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Effects of Anaerobic Fatigue on the Tuck Jump Assessment Performance in Female Collegiate Club Athletes

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Purpose: To determine the impact of a fatigue trial on the scores and number of jumps in a Tuck Jump Assessment (TJA) in female collegiate club athletes. The TJA is a 10-second plyometric jumping assessment used to replicate sport and identify lower extremity landing patterns. Scores from the TJA are summed together and those who score a 6 or higher are suggested for intervention training. **Methods:** Sixteen female club athletes (age: 20.9±1.9 years, weight: 59.13±7.72kg, height: 64.56±2.63cm) completed the TJA twice, once before performing a Wingate protocol and then again after. A dependent sample t-test was performed to determine any statistical differences between the TJA scores and the number of jumps between pre-Wingate and post-Wingate trials. **Results:** There was a statistically significant difference between scores for the TJA pre-Wingate (5.8±2.1) and post-Wingate (7.7±1.4) ($P<0.0001$), with nearly 2 more flaws following the Wingate protocol. There was also a statistically significant difference between the number of jumps for the pre-Wingate (15.1±3.6) and post-Wingate (16.9±2.5) ($P = 0.022$) with approximately 1 more jump following the Wingate protocol. **Conclusions:** The Wingate protocol had an impact on both the number of flaws and number of jumps, suggesting that athlete fatigue caused by completion of the Wingate protocol contributed to the increased number of errors in the TJA. The most common flaws were "pause between jumps" and "feet do not land in the same footprint". A statistically significant difference between the number of jumps pre- to post-Wingate TJA was also found. There were a greater number of jumps in the post-Wingate TJA than pre-Wingate. Due to the increased scores in the post-Wingate condition, having athletes complete a fatiguing protocol prior to the TJA may provide a more sport-like level of exhaustion. Recreating similar conditions athletes are sustaining during their sport could give a more accurate representation of the TJA, thereby making it a more clinically relevant and viable tool to use. **Key Words:** *functional hop test, anterior cruciate ligament, anaerobic test*

INTRODUCTION

Sports with repetitive jumping and landing activity can predispose athletes to several kinds of lower extremity injuries[1-3], ranging from overuse injuries[1,2] to more traumatic acute injuries such tears of the anterior cruciate ligament (ACL)[3]. Sports that specifically require repetitive jumping and landing, such as volleyball[1], gymnastics[2], and dance[3], have been shown to have a high rate of lower extremity injuries.[1-3] The tuck jump assessment (TJA) is a 10-second, clinician-friendly plyometric screening tool used to assess lower extremity landing technique flaws.[4,5,6] The TJA consists of a 10-point scoring system,[4,5,6] with higher scores indicating more technique flaws that could lead to an increased risk factor of lower extremity injuries.[7] Scores of a 6 or higher should seek intervention training.[4] Oftentimes, risk of lower extremity injuries is due to a lack of neuromuscular control.[4,5,7-9] Several studies have shown that fatigue can cause a decrease in neuromuscular control and biomechanics during jumping and landing tasks.[3,10-12]

Fatigue can be defined as a decline in muscular ability to maintain necessary mechanical work for a given function.[13] Fatigue has also been shown to have many effects on athletic performance, including a decrease in muscle control and strength[13], decrease in ability to generate power[14], and

impaired strength, biomechanics, and central activation[12]. More specifically, several studies have shown that implementing a fatiguing protocol has shown a significant decrease in participants' biomechanics, therefore decreasing their abilities to perform a functional test when comparing groups under pre-fatiguing and post-fatiguing conditions.[10-12]

Limited research has been performed with the TJA in combination with a fatiguing method prior to this current study.[4-7] The TJA was created to replicate sport activity, however, if fatigue is not achieved, then the validity of the TJA may be limited.[4,5] Two of the 10 technique flaws impacting the score of the TJA include "fatigue in technique" and "pause between jumps". Smith et al. found that landing patterns in female college-aged athletes had a lower number of technique flaws in their jumps when compared to a college cohort group.[5] Recently, some literature has started investigating the number of jumps participants are completing in the 10-second time period.[5] The TJA does not account for number of jumps in the 10-flaw criteria. Therefore, more research is needed to determine if standardizing this will increase the validity of the TJA and its scores as a tool for assessing lower extremity landing patterns.

Therefore, the purpose of this study was to determine the impact of a fatigue trial on the scores and number of jumps in a Tuck Jump Assessment (TJA) in female collegiate club athletes. If there is a significant difference between TJA scores and number of jumps under normal and fatigue conditions (pre- and post-Wingate), current procedures for the TJA may not be appropriate in eliciting sport-type energy expenditure.

