup: 2 cameras, one in the frontal plane and other in the sagittal plane. No details provided regarding distance from jumper or speed of camera. Raters: The 5 raters were instructed to read a copy of Myer et al[5] to understand the description and scoring of the TJA, given 1 practice video to score, and 40 participant videos with a view of both the frontal and sagittal planes. To determine interrater reliability, the raters watched the 40 videos and scored them on the 10 flaws and were encouraged to watch the videos at different speeds. Approximately 1 mo later, raters 1, 2, and 5 scored the videos again to determine if there was intrarater reliability.	Participants: The participants were verbally instructed on the TJA and were given a demonstration. The instructions were to stand with 1 foot on the tape and perform the tuck jump with high effort for 10 s. They were told to lift their knees to be level with their hips and return to the start position after every jump. Warm-up: not specified. Number of jumps performed: 1 round of 10 seconds Camera set-up: 2 high definition cameras, one in the sagittal plane and other in the frontal plane. Distance from jumper and speed of camera not provided. Raters: The raters were instructed to view each video no more than 3 times prior to scoring, and scores were to be determined independently from other raters.	Participants: Participants totally attended 3 sessions, 1 wk apart, under the same conditions. During session 1, subjects were familiarized with the test. Videos were collected in the second and third sessions and were retrospectively analyzed by a single examiner with emphasis on within-subject variation. Prior to testing performance in sessions 2 and 3, subjects participated in a 10-min warm-up of dynamic stretches. Once the participants entered the testing room, they were instructed to place their feet on a piece of tape and to land where they began their jump. Participants were also instructed to minimize ground contact time. The authors did not expand on the type of stretching completed by the participants. Warm-up: 10-min standardized warm-up Number of jumps performed: 1 round of 10 seconds Camera setup: 2-dimensional video was captured at a speed of 50 Hz using 2 high-definition video cameras positioned in the frontal and sagittal planes at heights of 0.70 and 5 m, respectively, from the center of the capture area. Raters: After the initial viewing, the rater scored the videos on 2 occasions that were separated by 7 d. Instructions given to the rater as to what playback speed was appropriate when viewing the videos were not provided in the article. Although information is given about the authors' credentials and backgrounds, it is not identified who the single rater is nor is any information about him provided.	Participants: Participants were familiarized with testing procedures 1 wk prior to testing. Participants were instructed to place their feet in the middle of a rectangle on the floor consisting of 4 smaller rectangles. They were instructed to lift knees to hip height and attempt to land with the same foot placement with their feet shoulder width apart. Warm-up: 10-min neuromuscular warm-up including strength and dynamic stretching Number of jumps performed: no more than 2 trials before collection of data; 1 round of 10 seconds for data collection Camera setup: 3 m from participant in both the frontal and sagittal planes. Use of iPad 5 and/or iPhone 6. Raters: raters used a modified scoring scale (0–2) to grade participants to give more objective information about severity of dysfunction related to perceived likelihood of ACL injury. The raters were instructed to watch the videos as many times as needed at their preferred playback speed. The raters reviewed the video and rescored 1 wk later.

(continued)

