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Evaluating the Effects of Match-Induced Fatigue on Landing Ability; the Case of the Basketball Game

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ABSTRACT

International Journal of Exercise Science 14(6): 768-778, 2021. This paper examines the effect of match–induced fatigue on lower limb biomechanics, in the case of a basketball game. For this purpose, sixteen male basketball athletes, ages 18 to 22, performed a jump-landing task prior and post a recreational basketball game. The Landing Error Scoring System (LESS) was used to examine the biomechanics of landing. The Vertical jump (VJ) and the Borg Rating of Perceived Exertion (RPE) scale pre- and post-game were employed to assess the level of fatigue induced by the basketball game. In order to compare pre and post measurements, t-tests for dependent samples were used. The performance of the VJ test post-game was found to be significantly lower (t (15) = 3.83, p = 0.002) showing a large effect (Cohen's d = 0.9) compared to pre-game measurements. Further, the LESS scores were significantly (t (15) = 2.33, p = 0.034) higher post-game with a medium effect (d = 0.5). The differences in LESS scores were due to errors in the landing technique which is bound to be influenced by biomechanics. Moreover, the Borg RPE scale was found to be significantly higher (t (15) = 10.77, p < 0.001) post-game showing a very large effect (d =2.6). It is important to note, that these significant differences occurred with a merely medium level of fatigue (6.6 ± 0.3 pre-game vs 11.9 ± 1.0 post-game). The results of this study would be of great benefit to sports science teams and coaches for formulating effective strategies to improve athletes' performance and reduce the likelihood of injury.

KEY WORDS: Landing Error Scoring System, anterior cruciate ligament, risk factors, prevention, lower limb

INTRODUCTION

During a sports game, athletes are exposed to fatigue that may have a significant effect on their ability to perform well (20). Further, fatigue might increase the likelihood of getting injured (38). Thus, it is crucial to evaluate the impact of fatigue on the athletes' performance, during a sports game. This would be highly important for sports injury science teams and team coaches to formulate plausible strategies for team efficacy as well as reducing the possibility of an injury.

Even though the topic of fatigue is well represented in the sports science literature, only few studies have examined the impact of a real match game on the athletes' performance. Especially, a field study for the case of a basketball game has not been carried out before.

Basketball is a sport characterized by intermittent, high-intensity exercise. The sport imposes a highly variable load on athletes (24), when engaging in common tasks such as jumping, sprinting, and changing directions (20). Note that the number of injuries in basketball is among the highest compared to other sports. It ranges from 7 to 10 per 1000 athlete-exposures (A-E), either during training or during a game (1, 17). The lower limb injuries happen most frequently, constituting almost 60% of all injuries (17). From these lower limb injuries, the ankle sprain, knee injuries, and muscle strain injuries are frequently observed (17).

Neuromuscular fatigue is a modifiable factor that may affect the lower limb injury risk (4, 38, 39). Fatigue is caused by exercise, produces a reduction of muscle power (18), and is divided into peripheral and central (6, 21). Regarding the physiological mechanism, central fatigue occurs in the nervous system before the neuromuscular junction. Peripheral fatigue occurs, mainly, in the metabolic mechanisms after the neuromuscular junction (6, 21). These mechanisms harm the ability of muscles to generate proper function and cause alterations in neuromuscular control (16).

A wide variation of fatigue protocols have been used in previous studies. Peripheral fatigue protocols target a specific muscle and are short in duration (4, 26). On the other hand, central fatigue protocols target both the motor control and the cardiovascular system. They are long in duration and consist of agility drills that simulate more realistic sports situations, such as running on a treadmill, and jumping (4, 6, 39).

Several studies have incorporated functional tasks using fatigue protocols, with conflicting results on biomechanics of function. Note that there are significant methodological differences among the studies. In a study that used a 14-minute functional fatigue protocol, the volunteers exhibited poor landing technique after the fatigue protocol, as revealed with the Landing Error Scoring System (LESS) (39). The protocol consists of exercises such as step-ups/step-downs, squat jumps, plyometric bounding task, sprinting and pivoting (39). A study employing such a protocol (27) found an increased knee valgus angle and increased internal rotation during landing.

