Research Paper: Association Between Cognitive Function and Mechanical Pattern of Landing

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Citation: Mohammadkhani N, Balouchy R, Ghasemian M. Association Between Cognitive Function and Mechanical Pattern of Landing. Journal of Modern Rehabilitation. 2020; 14(3):151-158. http://dx.doi.org/10.18502/jmr.v14i3.7713

doi: http://dx.doi.org/10.18502/jmr.v14i3.7713

Article info:
Received: 05 Feb 2020
Accepted: 21 May 2020
Available Online: 01 Jul 2020

Keywords:
Cognitive functions, Attention, Sport injuries

ABSTRACT

Introduction: In examining the factors affecting sports injuries, the emphasis is always on physical variables, while cognitive and psychological characteristics can also be effective. Hence, the present study aimed to investigate the relationship between sustained attention as a neurocognitive function and landing error as a mechanical factor associated with lower limb injuries.

Materials and Methods: 44 female basketball players aged 18-25 years at the national league level participated in this study. The participants were assessed using the continuous performance test, and their landing-jumping was evaluated by the landing error scoring system in two conditions of high and low cognitive load.

Results: The results showed that people's landing errors increased significantly as a result of increased cognitive needs (P=0.0001). Also, the findings revealed a positive correlation between omission and commission errors with landing error scores in both low and high cognitive load conditions (P<0.05).

Conclusion: Sustained attention could predict the landing error score that is considered a key risk factor of lower limb injuries. It is recommended that multiple cognitive and physical assessments be used to identify athletes at risk of injury. Hence, cognitive enhancement protocols may be effective along with physical preparation programs.

1. Introduction

Researchers have always sought to investigate the factors that influence sports injuries so that by recognizing them, they can design strategies for the prevention and treatment of sports injuries [1]. The risky variables of sports injuries have been classified into two main categories: internal and external factors [2]. The external factors consist of sport type, exercise methods, over-training, equipment, and the practice area. The internal factors include the athlete's individual physical and mental characteristics such as age, gender, abnormal physical maturity, personality, and so on [3]. The lower limb injuries, especially in the knee and ankle joints, are common in athletes [4].

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One of the movements that cause lower limb injuries and is considered to be the most common mechanism of non-contact injuries is landing after jumping, which is very common in many sports such as volleyball, basketball, and football [5]. Previous research shows that the quality of landing skills and its mechanical properties can be risk factors for lower limb injuries due to the significant force exertion on the joints and ligaments [5, 6]. Landing can exert force 2 to 12 times greater than the bodyweight on joints and ligaments [7]. Some researchers have suggested that this movement is one of the most important mechanisms involved in anterior cruciate ligament injury in female basketball and volleyball players [8, 9]. By enhancing the quality of landing movement patterns, the likelihood of injury occurrence can be greatly reduced [10]. To measure the quality of landing and mechanical properties associated with the occurrence of injuries, researchers have developed a Landing Error Scoring System (LESS). The studies show that LESS can identify individuals who may be at risk of lower extremity injuries. Besides, LESS is sensitive to changes due to technical correction interventions [11].

Although physical factors are generally considered in this field, psychological and cognitive characteristics as internal factors can affect the risk of injury in sports. For example, it has been shown that psychological stress has a significant relationship with injuries incidence in female football players [12]. New approaches show that in addition to common psychological characteristics such as anxiety and stress, neurocognitive factors may play a role in sports injuries [13-15]. Inappropriate motor coordination and poor movement timing are considered risk factors for injuries [16]. On the other hand, the neurocognitive ability is closely related to neuromuscular coordination and consequently the occurrence of injuries [17]. For example, research has shown that postural control in complex dynamic movements, which is one of the main causes of injury and requires a high level of attention [16, 18, 19].

