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Original Research

The Effect of a Fatigue Program on the Kinematics of Lower Limb Joints in Basketball Players with Dynamic Knee Valgus Pattern in Various Positions

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ABSTRACT

The beginning of metabolic exhaustion may have an impact on the knee joint's dynamic stability when playing sports, which could raise the risk of knee injury. The present study aimed to examine the effect of a fatigue program on the kinematics of lower limb joints in basketball players with a dynamic knee valgus pattern in various positions. In this study, 27 basketball players with dynamic knee valgus patterns were purposefully selected and divided into three groups: guard (mean age= 19.77±2.68 years, mean height= 177±4 cm, and mean weight= 63.40±5.10 kg), forwards (mean age= 20.22±2.90 years, mean height= 187±4 cm, and mean weight= 76.80± 2.94 kg) and centers (mean age= 22.33±3.27 years, mean height= 199±4 cm, and mean weight= 98.84±18.42 kg), within the age range of 16 to 26 years. To evaluate the angles of the lower limb in the sagittal and frontal planes, we used two digital cameras. We placed them at a distance of 366 centimeters and a height of 105 centimeters relative to the subject. The subjects performed three counter-movement jumps. We conducted the analysis using KINOVEA software. In this study, the fatigue protocol consisted of 40 minutes of basketball play, carried out legally and considering all rest periods. To compare the means of the research variables, we used mixed analysis of variance (2*3), one-way analysis of variance, and Bonferroni post hoc tests. We conducted all hypothesis tests at a significance level of 0.05 or less. The results showed that the application of the fatigue protocol during landing in the sagittal plane led to a significant decrease in the maximum knee flexion angle in the guard group (p= 0.035), initial ankle contact in the forward group (p= 0.044), initial ankle contact in the center group (p= 0.016), and maximum ankle plantar flexion in the center group (p= 0.018). In the frontal plane, the fatigue protocol also caused an increase in maximum knee valgus in the dominant leg of the center group (p= 0.039) and in the non-dominant leg of all three groups: guard (p= 0.019), forward (p= 0.002), and center (p= 0.009). Between-group comparison, there was a significant difference in initial hip joint contact between the guard and forward groups (p= 0.031) and maximum knee valgus of the dominant leg between the forward and center groups (p= 0.041). From alternative perspectives, researchers did not find any appreciable variations, though. The functional exhaustion employed in this study impacted a few factors related to the patient's lower limb joints, according to the study's findings. The valgus angle of the non-dominant leg increased in all three groups, and the valgus angle of the dominant leg increased in the center group in the frontal plane. Guards and forwards frequently perform the lay-up movement during the game, which could contribute to this. In a lay-up, the last foot to leave the ground is the player's non-dominant foot, which places more stress on it. On the other hand, center players often perform jumps and landings with both feet under the hoop in the paint area for rebounds, which could increase the valgus angle in both legs.

Keywords: Dynamic knee valgus, Kinematics, Fatigue, Basketball.