Table 2 *(continued)*

Article	Herrington et al[8]	Dudley et al[9]	Mayhew et al[10]	Read et al[11]	Fort-Vanmeerhaeghe et al[12]
Outcome measures	Primary outcome: interrater reliability and intrarater reliability	Primary outcome: interrater reliability and intrarater reliability	Primary outcome: interrater reliability	Primary outcome: intrarater reliability	Primary outcome: interrater reliability and intrarater reliability
Main findings	Interrater reliability was found to be very good/excellent by kappa value ($\kappa = .88$). The kappa rating was determined using the Landis and Koch scale. A kappa score of .81–1.0 was very good to excellent. Disagreement was found 7 times in total, and the authors failed to agree on 2 criteria after discussion. The authors disagreed on thighs not reaching parallel, thighs not equal side to side, foot contact timing not equal, does not land in same footprint, pause between jumps. Thighs not parallel and pause between jumps were disagreed upon twice each and the others just once. For each biological sex of the participants, intrarater reliability was also determined. For male participants, scorer 1 had a kappa score of $\kappa = 1.0$, meaning no differences were found in scoring 1 month later. Scorer 2 had a kappa score of $\kappa = .86$, disagreeing on 3 points. For the female participants, scorer one had 100% agreement and scorer 2 had a kappa score of $\kappa = .81$ (96% agreement).	The most frequently identified and agreed-upon flaw by the raters was thighs not reaching parallel, and the average number of flaws identified was 6.30 (1.76). The interrater reliability between the 5 raters was poor (ICC = .47; 95% CI, .33–.62), but interrater reliability between the 3 raters improved for the second scoring session. The first session interrater reliability results were ICC = .52; 95% CI, .35–.68, and the second scoring session improved to ICC = .69; 95% CI, .55–.81. Intrarater reliability ranged from poor (.44; 95% CI, .22–.68) to moderate (.72; 95% CI, .55–.84)."	Interrater reliability was determined to range from fair ($\kappa = .46$; 95% CI, .35–.56) to very good ($\kappa = .86$; 95% CI, .74–.94) for individual flaws using the Fleiss kappa coefficient. The composite score ranged from $\kappa_w = .62$ (95% CI, .48–.76) to .80 (95% CI, .70–.90), which is fair to very good using a weighted kappa score. The most frequent flaws found by the raters were thighs not reaching parallel and knee valgus upon landing. The least frequently identified flaws were pause between jumps and technique decline prior to 10 s. It was found that the knee and thigh motion category had clinically acceptable agreement between raters: LE valgus at landing ($\kappa = .83$; 95% CI, .72–.93), thighs not reaching parallel ($\kappa = .84$; 95% CI, .74–.94), and thighs not equal side to side ($\kappa = .86$; 95% CI, .75–.96).	Intrarater reliability of the composite TJA scores was deemed strong, with an ICC of .88. High within-subject variance was also indicated by a low kappa agreement ($\kappa < 1$). This kappa finding suggests that variations in score between the first and second sessions may be due to participants rather than the rater. Researchers recognized and discussed the within-subject variance and identified that the typical error range reported (0.89–1.01 in pre- and post-PHV players, respectively) would be considered acceptable and indicated that changes in total score greater than 1 following an intervention would be classified as a real change in performance rather than a change due to confounding variables. Flaws of knee valgus, feet not parallel, and pause between jumps were also found to have acceptable reliability in the pre-PHV group. By contrast, knee valgus on landing, thighs not parallel in flight, and contact noise were found to have acceptable reliability in the post-PHV group. The researchers also noted that the only reproducible flaw between both participant groups was knee valgus at landing.	Kappa measure of agreement between the 2 raters was good to excellent with an average percentage agreement across all scoring criteria of 92.1%. Interrater reliability for the total score (7.88 [1.98]) was excellent (ICC = .94; 95% CI, .88–.97). Kappa measures across the 2 scoring sessions were also good to excellent. Average percentage agreement was 90.8% for rater 1 and 95.4% for rater 2. Overall, intrarater reliability for the total score was excellent for both rater 1 (ICC = .94; 95% CI, .88–.97) and rater 2 (ICC = .96; 95% CI, .92–.98).
Level of evidence	Level 2	Level 2	Level 2	Level 2	Level 2
Strobe	15/22	16/22	17/22	16/22	15/22
Conclusion	The TJA has very good to excellent interrater and intrarater reliability. No information was given with regard to the training of the raters in this study. One of the raters in this study is one of the founders of the TJA, which could explain the lack of information regarding the raters. This study also had the smallest number of participants completing the tuck jump. Speed and number of views allowed by the raters were consistent with 3 views per video at normal speed, minimizing the risk of viewers watching the videos at different speeds or different numbers of times.	The authors demonstrated poor interrater reliability. This could be attributed to the fact that the raters in the study all had different levels of clinical experience. The authors did try to create some consistency in the training of the raters by requiring that they read an article by an original creator of the TJA and score a practice video; however, there has to be a more standardized training for the raters. In addition, the authors did not standardize the playback speed or how many times the raters could watch the videos.	Authors determined interrater reliability for the composite scores of the TJA to be fair to very good. However, these results suggest that caution must be used when interpreting the reliability of the TJA-based kappa value due to the variability in internal consistency among the individual flaws. Therefore, the researchers recommended that the flaw category of knee and thigh motion—knee valgus at landing, thighs not parallel, and thighs not equal side to side— be used to determine athletes' risk for LE injury.	The TJA demonstrated strong intrarater reliability. The researchers also suggested that variation in test scores were likely due to variability within the performance of participants across trials rather than the examiner. Issues arise with this study due to the fact that no background information was given for the rater. Therefore, readers cannot determine if this principal rater was proficient in scoring the TJA. The researchers also pointed out that knee valgus is the only flaw that was reproducible among both participant groups; they suggested that not all 10 of the TJA flaws were reliable for determining an athlete's risk of ACL injury. Therefore, the researchers suggested that only the flaw of knee valgus should be used to determine athletes' risk for LE injury.	The modified TJA demonstrated scores of good to excellent for almost all of the individual criteria assessed, and the percentage of exact agreement of interrater and intrarater reliability was excellent across all criteria. However, the authors failed to elaborate on the training provided to the raters regarding the grading of the modified TJA, which is important for replicating results of the same quality in the future.