The neurocognitive function has been proved to be a risk factor for sports injuries [13, 14, 17, 20]. There are several definitions for neurocognitive functions, in which different features are mentioned as its components [21]. In this regard, some of these components are associated with higher-level brain functions, and some with lower-level brain functions [22]. Attention is the main component of neurocognitive functions [23]. There are several types of attention. Selective attention and sustained attention are the main types of attention. In selective attention, one should pay attention to some stimuli and ignore other stimuli, while in sustained attention, people must maintain attention over time [23]. To achieve successful performance, athletes need to know how and when to pay attention to information. This is what is required in many sports [24]. Studies have shown that cognitive characteristics can be effective in the occurrence of sports injuries [13, 17].

Olsen, Myklebust, Engebretsen, and Bahr (2004) used video analysis of the Anterior Cruciate Ligament (ACL) injury scene and found that the athletes' attention got distracted from performance to the opponent and other goals at the time of injury [25]. Swanick et al. (2007) reported that people with non-contact ACL injury got a lower score in neurocognitive parameters such as processing speed and visual-verbal memory. They suggested that poor neurocognitive function may be a risk factor for anterior cruciate ligament injury [20].

Wilkerson (2012) reported that the reaction time as a processing speed may be an indicator of an increased risk of lower extremity sprains and strains among football players [17]. Besides, Shibata et al. (2018) compared the biomechanical characteristics of landing in two groups of athletes with a high and low level of neurocognitive functions. Their results showed that people with lower neurocognitive functions were more at risk of ACL injury due to dysfunctional muscular activity around the knee [14]. Hesami et al. (2020) indicated that along with physical factors, cognitive functions play a significant role in injury rate prediction in volleyball players [13].

Considering the relationship between the landing skill pattern and the probability of lower limb injuries as well as the relationship between cognitive functions and sports injuries incidence, the present study sought to investigate the relationship between sustained attention as a cognitive function and landing error as a predictor of lower limb injuries in basketball players. For this purpose, in the first assumption, changes in landing error are investigated as a result of increasing the cognitive load of the task to determine whether the probability of injury rises with increasing the processing needs of the task. After that, we investigate whether athletes' sustained attention ability can predict changes in landing error.

2. Materials and Methods

A correlational and cross-sectional research design was employed in this study. All performed procedures were in accordance with the ethical standards of the Research Committee of Allameh Tabataba'i University. A total of 44 female basketball players aged 18 to 25 years at the national league level participated in this study voluntarily. The participants were selected based on the inclusion criteria: being right-handedness, participating in the national league and lacking a history of sports injury occurrence in the last six months. On the first day, the participants' demographic and personal health information was obtained. After giving initial instruction about the study, informed written consent was obtained from all participants. The participants were assessed by a sustained attention test and LESS.

Sustained attention assessment

Sustained attention was evaluated by the Continuous Performance Test (CPT) [26]. There were 200 stimulants divided into two types; the first type was the stimulus that participants had to respond to by pressing the space key on the computer keyboard. Failing to respond was considered as an omission error. However, the participants were exposed to stimuli that should have been ignored. Responses to this category of stimuli were recorded as a commission error. The stimulus arrangement was random, and people were unaware of the order of the stimuli. The components consisted of the reaction time in correct responses (the speed of information processing), the standard deviation of reaction time (response variability), the omission error (inattention), and the commission error (response inhibition).

Landing error scoring system

The Landing Error Scoring System (LESS) is a practical tool that evaluates landing technique errors in a wide range of visible items during movement. This scoring system is a clinical assessment used to identify inappropriate patterns during post-jump landings. This scoring is done by the evaluation of the recorded video images of the two frontal and sagittal views of the person's jumping and landing [27]. The test is performed by participants jumping from a 30-cm platform and landing in front of the platform at a distance of approximately 50% of their height. Then, they immediately make a maximum vertical jump. The participants were instructed to jump as high as possible immediately after landing. No feedback was provided during the test unless people performed the task incorrectly.