In the case of investigating fatigue for the basketball sport, there are specific protocols that may be employed. These include the Basketball Specific Fatigue Protocol (BSFT) and the Basketball Exercise Simulation Test (BEST). It has been reported that these protocols mimic the basketball game demands to some degree (24, 34). These types of protocols consist of intermittent exercises that use a combination of running, jumping, changing directions, jogging, and recovery, in the same duration as a basketball game (34). A study using the BEST protocol observed a decline in quadriceps muscle strength that had a significant impact on jumping and sprinting performance (34). Also, applying an intermittent exercise protocol that simulates the demands of a 90-minute football game negatively altered the athletes' landing biomechanics (35, 37).

Clearly, looking at the sports science literature we can find reliable protocols for faithfully simulating sports specific tasks. However, most studies apply the protocols in artificial laboratory conditions, which differ to a high degree from the conditions of a real game. It would be therefore interesting to carry out a field study by applying Borg Rating of Perceived Exertion scale (RPE), LESS and vertical jump in a training basketball game.

To our knowledge, no previous study has yet examined the effect of fatigue on lower limb biomechanics after a real training basketball game. This study aims at evaluating this effect of a real training basketball match-induced fatigue. We hypothesize that after the basketball game, the biomechanics of landing would be negatively affected. Further, our thesis is that fatigue it would expose athletes at higher risk of lower limb injury.

METHODS

Participants

A power analysis test was performed with G*POWER 3.1.9.2 (University of Dusseldorf, Germany) (19) and determined that 16 participants were needed for a power of 0.80 with an effect size of 0.75 and an $\alpha = 0.05$. Sixteen ($n = 16$) healthy men basketball players ages 18 to 22 took part in this study. The participants were all students of the Department of Physical Education and Sport Science, University of Thessaly Greece. All participants were recreational athletes that participated in 3 to 6 days of basketball training sessions per week. The individual characteristics of the participants are presented in Table 1, showing descriptive statistics of their age, mass, height, Body Mass Index and Training Sessions/Week.

Table 1. Participant's characteristics

n = 16	Minimum	Maximum	Mean	SD
Age (yrs)	18	22	20.2	1.2
mass (kg)	58.2	109.9	77.8	11.0
Height (m)	1.74	1.91	1.82	0.1
BMI (kg/m2)	17.4	30.4	23.5	2.7
TS/W	3	6	4.1	0.9

Abbreviations: BMI- Body Mass Index; TS/W- Training Sessions/Week

In order to reduce the risk of bias, participants were excluded from the study if they had an injury or surgery in the past six months or a serious cardiovascular, respiratory, or neurological disorder. Half of the participants had a previous (more than six months before) injury, such as an ankle sprain ($n = 6$), a meniscus tear with no surgical consideration ($n = 2$), plantar fasciitis ($n = 1$). None of the participants had an ACL injury or had any previous surgery on lower limbs. The study was approved by the Ethics Committee of the Department of Physical Education and Sport Science, of the University of Thessaly with protocol number 1227 and number of decision 2-5/5-4-2017. Additionally, the study conformed to the directive of the Helsinki Declaration. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (28).

Protocol
The study was carried out in the university gymnasium. At first, participants were informed about the study, read, and signed, the consent form approved by the Ethics Committee. Next, the participants completed a questionnaire concerning demographics, physical activity levels, history of injury. Afterwards, the participants' height was measured via the Seca Stadiometer 208 (Seca, Hamburg, Germany), and the weight via the Seca Beam Balance 710. In both measurements the participants were standing on the apparatus with their shoes off.

To ensure that any fatigue from other activities is minimized, the participants were instructed not to take part in any physical activity the previous day. Moreover, the Borg RPE scale was used to record the level of fatigue before the beginning of the study. Subsequently, after ten minutes of warm-up, the participants performed the tests of the Vertical Jump (VJ) and the test of the landing task. Following the pre-game measurements, the athletes played a real training basketball game. The game had a typical duration of four 10-minute periods and despite been a training game it had a competitive pace. Teams had three substitute players, who were entered in the game cyclically so that all the participants had the same playing time. During the game control was exercised on participants regarding food and fluids intake by allowing athletes only to drink water.

At the end of the game, participants were tested for a second time (post-game) on their subjective sense of exertion via the Borg RPE scale (10). Additionally, directly they were tested on the vertical jump and the jump-landing task for a second time (post-game). To reduce the risk of bias the various tests were carried out immediately after the game, so that we avoid changes in the levels of fatigue due to elapsed time. Further, the athletes were divided in two groups of 8, so that each group was tested on jump-landing task and vertical jump respectively. This process was repeated vice versa. The elapsed time due to the sequential nature of the process presents a limitation which is further discussed next. To reduce the introduction of bias we aimed at minimizing the elapsed time between tests.

