

The Effects of Fatigue on Jump-Landing Mechanics in Elite Malaysian Baseball Players

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ABSTRACT

19 elite baseball players (male: $n = 9$; female: $n = 10$) participated in this study. In a repeated measures study design, participants were required to attend to a testing session where they performed a 6×40 m repeated sprint ability (RSA) test with 20 s rest interval between 40 m bouts. A 2 (time: pre-, post- test) \times 2 (sex: male, female) repeated measures analysis of variance was utilised to study the changes in LESS scores before and after the RSA exertions. Before (pre-test) and after (post-test) the RSA, all participants were instructed to perform three successful trials of a drop vertical jump task (DVJ) off from a 30 cm elevated platform. There was no discernible gender difference in LESS scores. Repeated sprint exhaustion did not appear to have an impact on the results, but more investigation into the various types of fatigue may provide richer details about their contributions to players' landing kinematics. Baseball players, especially fielders, may find the LESS to be quite useful for screening their risk of lower limb injuries. To further assess the injury risk among pitchers, future studies might also take a single-leg LESS variation into account.

Keywords: Baseball, Landing Error Scoring System, Lower limb injuries

INTRODUCTION

Baseball has seen an increase in injuries since 1989 through to 2020 (Conte et al., 2001; Platt et al., 2021; Posner et al., 2011). Reported injuries per 1000 athlete-exposures (A-Es) have increased from 3.55 A-Es in 2008 (Posner et al., 2011) to 8.66 A-Es in 2020 (Platt et al., 2021). This calls for increased concern among coaches, physicians, and baseball players in any competition level. Unsurprisingly, most injuries in baseball occur in the upper extremities, especially among pitchers, however, lower extremity injuries have been the more prominent injury among fielders (Platt et al., 2021; Posner et al., 2011). Unfortunately, there seems to be a scarcity of literature in studying lower limb injuries in baseball. In an epidemiological study by Salhab et al. (2019), the most common lower limb injuries in baseball identified were thigh and knee injuries, and the trend of injury occurrence in the lower limbs has been increasing. On average, lower limb injuries in baseball causes up to 46 days of absence from participation from the sport, and knee injuries have been responsible for the most absence from participation over 60 days in baseball (Salhab et al., 2019).

Knee injuries are the most common injury among elite athletes in most sports (Wahab et al., 2015). Studies into knee injuries have led to advances in injury risk screening as well as methods of injury prevention. Many injury prevention programs have been introduced such as the Sportmetrics™ (Hewett et al., 1996; Noyes et al., 2011), PEP (Gilchrist et al., 2008; Mandelbaum et al., 2005), Harmo Knee (Shojaei et al., 2011), Knaekontroll (Waldén et al., 2012), and the FIFA 11+ (Owoeye et al., 2014; Silvers-Granelli et al., 2015; Soligard et al., 2008), with evidence of reduced injury reduction with better compliance to the programs across different

sports such as volleyball, basketball, and soccer. Injury risk assessments have also been introduced to enable practitioners to stratify individuals according to their risk level classifications to improve the efficacy of injury prevention programs. Padua et al. (2009) introduced a systematic Landing Error Scoring System (LESS) to identify at-risk individuals using two-dimensional motion analysis.

The utility of injury risk assessment tools such as the LESS in sports may be highly beneficial for teams' and coaches to identify individual improvement areas and effectively implement specific lower limb injury prevention exercise programs for players. In addition, studies have reported increased injury occurrence in later stages of match-play (Ekstrand et al., 2011; Hawkins et al., 2001) thus suggesting that fatigue may play a role in increasing the risk of injuries in a match. However, there has been a scarcity of studies regarding lower limb injury risk assessment in baseball. Thus, this study aimed to investigate the injury risk status of Malaysian elite baseball players using the LESS before and after fatigue from high intensity exertions.