After instruction, each participant performed two practice trials and then three test trials. If during landing, the person had not reached the specified horizontal distance or had not made the maximum vertical jump after landing, that trial would have been removed and repeated. Two video cameras were placed at a distance of 4.8 and 4 m, respectively, to capture images of people landing and jumping from the frontal and sagittal views. The LESS consisted of 17 scored items. By reviewing a recorded video in the first 15 items, the correct movement pattern was given a 0 and the wrong pattern 1 score, but items 16 and 17 had a different scoring system. The final score for each landing was calculated by the sum of the scores of all items. LESS is a valid and reliable tool that uses patterns for an overall assessment of landing mechanics and higher LESS scores (higher error) indicate risky landing techniques [27]. Studies have shown that a higher score is associated with a higher potential of lower limb sports injuries [28]. The researchers have confirmed the validity of LESS compared to the three-dimensional motion analysis system [29] and have also mentioned its predictive ability to identify people at risk of injury [11].

Study procedure

At the first stage, the participants were informed about the test process but they were not aware of the purpose of the study. After instruction about the test process, the participants performed computerized CPT to evaluate sustained attention. To perform this test, the person must come into a separate room in the lab individually. This room has a quiet environment without disturbing factors. Also, for test completion, the participants had to be in a suitable state without uncomfortable feelings such as drowsiness and fatigue. In the second stage, the subjects performed the landing-jumping test with two different cognitive loads. At the first task, landing-jumping was performed without a cognitive task, while, in the trials with cognitive load, the secondary task was used with a digits span backward paradigm [30].

In these trials, the participant stood on the jumping board and before jumping, the examiner gave them five random numbers. The numbers were expressed from a list prepared in advance and randomly combined. The subjects had to make their landing immediately after the last number. After completing landing-jumping, the participants had to express these numbers in reverse order or from the end to the beginning. The examiner recorded the accuracy of responses. Then, the examiner watched the landing-jumping videos to calculate the landing error score. To bias prevention, the examiner was unaware of which videos belonged to which cognitive load trails. Hence, both participants and the examiner were blinded.

To investigate differences in landing error scores in two conditions with high and low cognitive load, the paired t-test was used. Besides, the Pearson correlation and regression tests were used to investigate the relationship between attention and landing error scores in different conditions. All data were analyzed in SPPS V. 20.

3. Results

Based on the demographic information of the participants, the means and standard deviations of weight, height, and body mass index were 63.04±6.38 kg, 168±6.21 cm, and 20.84±1.72 kg/m², respectively. Table 1 presents the mean and standard deviation of the test scores in different conditions. Comparing landing error scores in low cognitive load condition with high cognitive load using the paired t-test, we found that landing error increased significantly due to increased cognitive load (t_{43}=9.03, P=0.0001).

The correlation test findings between sustained attention subtests with landing error scores during the landing-jumping with low cognitive load revealed a significant relationship between omission error and landing error score of basketball players (r=0.62, P=0.0001). Accordingly, with an increase in the omission error, the players' landing error also increased. In addition, there was a significant relationship between commission error and landing error score (r=0.37, P=0.012). The reaction time results showed no significant relationship between this component and the landing error score of basketball players (r=0.098, P=0.52). Also, there was no significant relationship between reaction time variability and landing error score (r=0.18, P=0.23). Then, the mentioned cognitive components entered the regression test to predict the error score of landing. The results showed that the regression model is significant in predicting landing error ($F_{1,43}$=6.74, P=0.0001, R^2adj=0.34). The CPT subtests revealed that only omission error could significantly estimate the landing error variance (P<0.01) (Table 2).

On the other hand, the association between CPT subtests' components and landing error scores in high cognitive load conditions showed significant correlations between landing error score, omission error (r=0.70, P=0.0001), and commission error (r=0.49 , P=0.001). However, no significant relationship was found between landing error score with reaction time (r=0.03, P=0.83) and reaction time variability (r=0.17, P=0.24). Also, the results of regression revealed a similar pattern with low cognitive load conditions. Accordingly, the regression model was significant in predicting the landing error score ($F_{1,43}$=12.18, P=0.0001, R^2adj=0.5). Also, among the CPT subtests' components, only omission error could significantly estimate the variance of landing error score in high cognitive load condition (P<0.01). The regression components of these variables are presented in Table 3.