Landing task: To assess the landing biomechanics, we used the Landing Error Scoring System (LESS) (31). Jump-landing is the most often activity tested, given that it is connected with lower limbs injuries (4, 31, 33). Laboratory studies, including 3D motion analysis, are the gold standard for this type of examination (13). However, a clinical assessment instrument such as LESS is used quite often for jump-landing activity (30, 31, 39). LESS is an inexpensive tool that can be used in a field study and provide the capability for assessing larger groups in less time (31). The aim is to identify a high-risk movement mechanism of the lower limbs and core. The LESS test is based on the recording of "errors" in the initial contact and maximum knee flexion during a jump-landing task (30). Previous studies have proven the validity and reliability of the LESS instrument (31), as well as the very good interrater reliability between expert and novice rater (29). The procedure includes a horizontal jump from a 30-cm box to a distance of 50% of the participant's height, followed by a maximum vertical jump (31).

Participants performed a 10-minute warm-up and then two trials of the test for familiarization. Three valid trials were recorded for the analysis. We did not give instructions about the proper technique of landing. However, we gave specific instructions regarding the valid execution of the test. The instructions given to the athletes were to jump forward but not vertically; to jump off the box with both their feet landing in front of the mark that we had placed on the ground; and to do a maximum vertical jump after landing without any stopping among landing and vertical jump (31). Two conventional video cameras 30-Hz (Panasonic HC – V 770 & Sony HDR – CX625) were placed in the front and right of the landing area on tripods to a height of 1.20 cm and distance of 3.45 cm, to record the frontal and sagittal plane of the participants, as it has been described before (31).

The videos from the jump-landing task were collected and analyzed later by the lead author via the free 2D movement analysis software (kinovea 0.8.26 experimental version). The landing technique was assessed via the LESS scoring form as it has been described in a previous study (30). The lead author of this paper assessed all the videos and completed the scoring form for all participants. The main attention during landing was given to the initial contact and the maximum knee flexion. The scoring form had seventeen scoring items, in which landing errors were noted. The items that were evaluated comprise of: the flexion angles of the knee; hip; trunk; the ankle plantar or dorsiflexion; the medial knee position; and the lateral trunk flexion; the stance width; the internal or external foot position; the symmetrical foot contact at initial contact; as well as the knee; hip; trunk; and medial knee position range of motion among initial contact and maximum knee flexion. Also, the scoring form includes one item that the rater scored about their overall impression of the angles' displacement between the initial contact and maximum knee flexion. Lastly, one item that the rater scored about the overall impression of landing (30). A lower score in LESS means a better landing technique. According to Padua *et al*. (31), the LESS score is divided into four categories: perfect landing technique ≤ 4, good landing technique > 4 to ≤ 5, moderate landing technique > 5 to ≤ 6, and poor landing technique > 6. The mean score of the three trials was used for the statistical analysis (30, 31).

Vertical jump (VJ): To measure the height of the VJ, we used the Bosco Ergojump system (Byomedic, S.C.P., Barcelona, Spain) (12). The participants were standing with their arms on their hips and, from the position of knee flexion 90^0, were performing maximum vertical jumps. Three trials were performed, and the higher jump was used for the analysis (12).

Borg Rating of Perceived Exertion (RPE) scale: We used the 20-points scale of Borg RPE to assess the subjective sense of fatigue on each individual (10). At the beginning of the study, individuals were informed about the proper use of the scale. The Borg RPE instrument was used prior to and post the game. The researchers showed to the individuals the scale and asked them to show the point that better reflected their sense of fatigue.

Statistical Analysis

At first, descriptive statistics analysis was performed. Next, a t-test for dependent samples was carried out, using the level of significance at $p < 0.05$. The evaluation of the effect prior to and post-game for the tested hypothesis was estimated using the Cohen's d method (9, 14). Changes in the Borg RPE, VJ, and LESS mean scores were calculated and compared prior to and post the basketball game. For the statistical analysis, the software package IBM SPSS Statistics 21.0 was used.