METHODOLOGY

Study Design

A repeated measures study was used to determine if the scores of the TJA differed significantly between 2 different conditions: pre-Wingate TJA and post-Wingate TJA. The independent variable was protocol with 2 levels, normal and fatigued. The dependent variables were TJA scores and the mean number of jumps during the TJA.

Participants

A sample size estimation was conducted with an effect size of 0.50, alpha set to 0.05 and statistical power set at 0.80. Therefore, the *a priori* estimate suggested 32 participants would be needed to detect a statistically significant difference. A total of 16 participants volunteered to partake in this research. All of the participants were females who met the inclusion criteria. The inclusion criteria established were female club athletes at a Division I Southwestern public undergraduate and graduate university between the ages of 18-26. Exclusion criteria included an ACL injury within the last 2 years, sport-related concussion within the last 6 months, or any current injury that would affect their ability to participate in their practice.

Participants were recruited using the university email addresses and one in-person recruitment in the beginning of an exercise science class. All email addresses were obtained with consent from the IRB and the club sports director. Two emails were sent out with a 1 week wait period in order to allow participants to respond to the initial email. In-person recruitment was approved by the IRB and the professor of the class. An approved script was read and followed by any questions. The investigator's email address was left for anyone who was interested in the research study and met the inclusionary criteria. After participants that had shown interest in the study replied via email, an appointment was made for the participant to complete the single day testing session for the pre- and post-Wingate TJA.

The Institutional Review Board approved the research study. All of the participants included in the study were provided with an informed consent which was signed prior to data collection.

Procedures

Participants were tested in a single session which lasted approximately 1 hour. Following the consenting process, a demographic questionnaire was completed by each participant. Each participant was then randomly assigned an identification number in order to keep her information confidential. Height, weight, blood pressure and heart rate were recorded prior to the pre-Wingate TJA.

The pre-Wingate TJA began with a 5-minute warm up on a Monark ergometer with no resistance, followed by a 5-minute rest period. During the rest period, verbal instructions were given for the TJA.[5,9] Participants were told to jump repeatedly for 10 seconds with a high level of effort, bringing their thighs up to parallel and landing softly in the same footprint, and then immediately jumping again. The jumping portion of both conditions were recorded in the frontal and sagittal plane. Immediately after the pre-Wingate TJA, the participants' heart rate and blood pressure were measured.

A 30-minute rest period allowed each participant to return to baseline heart rate and blood pressure that were recorded prior to the post-Wingate TJA being started. This helped confirm that each participant fell within her baseline measures. The Wingate protocol was explained to the participants during the rest period prior to the testing session.

The post-Wingate TJA consisted of a warm up on a Monark ergometer that required the participant to pedal within 60-65 revolutions per minute (RPM) for the entire 5-minute period. The participants were given 3 separate periods during the last minute of the warm up time to pedal at their calculated resistances for 5 seconds. This allowed participants to be exposed to their calculated resistance prior to the Wingate test. Resistance was calculated by 7.5 percent of the participant's total body weight.[15] The Wingate was performed at each participant's calculated resistance for a 30-second sprint. According to Bar-Or et al. the Wingate protocol is most commonly used for anaerobic energy pathway, thus using this as the fatigue factor in the post-Wingate TJA allows participants to deplete the anaerobic pathway, allowing for anaerobic fatigue.[15] After the Wingate was completed, participants were re-instructed on the TJA and performed the test using the same method as the pre-Wingate TJA.

Another member (M.V.) of the research team was blinded to which TJA condition a participant completed in each of the videos. The pre-Wingate and post-Wingate TJA videos were scored from the 10-flaw criteria from a previously published article.[15] The intrarater reliability has been reported as good to excellent of scoring multiple sessions of the TJA.[16] In Table 1, the 10 technique flaws that could be identified during the TJA are broken down into "knee and thigh motion", "foot position during landing" and "plyometric technique".[16] In Figure 1, the 6 photos are the incorrect techniques that are associated with technique flaws seen from either the frontal or sagittal view during the jump. The remaining 4 technique flaws not pictured are associated with plyometric technique during the duration of the jump and cannot be captured through a still photo. If a technique flaw is present at least once, a value of 1 is given for that particular technique flaw. The lower the score, the fewer technique flaws that occurred.[16]

Knee and Thigh Motion	
1	Lower extremity valgus at landing
2	Thighs do not reach parallel (top of jump)
3	Thighs not equal side-to-side (during flight)
Foot Position During Landing	
4	Foot placement not shoulder width apart
5	Foot placement not parallel (front to back)
6	Foot contact timing not equal
7	Excessive landing contact noise
Plyometric Technique	
8	Pause between jumps
9	Technique declines prior to 10 seconds
10	Does not land in same footprint

Table 1. Tuck Jump Assessment (TJA) Scoring Criteria[9]
Bolded technique flaws are seen in Figure 1.