4. Discussion

The present study was set to investigate the relationship between sustained attention and mechanical factors associated with lower limb injuries during landing. For this purpose, LESS calculated based on the joints angles during landing was considered as mechanical mechanisms

Table 1. The Means±SD of the tests scores in different conditions

Components Statistics	Omission Errors (Frequency)	Commission Errors (Frequency)	Reaction Time (ms)	Reaction Time Variability (Millisecond)	Landing Error Score, Baseline (Points)	Landing Error Score High Cognitive Load (Points)
Mean±SD	3.91±2.87	0.95±0.93	404.34±52.97	88.95±12.31	2.7±1.42	4.47±2.02

JMR

Table 2. Regression components of CPT in predicting landing error score in low cognitive load condition

Model	Unstandardized Coefficients			t	Sig.
	Standard Error	B	Beta		
Constant	1.75	2.92	-	1.67	0.1
Omission error	0.08	0.36	0.7	4.13	0.0001
Commission error	0.29	-0.01	-0.007	-0.03	0.97
Reaction time	0.004	0.0001	-0.004	-0.033	0.97
Reaction time variability	0.02	-0.01	-0.15	-0.89	0.38

JMR

Table 3. Regression components of CPT in predicting landing error score in high cognitive load condition

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	Standard Error	B	Beta		
Constant	2.15	6.94	-	3.22	0.003
Omission error	0.1	0.53	0.73	4.95	0.0001
Commission error	0.36	0.038	0.18	1.04	0.3
Reaction time	0.004	-0.003	-0.068	-0.58	0.56
Reaction time variability	0.024	-0.043	-0.26	-1.76	0.086

JMR

of lower limb injuries, and CPT was examined as neurocognitive function. The reason for using sustained attention as a neurocognitive function was research findings which showed that attention could predict the occurrence of sports injuries in athletes during competitions [13].

On the other hand, the reason for using LESS was the results of research that showed that this system may identify people who are at risk for lower limb injuries [11, 28]. Since research has shown that the quality of a person's landing indicates how much he or she is at risk of lower limb injuries during landing, the landing error pattern was examined in two conditions with high and low cognitive load. As expected, the results showed that people's landing errors increased significantly as a result of higher cognitive needs. Accordingly, increasing the cognitive load of sports tasks seems to increase the likelihood of sports injuries. In this regard, people with higher cognitive ability can control their minds, allocate more capacity of their mental capacity to motor performance, which reduces the risk of injury. Therefore, one of the approaches that can reduce the cognitive load of sports performance is to increase the skill level and bring people to the stage of automation [31].

Although this solution seems logical, usually athletes with different levels of competition reach the automatic stage and during the game, they pay attention to strategies, information about the opponents and teammates, the position of the ball, the spectators, anxiety and worry, and decisions that have to be made. Therefore, the cognitive or memory load can increase, and athletes with a high level of attention can reduce the cognitive load by optimizing their attention to the relevant stimuli [32]. To test this hypothesis, the relationship between sustained attention and landing error score was examined. The results showed a positive correlation between omission and commission errors with landing error scores in both low and high cognitive load conditions. In other words, with omission and commission errors, the amount of landing error increased in both conditions. This relationship is important in the case of sports injuries, as the landing error score is considered a component related to the occurrence of injury [11, 27].

Padua et al. (2015) proved a significant relationship between the landing error score as a mechanical-functional component and lower extremities injuries, so LESS is a tool for screening ACL injury [28]. The most important finding of them was that young elite athletes with higher landing error scores were at higher risk of non-contact ACL injuries than those with lower scores [28]. Accordingly, the quality of movement was also a biomechanical risk factor predicting non-contact injuries of the ACL. Interestingly, this relationship was observed in both conditions with low and high-cognitive load, so landing errors could be estimated by sustained attention regardless of the task cognitive load. However, as the cognitive load increased during landing, this relationship became stronger (which was expected).