Abbreviations: ACL, anterior cruciate ligament; CI, confidence interval; DPT, doctor of physical therapy; FA, football association; ICC, intraclass correlation; LE, lower extremity; PHV, pead height velocity; PT, physiotherapists; SC, strength and conditioning; TJA, tuck jump assessment.

consists of 2 options; criteria are either met or not met.[5–7] By contrast, the modified scoring system allows the rater to determine how severe the flaw is, giving 3 options for scoring: 0, 1, or 2.[12] Reliability in scoring the TJA can be altered based on the use of different scoring systems. The option of determining the severity of a flaw can allow for more specialized training to correct the flaw based on modifiable risk factors identified by Myer et al[7] and Lininger et al[16]; however, this scoring system also introduces a greater degree of subjectivity when scoring the TJA. Standardization of scoring is needed in order to provide raters with the preferred scoring system.

In the research used for this study, reliability was found to be good to excellent in 4[8,10–12] of the 5 studies. However, 2 of the studies that deemed that the TJA had either strong intrarater reliability (intraclass correlation = .88)[11] or fair to good interrater reliability (κ_w = .62–.80),[10] and stated that although the composite score of the TJA demonstrated reliability, caution should be taken when interpreting the total score as there is high within-subject variation across a number of flaws.[11] Statistical analysis to determine if scores for each of the 10 flaws were reproducible independent of one another concluded that only 1 flaw demonstrated substantial agreement in both prepeak height velocity and postpeak height velocity youth athletes (κ = .78 and .67, respectively), that is, knee valgus at landing.[11] Thus, the authors suggested that not all 10 flaws scored on the TJA were reliable enough to determine an athlete's risk for ACL or LE injury and that perhaps only the flaw of knee valgus at landing should be used.[11] The Mayhew et al[10] study also concluded that the interrater reliability of individual flaws varied from fair to very good (κ = .46–.86) and demonstrated that knee valgus at landing, thighs not parallel, and thighs not equal side to side were found to have the best reliability among the flaws. Standardization of particular variables must be done for future research in order to determine the true reliability of the TJA. Another consideration with regard to the published literature on the reliability of the TJA is that the original author of the TJA was an author and sometimes a rater for 3 of the 5 articles that demonstrated good to excellent reliability[8,11,12]; this may serve as a source of potential bias. In addition, one of the studies that indicated that the TJA demonstrated good to excellent reliability had the lowest number of participants in the study and, therefore, the lowest power of any of the studies examined.[10] Fort-Vanmeerhaeghe et al[12] demonstrated strong reliability for the TJA; however, they used a modified scoring system. This presents another inconsistency in the available research as the modified scoring system rates TJA flaws differently than the other studies reviewed. Although Dudley et al[9] determined poor reliability overall, the reliability increased on the second viewing of the videos, suggesting a possible learning curve. All of the studies that were assessed and presented data to support the reliability of the TJA also contained confounding variables of results and potential sources of bias.[8,10–12] Therefore, based on the scarce body of evidence currently available, a clear decision cannot be determined as to whether the TJA is reliable in healthy subjects in terms of interrater and intrarater reliability.

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