RESULTS

The results are presented in Table 2. The performance of VJ post-game was significantly lower (t (15) = 3.83, p = 0.002) than pre-game, with a large effect indicated by d = 0.9. Further, the fatigue level, as it was recorded by Borg RPE scale, was significantly higher (t (15) = 10.77, p < 0.001) post-game, with also a large effect d = 2.6. The scores of LESS were significantly higher (t (15) = 2.33, p = 0.034) post-game with a medium effect indicated by d = 0.5. it is important to note that we recorded more errors in the landing technique after the game. Table 2 shows also further information on measures on dispersion and the Confidence Interval (CI) at 95% level.

Table 2. Differences between pre and post the basketball match on Borg exertion rating scale, Vertical Jump and Landing Error Scoring System (LESS)

n = 16	PRE			POST				
	Mean	SD	CI (±)	Mean	SD	CI (±)	p -Value	Cohen's d
BRPE	6.6	0.7	0.3	11.9	1.9	1.0	< 0.001	2.6
VJ	36.7	4.2	2.2	34.6	4.1	2.1	0.002	0.9
LESS	7.1	1.3	0.7	7.7	1.4	0.7	0.034	0.5

Abbreviations: BRPE- Borg exertion rating scale; VJ- Vertical Jump; LESS-Landing Error Scoring System; CI-Confidence Interval

DISCUSSION

The aim of this study was to evaluate the effect of basketball match-induced fatigue on the athletes' efficacy via the clinical assessment tools of Borg RPE scale, VJ and LESS. For the purpose of the investigation a real simulation training basketball game has been employed. Findings showed that the participants landing abilities were significantly reduced after the game by making more errors on the LESS test. Mostly recorded were the reduced trunk flexion at initial contact, the reduced flexion displacement of the knee, hip, and trunk among initial contact and maximum knee flexion, and the narrow stance width. These changes indicate a tendency for a higher ACL risk pattern, as a stiffer landing has been linked with ACL injury (23).

Regarding the differences in LESS scores (prior and post-game) the effect is characterized as medium. The changes on Borg RPE and VJ scores (prior and post-game) were also significant showing a large effect. These changes point out the presence of fatigue post-game and the loss efficacy in the athletes. The perceived level of fatigue was medium but significantly caused negative changes in landing technique after the game.

Worsening of the landing ability is an essential factor that increases the risk of ACL injury (23, 36). The above results are consistent with previous studies that had observed a deterioration of landing ability after the effect of fatigue. This occur in spite of the fact that previous studies had employed various types of fatigue protocols (5, 33, 38). In a similar field study, but for the case of football match-induced fatigue, again we had negative effects in the landing ability (3). In contrast to the above studies, systematic reviews and metanalysis have concluded that fatigue does not produce changes in biomechanical factors that are involved in non-contact ACL injuries (4, 6, 13).

As a result, we may conclude that there is no stable effect of fatigue protocols on biomechanical variables that are responsible for ACL injuries (6). These variables include decreased hip and knee flexion angles, increased internal rotation of the hip, increased knee valgus, increased internal or external rotation of the tibia, increased activation of quadriceps along with decreased activation of hamstrings (2, 4, 8, 23). Additionally, some fatigue protocols have led to contradicting results concerning the exposure to ACL injury resulting from fatigue (13). Such contradicting results include greater peak angles in the knee and hip during landing and decreased landing forces compared with non-fatigued athletes (13). These discrepancies among studies call for continuation of research on this topic (4).

Participants in our study had poor to moderate landing ability indicated by their LESS scores. The scores ranged from 5 to 10 with a CI 7.1 ± 0.7 (pre-game). Post-game the scores slightly increased showing marginal poorer landing ability (range 6 to 11, CI 7.7 ± 0.7). We are uncertain what would happen if the participants had a good landing ability prior to the game. In other words, a better landing technique pre-game probably would have some effect on the LESS scores. For example, whereas we noticed a stiffer landing post-game, we did not notice changes on knee valgus angles in the frontal plane.

Previous studies had used peripheral and central fatigue protocols to assess the effect of fatigue on lower limb biomechanics. Several of them had tried to simulate the real impact of a match (34, 39). These studies had taken into consideration strong criteria to evaluate the magnitude of fatigue of participants. More specifically, they had considered as a crucial point the reduction of 5 cm of a maximum VJ in comparison with the pre-fatigue examination (39), or a decline of 10% or more in other studies (16, 22), usually in three consecutive attempts (16, 39).