Accordingly, in the low cognitive load condition, 34% of landing error variance changes were estimated from cognitive components, while in the high cognitive load condition, 50% of landing error variance was predictable. On the other hand, although in the components of performance accuracy in the CPT-test, a significant relationship was observed with the landing error score, in the components of performance speed such as the reaction time and its variability, this relationship was not observed. However, the reaction time seemed to be an important component in explaining motor performance, and previous studies have shown that this component, as a neurocognitive component, is associated with sports injuries [17, 20].

In this regard, Williams and Anderson (1997) showed that the rate of injuries in athletes is related to limitations in visual attention in conditions of stress and negative events [33]. Olsen et al. (2004) found that at the time of ACL injury, athletes focused on the irrelevant stimuli that distracted their attention from performance [25]; as a result, attention is a key factor in injuries occurrence. Hence, athletes with poorer attention may perform movements such as sudden changes in the landing point or unexpected movements that predispose them to injury. The present findings are consistent with the findings in which cognitive components and the occurrence of sports injuries were correlated [14, 17, 20].

However, there was a slight difference in detail. For example, the study of Swanik et al. (2007) emphasized the history of injury and found that processing speed was lower in people with a history of non-contact ACL injury [20]. Also, the findings of Wilkerson (2012) emphasized the frequency of injury, while the present study emphasized the functional and mechanical components associated with injury [17]. Shibata et al. (2018) showed that people with lower neurocognitive ability had more muscle activity in the quadriceps muscle than the hamstring muscle when landing unexpectedly; this muscle activity pattern enhances the load on ACL and consequently increases the risk of ACL injury [14].

On the other hand, Wilkerson (2012) showed that this relationship was observed in reaction time [17], but the present study demonstrated that important components of decision accuracy such as omission and commission errors could play a more important role in predicting injury. Based on the literature, omission error is considered a component of inattention, and commission error a response inhibition [34]. In this regard, people with a higher cognitive function in general and sustained attention, in particular, may have lower landing error scores, and consequently, they are less at risk of injury. Researchers have found that long-term stress in athletes can alter the function of neural networks in the brain that are linked to attention, and this decrease in attentional capacity may increase the risk of injury [35].

The previous study also showed an association between omission and commission errors and the rate of sports injuries during competition season in volleyball players. Accordingly, the volleyball players with lower omission and commission errors at the beginning of the competition season suffered less sports injuries during the competitions [13].

Based on the current findings, although a significant correlation was observed between sustained attention and landing error score, only a part of the variance of landing error changes was predicted by this component, and the remainder was estimated by other factors. Also, given the wide range of cognitive functions, further research is needed in this field to examine the role of other components. Besides, considering the completely different nature of different sports, it seems necessary to conduct such research in different sports and different expertise levels. On the other hand, the difference between the landing patterns in the real competition condition and experimental trials can be considered as one of the limitations of this study.

Moreover, based on the current findings, future research should address the question of whether sports injuries occurrence can be reduced by enhancing cognitive functions through common interventions such as brain stimulation or cognitive training. Accordingly, it is recommended that multiple cognitive and physical assessments be used to identify athletes at risk of injury. Hence, it seems that cognitive enhancement protocols may be effective along with the physical preparation program.

5. Conclusion

In general, sustained attention, i.e., the ability to maintain attention over time, could predict the landing error score. Considering the role of landing errors in the occurrence of lower limb sports injuries, especially in sports such as basketball, sustained attention may be a key factor in predicting sports injuries. Therefore, people with different levels of attention can be expected to be exposed to a different probability of injury occurrence.

Ethical Considerations

Compliance with ethical guidelines

All performed procedures were in accordance with the ethical standards of the Allameh Tabataba'i University Research Committee. All ethical principles are considered in this article. The participants were informed about the purpose of the research and its implementation stages; they were also assured about the confidentiality of their information; moreover, they were free to leave the study whenever they wished, and if desired, the research results would be available to them.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors contributions

All authors contributed in preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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