METHODS

Data Collection Procedures

19 elite baseball players (male: $n = 9$; female: $n = 10$) participated in this study. Their mean age, body mass, and height were 25.95 ± 6.88 years old, 58.40 ± 7.69 kg, 1.59 ± 0.05 m respectively. All participants consented and admitted they were free from lower limb injury. In a repeated measures study design, participants were required to attend to a testing session where they performed a 6×40 m repeated sprint ability (RSA) test (Rampinini et al., 2007). In between each 40 m bout, participants were allowed 20 s of passive rest. Sprint times were recorded using timing gates (Brower Timing Systems, Utah, USA), while the 20 s rest intervals were timed using a handheld stopwatch. Before (pre-test) and after (post-test) the RSA, all participants were instructed to perform three successful trials of a drop vertical jump task (DVJ) off from a 30 cm elevated platform (Figure 1). A successful trial was considered only when participants were able to land at a distance 50 % of their individual body height. The landing mechanics of the DVJ were recorded at 120 Hz from the frontal and sagittal planes for a Landing Error Scoring System (LESS) assessment (Padua et al., 2009).



Figure 1 Setup for LESS DVJ task. Participant stands on a 30cm elevated platform.

Statistical Analyses

Data were analysed using the Statistical Product and Service Solutions SPSS (v.28, IBM SPSS, Illinois, USA). Independent t-test was employed to investigate for any differences between male and female participants in LESS scores during pre-test. A 2 (time: pre-, post- test) \times 2 (sex: male, female) repeated measures analysis of variance was utilised to study the changes in LESS scores before and after the RSA exertions. Mauchly's test for sphericity was conducted to assess the sphericity assumption and any violation of the assumption was corrected based on the Greenhouse-Geisser epsilon. If the epsilon was < 0.75 , the Greenhouse-Geisser correction was referred to, otherwise, the Hyunh-Feldt correction was referred to. Post-hoc analyses were performed using Bonferroni correction procedures to reduce Type II error rate. Alpha was set to 0.05 for all analyses.

RESULT

Means and standard deviations are presented in Table 1. Baseline assessments showed no differences between male and female LESS scores ($p = 0.723$). There was no significant main effect of time on the LESS scores ($F_{1,17} = 1.054$; $p = 0.319$; $\eta^2_{\text{partial}} = 0.058$). Sex and time showed no interaction effect of the LESS scores ($F_{1,17} = 0.281$; $p = 0.603$; $\eta^2_{\text{partial}} = 0.016$), indicating that sex does not seem to affect LESS scores.

Table 1 Descriptive statistics of LESS scores

Sex		Mean	SD
Pre-test	Female	3.6	0.7
	Male	3.4	1.2
	Overall	3.5	0.9
Post-test	Female	4.0	1.5
	Male	3.6	0.9
	Overall	3.8	1.2

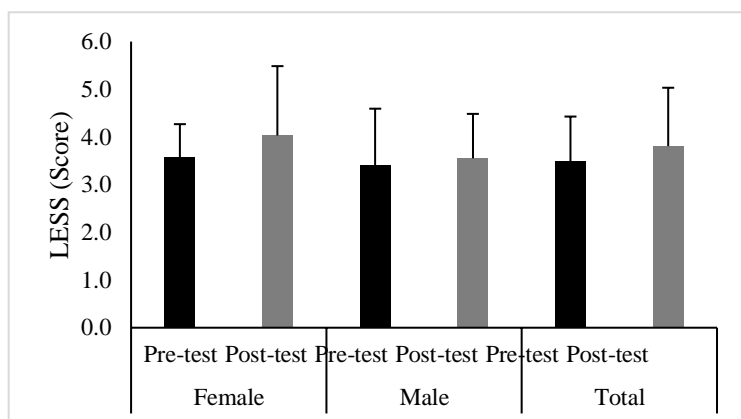


Figure 2. Changes in LESS scores pre- and post- fatigue

DISCUSSION

Key Findings

The main findings of this study were that no significant differences were observed between the pre-test and post-test scores for all participants regardless of sex. No significant difference was observed between male and female participants both pre- and post-tests. Increments in LESS scores were ranged between 5 – 12 % for both male and female participants, however the magnitude of change was not significant. Mean LESS scores indicated that participants were in the moderate risk category.