The decline in the VJ in our study was lower compared to the above criteria. Post-intervention, we observed a decline in VJ smaller than 5 cm and at a percentage of 5.7%. Also, another criterion used in this study to evaluate the value of fatigue was the Borg RPE scale. Most studies considered as a criterion for fatigue a score of seventeen or more, which describes very hard to extremely hard exertion (5, 32, 40). In our study, the score in the Borg RPE scale post-game was lower, compared with the above criteria. Specifically, there was a large deviation among the participants. The range of scores (8 to 15) and the mean value of 11.9 indicate a low, to moderate fatigue level and only in some participants, high level. However, it has been reported that after professional football games the Borg RPE values were in the range between "high" and "very high" (15 to 17), which shows that players were not entirely exhausted (6). Also, evidence indicates that adaptations in the biomechanics of lower limbs can even be observed at a fatigue level of 50% (6, 11).

Fatigue protocols produce a higher level of fatigue than fatigue caused in a real game (4). Also, they set individualized criteria for each subject to complete the protocol. On the other hand, match-induced fatigue has only a specific duration (4). Although the level of fatigue post-intervention was low, this level managed to cause alterations on landing biomechanics. A previous study suggested that fatigue protocols may not reflect the fatigue associated with the specialized requirements of a sport (15). Real game demands promote physiological and psychological responses, which when they interact with other factors, can lead to an increase of injuries as the game progresses (15). The cause of fatigue is multifactorial and is dependent on different factors such as psychological, physiological, and stress-recovery imbalances (6). The reported fatigue protocols may be too simplistic to be capable of capturing the multifactorial nature of fatigue (6).

This study has various limitations that are important to mention. First, the basketball game was not an official match but a training-simulation basketball game. This probably had an impact on the level of fatigue which was indicated by the low Borg RPE scores post-game. These low scores might be due to fact that players may not have put themselves at the highest competitive level. Also, the changes in the vertical jump and Borg RPE scale post-game point out that the fatigue level was not high enough. Additionally, in our study, the fatigue protocol had a specific duration, which was the same as a regular basketball game. In other studies, participants continue with the fatigue protocol until they reach specific criteria, as mentioned above. Considering only the duration as a factor for fatigue can be problematic because the different characteristics of participants are not taken into account. Further, participant’s differences in cardiovascular, respiratory endurance, musculoskeletal strength and endurance, may explain the deviation in the Borg RPE scores (4, 41). Likewise, the variation in training per week among the participants is worth noting. Many participants did three training sessions per week, while others did more regularly, until six sessions per week.

Despite the limitations reported above, this paper fills the gap in the contemporary sports science literature by applying match-induced fatigue protocols in the case of a real simulated basketball game. A simulation game provides the ability of recording various athletes’ parameters such as participation time, how many jumps they performed in the match and various physiological parameters in a more realistic situation.

In summary, after the basketball game, participants had higher LESS scores which indicates a poorer landing technique. These findings can be used by sports science teams, coaches, and players in order to formulate effective strategies for the reduction of the likelihood for an injury. The results of this study suggest the importance of prevention procedures so that the landing ability of basketball athletes to be improved.

Further, our findings can be used by coaches to consider plausible tactics for the reduction of the fatigue effect on the athletes’ performance. Specifically, this is important during a tournament that includes consecutive games. Looking at the results of this study it seems that the produced fatigue level appears to have different outcomes compared to that produced by fatigue protocols that attempt to simulate the impact of a real match. The complexity involved in a real game situation is clearly very hard to capture. Thus, the approach of match-induced fatigue taken in this paper improves the validity of the results.

The high complexity of a real game is also noteworthy in sports injuries which have a multifactorial nature, and one factor alone is only one piece of the total picture (7). Fatigue is not the main factor, but it is one that could affect the risk of lower limb injury. Consequently, future studies are required to determine the effect of fatigue on the neuromuscular characteristics of lower limbs. This will help to enrich the lower limb injury prevention programs with more effective strategies. Also, it would be beneficial to integrate components coping with fatigue in the injury prevention programs. These programs should consider the multifactorial nature of fatigue, which include factors such as psychological, physiological, and stress-recovery imbalances (6). This calls for a new holistic approach to analyzing the effect of fatigue on the athletes' efficacy that may be facilitated by systems thinking and Systems Dynamics method (7, 25).

Further, it would be interesting if future studies examine the changes in the biomechanics of lower limbs during the match at different time periods. In addition, future studies should consider the impact of the different characteristics of each subject concerning cardiovascular endurance, muscle strength and endurance on fatigue. Ultimately, applying fatigue protocols in an official basketball competitive match would be an interesting future study.

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