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INTRODUCTION

Femoral adduction and internal rotation, combined with tibial abduction and external rotation, result in dynamic knee valgus during jump or squat landings [1]. Dynamic knee valgus motion is, therefore, frequently considered a significant risk factor for acute knee injury. According to reports, there is a link between increased motion in dynamic knee valgus during dynamic activities (which can result in medial collapse during functional activities such as landing, running, and so on) and increased lower limb injuries, resulting in excessive stress on the knee joint or hip joint. [2] The prevalence of anterior cruciate ligament injuries in basketball is higher than in other sports disciplines because of the frequent observation of these mechanisms in sports like basketball [3]. Abnormal neuromuscular performance in the lower limbs can increase knee valgus [4, 5]. In other words, neuromuscular performance deficiencies are a significant factor in non-contact ACL injuries among athletes, elevating the load on the lower limb joints and increasing the risk of anterior cruciate ligament injury during sports activities [6]. Various factors contribute to destabilizing knee stability and causing injuries, with fatigue being a factor that plays a role environmentally and centrally in injury occurrence [7]. The onset of metabolic fatigue may influence dynamic joint stability during sports participation, increasing the risk of knee injuries [8]. Additionally, there is evidence indicating a higher prevalence of injuries towards the end of competitions, highlighting the association between fatigue and injuries [9]. Thus, it’s critical to evaluate how weariness affects an athlete’s performance during a sporting event. Although the literature on sports science has extensively documented the effects of exhaustion, there isn’t much research that explicitly looks into how real-game fatigue affects an athlete’s performance. Basketball is a sport where workouts are high-intensity and sporadic. Athletes undergo a significantly varied load when doing everyday tasks, including jumping, running, and changing direction [10]. Nearly 60% of basketball-related injuries are to the lower limbs [11]. One variable that can be changed to affect the likelihood of lower limb injuries potentially is neuromuscular fatigue [12–14]. Researchers classify exercise-induced fatigue into two types: [15] peripheral and central fatigue, which both decrease muscle strength [1٧, 1٦]. When considering the physiological process, peripheral weariness mainly, arises in metabolic systems following neuromuscular connection, whereas central exhaustion develops in the neurological system before neuromuscular connection [16, 17]. These pathways lead to changes in neuromuscular regulation and impair the muscles' capacity to produce their best work [18]. Numerous other fatigue procedures have been used in earlier research. Protocols for mitigating environmental fatigue focus on particular muscles and have a brief duration [12, 19]. On the other hand, central fatigue procedures seek to induce exhaustion in the cardiovascular and motor control systems. They last longer and include agility drills that mimic more authentic sports postures, like running and leaping on a treadmill [12, 14, 16]. Particular procedures can be used for basketball fatigue assessment, such as basketball-specific fatigue protocols and basketball training simulation tests. These protocols have been reported to mimic basketball game demands to some extent [10, 20]. Such protocols involve interval exercises combining elements like running, jumping, change of direction, sprinting, and recovery within the time frame of a basketball game [20]. A study using a basketball training simulation protocol observed reduced quadriceps muscle strength, significantly impacting jump performance and sprint speed [20]. Furthermore, athletes’ landing biomechanics were adversely affected by an interval training regimen that replicated the demands of a ninety-minute soccer match [21, 22].

Researchers can determine dependable techniques for mimicking particular sports tasks by looking through the sports science literature. Still, the majority of research uses artificial laboratory conditions for their protocols, which are very different from what happens in a real game. Therefore, conducting a field study in a practice basketball game would be interesting. According to the researchers’ knowledge, few studies have examined the effect of fatigue on lower limb biomechanics after an actual practice basketball game. Since basketball includes different playing positions, which differ in anthropometric characteristics, performance, and roles during the game, the extent of lower limb joint injuries might also vary among them. Conversely, the impact of fatigue on the kinematics of lower limb joints has consistently been a topic of contention. Some studies have observed that fatigue either increases or decreases joint angles of the lower limb, while others have observed no change. The purpose of the current research is to look at how a fatigue program affects the lower limb joint kinematics of basketball players who exhibit dynamic knee valgus in various playing positions.

MATERIAL AND METHODS

The study population consisted of semi-professional male basketball players with dynamic knee valgus deficiencies in the age range of 16-26 in Kermanshah, Iran. In this study, 27 basketball players with dynamic knee valgus deficiencies were non-randomly purposively selected into three groups: guards, forwards, and centers. The sample size in the present study was determined using results from a previous study [23] and G Power software. Based on this, with a confidence level of 0.95 and a test power of 80%, the software determined a sample size of 27 participants. Considering the potential dropout of participants, we included three additional individuals in each group beyond the sample size calculated by the software. Before the commencement of the study, participants completed medical and sports information questionnaires, and a consent form was obtained. Additionally, the ethics code with the number IR.GUILAN.REC.1402.083 was obtained from the University of Guilan. Before the study, we conducted a briefing session to provide participants with sufficient information about the research and assure them of its safety. We selected participants who were male and within the age range of 16 to 26 years old and had dynamic knee valgus defects. They had engaged in basketball training for at least two years and three times a week. Those who had experienced injury or surgery, significant cardiovascular, respiratory, or neurological disorders in the past six months, or had structural valgus or varus were excluded from the study.