The LESS score increments observed in this study were similar to previous studies by Gokeler et al. (2014). However, in their study, the magnitude of increments in LESS scores were greater. Specifically, healthy participants increased from a median of 2.5 to a median of 6 post- fatigue. In the current study, the mean LESS scores at pre-test was 3.5 and only saw an increment to a mean of 3.8. The differences in magnitude may be attributed to the fatigue protocols employed in the two studies. This study employed a short-term RSA, which involved high intensity sprints, while Gokeler et al. (2014) employed a repeated counter-movement jump protocol until participants were unable to reach 70 % of their maximum vertical jump height. The difference in fatigue mechanisms (central *versus* peripheral fatigue) may have been critical to the changes observed between

the two studies. This may warrant further investigation into the influences of different types of fatigue on the LESS scores.

Despite the similarities in male and female LESS scores, female players showed a higher post-test score compared to males. Kuenze et al. (2018) reported similar trends in LESS scores between male and female participants. This may be attributed to the general landing patterns between male and female participants. Kuenze et al. (2018) pointed out that females had a greater tendency to trunk flexion, stiff landing, knee valgus and poor overall landing errors compared to males due to consistent kinematic movement profiles of females with ACL reconstructed populations (Delahunt et al., 2013) and at risk of injury (Hewett et al., 2005). This may explain the increases discrepancy in LESS score increments following high intensity exertions between male and females.

Utility of the Landing Error Scoring System in Baseball

The LESS scoring system is based on a set of defined criteria, which are used to measure various aspects of the landing, such as the position and orientation of the body, the estimated level of muscle activity (using three-dimensional motion analysis), and the forces and impacts experienced during the landing. One of the key benefits of LESS is that it provides a consistent and objective method for evaluating jump landings, which allows for comparison and analysis of performance over time. By analyzing the scores for a series of landings, it is possible to identify patterns and trends that may indicate areas for improvement or increased risk of injury. This can be particularly useful for athletes, coaches, and trainers, as it allows them to take proactive steps to address any issues and improve landing performance.

In the context of baseball, the LESS could be used to assess the kinematics of pitchers during the landing phase of their delivery. This could be useful for identifying areas for improvement in their technique and reducing the risk of injury, as pitchers are at risk for a variety of overuse and traumatic injuries due to the high forces and stresses experienced during the throwing motion. However, the landing phase of a pitch only involves one leg (unilateral landing). Perhaps a single-legged kinematics assessment such as the Single Leg-Landing Error Scoring System (O'Connor, 2015) may be more representative of the motion during pitching in baseball, however it was not implemented in this study. This could perhaps be explored in future research endeavors.

Pitchers typically generate large amounts of force and torque during the landing phase of their delivery, and these forces can be transmitted through the lower extremity (MacWilliams et al., 1998) and spine (Young et al., 1996), potentially leading to injuries such as stress fractures, muscle strains, and ligament sprains. By using LESS to evaluate the kinematics of the landing phase, it is possible to identify any deviations or errors in technique that may increase the risk of injury and implement corrective strategies to address these issues. In addition to pitchers, LESS could also be used to assess the jump landings of position players when fielding or throwing the ball as fielders are found more likely to be injured in the lower limbs (MacWilliams et al., 1998; Platt et al., 2021; Posner et al., 2011). By evaluating the kinematics of the players' landings, it may be possible to identify areas for improvement and reduce the risk of injury for these players as well.

CONCLUSION

No significant difference in LESS scores can be observed between sexes. Fatigue from repeated sprints did not seem to affect the scores, however further interrogation regarding different types of fatigue may reveal richer information on their roles towards players' landing kinematics. The utility of the LESS may be highly beneficial for the lower limb injury risk screening of baseball players, especially among fielders. However, future investigations could also consider adding a single-leg variation of the LESS for better evaluation of injury risk among pitchers.

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