Figure 1. Technique flaws from the Tuck Jump Assessment Scoring Criteria (Table 1).
1. Lower extremity valgus at landing 2. Thighs do not reach parallel (top of jump) 3. Thighs not equal side to side (during jump) 4. Foot placement not shoulder width apart 5. Foot placement not parallel 6. Foot contact timing not equal. Remaining technique flaws are assessed over the course of the 10-second jump and include excessive landing contact noise, pause between jumps, technique declines prior to 10-seconds and feet do not land in the same footprint and therefore a still photo is not possible.

Statistical Analysis

Participants' demographic information and the pre-Wingate and post-Wingate TJA scores were entered into a Microsoft Excel document and then transferred to and analyzed with SPSS (IBM; version 24.0) software. A dependent sample t-test was used to compare the pre-Wingate and post-Wingate TJA on each of the 2 dependent variables (scores from TJA and number of jumps). An *a priori* level was set to P = 0.05.

RESULTS

Sixteen female club athletes (age: 20.9±1.9 years, weight: 59.13±7.72 kg, height: 64.56±2.63 cm) completed the study. The TJA scores differed significantly from pre-Wingate TJA to post-Wingate TJA (P > 0.0001) (Table 2, Figure 2a). The scores increased from pre-Wingate TJA to post-Wingate TJA. There was also a statistically significant difference in the number of jumps from pre-Wingate and post-Wingate TJA (P = 0.022). (Table 2, Figure 2b). The number of jumps increased with approximately 1 more jump in the post-Wingate TJA.

Variable	Pre-Wingate TJA	Post-Wingate TJA	P-value	95% Confidence Interval
TJA Score (mean ± SD)	5.8±2.1	7.7±1.4	<0.0001	(-2.65, -1.10)
Number of Jumps (mean ± SD)	15.1±3.6	16.9±2.5	0.022	(-3.21, -0.29)

Table 2. Descriptive Statistics and Analytic Results for Pre-Wingate and Post-Wingate Tuck Jump Assessment (TJA) Scores and Number of Jumps

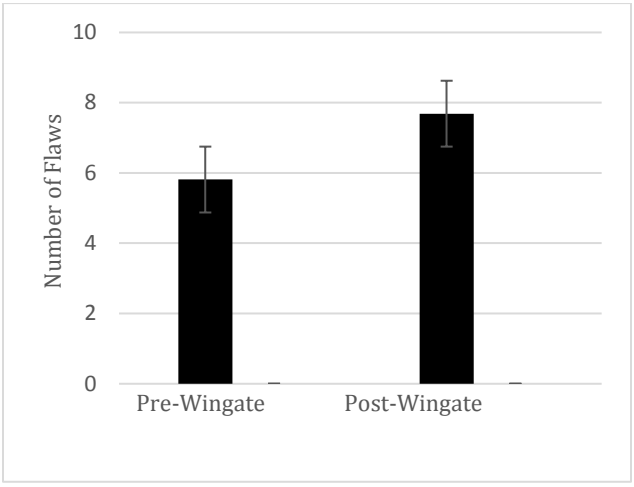

Figure 2a. Comparison of Number of Flaws from Pre-Wingate to Post-Wingate TJA

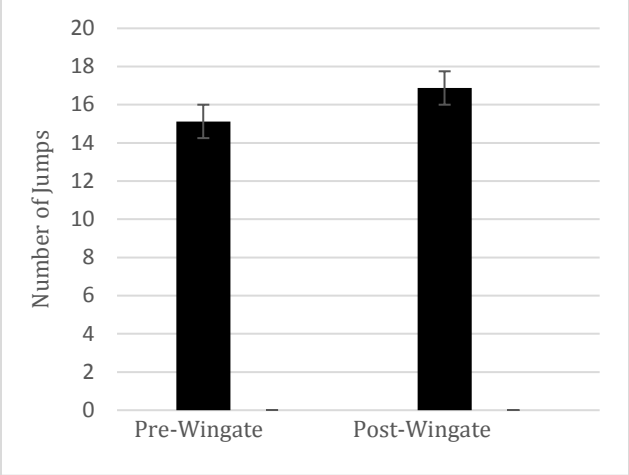

Figure 2b. Comparison of Number of Jumps from Pre-Wingate to Post-Wingate TJA

DISCUSSION

The TJA was created to be used as a clinician-friendly tool to help identify lower extremity landing patterns during plyometric jumping, as seen in sports. However, the TJA has not been assessed following a fatigue protocol. Therefore, the purpose of this study was to determine the impact of fatigue on the TJA scores and number of jumps in female club athletes.