For determining the anthropometric characteristics of the participants, digital height measurement was performed using an in-body BSM 170 digital stadiometer (Japan), and weight was measured using a Xiaomi Mi-smart-Scale2 smart scale (China). Additionally, shoulder width, hip width, leg length, lateral epicondyle width, external and internal malleolus width, and the Q angle were measured using a tape measure, calipers (Mitutoyo, Japan), and a goniometer. Marker-based plug-in gait analysis, involving 20 markers for each individual, was also utilized for the lower limbs [24]. Reflex markers were placed on the lateral malleolus, posterior heel, between the first and second metatarsal joints, lateral side of the shin, external epicondyle of the knee, center of the patella, outer side of the thigh, greater trochanter of the thigh, anterior superior iliac spine, and posterior superior iliac spine on both sides. Participants were asked not to engage in any physical activity the day prior to minimize weariness from other activities. Before the trial, fatigue levels were also recorded using the Borg Rating of Perceived Exertion (RPE) scale. As an initial screening, the Tuck Jump Assessment was employed to diagnose dynamic knee valgus patterns. With their feet shoulder-width apart, the competitors began the Tuck Jump by launching themselves vertically and raising their knees as high as possible. The thighs should be parallel to the ground at the highest point of the jump. The athlete should start the subsequent tuck leap after landing. Ten seconds were allotted to this test [25]. Players eligible for the test had to pass their patella over the imaginary line extending from the great toe. Their angle of incidence should be more than 8 degrees [26]. After selecting eligible players, each of them prepared at the designated basketball facility at 5:00 PM with the coordination conducted. Two cameras were used to record the angles. The researchers put the cameras 366 cm away and 105 cm high. The cameras paralleled the subject’s transverse and sagittal planes [27]. The countermovement jump was the target task in this research. Then, researchers instructed the participants to stand in the designated area and perform three countermovement jumps [28]. The cameras (Nikon D300) recorded the averages of the three jumps. The KINOVEA software was then used to measure the angles of the hip, knee, and ankle joints. The fatigue protocol in this study included 40 minutes of basketball play [29]. During the game, the organizers controlled the participants’ food and fluid intake, allowing them only to drink water. At the end of the game, participants were assessed for mental fatigue using the Borg RPE scale for the second time (post-game) and all, rest periods during the game adhered to those in regular gameplay. After the match, immediately to reduce the fatigue effect, the participant performed three counter-movement jumps again to measure the knee angles. A digital camera recorded the angles and analyzed them using KINOVEA software.

Angles of hip flexion and extension in the sagittal plane were determined by identifying markers placed on the anterior superior iliac spine, greater trochanter of the hip, and mid-thigh (Figure 1). Knee flexion and extension angles on the sagittal plane were obtained using markers on the mid-thigh, lateral condyle of the knee, and mid-tibia (Figure 2). We assessed knee valgus and varus patterns in the frontal plane using markers on the anterior superior iliac spine, middle of the patella, and second metatarsal (Figure 3). To derive ankle dorsiflexion and plantar flexion angles, we identified markers on the mid-tibia, lateral malleolus, and second metatarsal using KINOVEA software (Figure 4) [30].

We selected the first frame from the start of the movement to examine the moment of initial contact and the deepest flexion of the hip, knee, and ankle joints during landing. Then, an angle was drawn using three points for the hip joint (anterior superior iliac spine, greater trochanter of the hip, and mid-thigh), knee joint (mid-thigh, lateral condyle of the knee, and mid-tibia), and ankle joint (mid-tibia, lateral malleolus, and second metatarsal). Subsequently, we chose the last frame during landing and drew an angle according to the figure. Finally, the joint angle at the initial contact (first frame of the push-off phase) was subtracted from the joint angle at landing (last frame of the landing phase at initial contact and maximum flexion) to obtain the initial contact and most profound flexion angles of the hip, knee, and ankle joints in the sagittal plane [31].

Similarly, we chose the first frame from the start of the movement to examine the moment of initial contact and the most profound flexion of the knee joint in the frontal plane during landing. Then, the researcher drew an angle using three points for the knee joint (anterior superior iliac spine, middle of the patella, and second metatarsal). After following the previous steps, we selected the last frame during landing and drew an angle according to the figure. Finally, the joint angle at the initial contact (first frame of the push-off phase) was subtracted from the joint angle at landing (last frame of the landing phase at initial contact and maximum flexion) to obtain the initial contact and most profound flexion angles of the knee joint in the frontal plane [31].