The results of this study presented an increase in scores from the pre-Wingate TJA to post-Wingate TJA, therefore indicating an increase in the number of technique flaws after the implementation of the fatiguing protocol. The 2 technique flaws that were most common with participants were "pause between jumps" and "feet do not land in the same footprint". This increase in scores between the 2 performances of the TJA could be due to the fatigue factor each participant experienced during the Wingate test. The Wingate has 3 indicators that determine the effort each participant put in during the duration of the test. Peak power (PP), mean power (MP) and fatigue index.[14] Peak power defines the highest 5-seconds during the test and mean power is calculated by each participant's body weight and RPM. Fatigue index is calculated by the difference in PP from the minimum power all divided by PP.[14,15] Minimum power was calculated in order to determine the fatigue index. These indicators were not used in any statistical analyses due to the insignificant correlation with the study. This study did not specifically look at the effect of fatigue index on the post-Wingate TJA score because the Wingate was just used as a fatigue factor for the TJA rather than an additional analysis. Using the fatigue index in future research studies could help determine if it affected scores, and how that fatigue index varies based on sport and TJA score.

The most common flaw among the participants for both conditions were "feet do not land in the same spot". The other most common flaw that was identified was "pause between jumps". Both of these flaws were seen more frequently in the post-Wingate TJA.

Another result that was observed in this study was an increase in number of jumps in the post-Wingate TJA. Fatigue was previously defined as a decline in muscular ability to maintain necessary mechanical work for a given function.[13] With one of the necessary muscular functions in order to avoid flaws in the TJA being to avoid pauses between jumps in the 10-second timeframe, it would seem more likely that fatigue would cause a decrease in the number of jumps from pre- to post-Wingate TJA performances. The increase of jumps could be due to several factors, 1 being a possible learning effect. Participants had already completed the TJA in the pre-Wingate condition, providing a familiarization period with the test. Participants could also be more motivated to improve from first testing period, in addition with the fatigue factor. Athletes have to push themselves when they are fatigued in their sports in order to keep playing at the same level of competition throughout athletic activity. The athletes' possible tendencies to push themselves to compete at the same level as the first condition, if not better, could account for the increase in number of jumps.

Generalizing the results may be limited due to the number of participants that completed this study. Thirty-two participants were

needed for a statistically significant difference, however, only 16 were able to complete this study due to the end of the academic year. Another limitation may be due to the inclusion criteria, which was limited to female club athletes between the ages of 18-26. With this narrow inclusion criteria, the results cannot be generalized to high school or NCAA student-athletes. A final limitation of this study is that recently, Fort-Vanmeerhaeghe proposed the use of a different scoring range for the TJA.[18] Instead of the 0 or 1, as used in this current study, Fort-Vanmeerhaeghe has proposed a modified scale of 0 (same as the present study), and a 1 or 2 ("magnitude of the score") indicating that the participant failed to meet the criteria 2 or more times during the 10-second jump.[18] Because of this new addition to the literature base, the findings of the present study should only be generalized to the previously established scoring scale.

CONCLUSIONS

There is limited research for the TJA with a fatigue protocol. The TJA is a 10-second plyometric jumping assessment used to replicate sport and identify lower extremity landing patterns.[16] The combination of the fatigue protocol and the TJA may increase the validity of the TJA and increase the ability to identify those at risk for a lower extremity injury. The athletes who participated in this study not only increased scores from pre-Wingate TJA to post-Wingate TJA, but also increased the mean number of jumps from pre to post-Wingate TJA. This research suggests that fatiguing athletes prior to the TJA may identify technique flaws that may be more apparent after fatigue, which could be similar to actual sport participation.

Recreating a more realistic athletic condition for the athletes during the TJA is more likely to provide an accurate representation of how they will perform during actual activity. After the participants were fatigued, scores increased due to the fatigue factor, suggesting they are at higher risk for injuries to the lower extremity. Testing athletes under less athletic activity-specific conditions, with higher energy levels could provide limitations in indicating whether or not an athlete could be at risk for an injury when they expend more energy during athletic activity. Further research is needed to address fatigue prior to the TJA and the accuracy it has on the TJA scores and number of jumps.

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