Fig.1. The angle of the thigh in the sagittal plane at the moment of landing

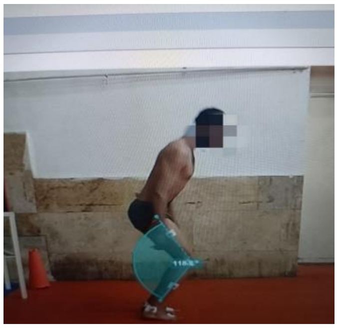

Fig.2. The knee angle in the sagittal plane at the moment of landing

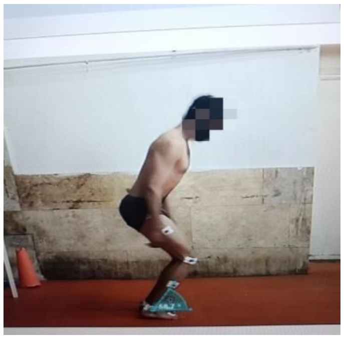

Fig.3. The ankle angle in the sagittal plane at the moment of landing

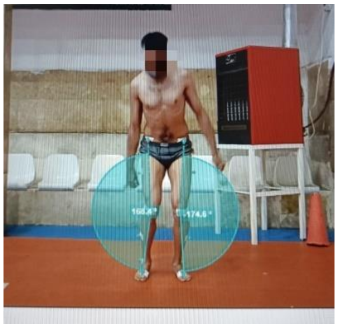

Fig.4. The knee angle in the frontal plane at the moment of landing

STATISTICAL ANALYSIS

For analyzing the obtained raw data from the study, descriptive and inferential statistics were utilized. Descriptive statistics, including the mean and standard deviation, were used to describe the demographic characteristics of the participants. The normality of the data distribution was assessed using the Shapiro-Wilk test. If the data followed a normal distribution, we employed a two-way ANOVA for each angle. Finally, we summarized the raw data from the study in Excel and analyzed it using SPSS version 23 (IBM Corp., Redmond, WA, USA). Please note that we set the significance level in this study at 95%, and the alpha level is less than or equal to 0.05.

RESULTS

The researchers have listed the mean and standard deviation of participants' demographic characteristics, including age, weight, height, body mass index (BMI), shoulder width, hip width, ASIS distance, knee condyle width, ankle width, lower limb length, Q angle, and Borg RPE, in Table 1.

Table 1. General Characteristics of Participants (Standard Deviation ± Mean)

Variables	Guard Group (9 individuals)	Forward Group (9 individuals)	Center Group (9 individuals)	**Significant Meaning ANOVA**
	Standard Deviation ± Mean	Standard Deviation ± Mean	Standard Deviation ± Mean	
Age (year)	۱۹.۷۷ ± ۲.۶۸	۲۰.۲۲ ± ۲.۹۰	۲۲.۳۳ ± ۳.۲۷	۰.۱۷۰
Weight (Kg)	۶۳.۴۰ ± ۵.۱۰	۷۶.۸۰ ± ۲.۹۴	۹۸.۸۴ ± ۱۸.۴۲	۰.۰۰۱*
Height (Cm)	177 ± 4	187 ± 4	199 ± 4	۰.۰۰۱*
Body Mass " Index (BMI) - Kilograms per "Square Meter	۲۰.۰۴ ± ۱.۳۸	۲۱.۸۲ ± ۱.۰۳	۲۴.۸۷ ± ۴.۲۰	۰.۰۰۳*
Shoulder Width (Cm)	۳۱.۰۰ ± ۲.۰۳	۳۲.۷۷ ± ۳.۷۰	۳۷.۶۶ ± ۲.۴۲	۰.۰۰۱*
Pelvic Width (Cm)	۲۷.۲۲ ± ۰.۶۶	۳۰.۱۶ ± ۱.۹۲	۳۲.۶۶ ± ۴.۲۷	۰.۰۰۱*
Distance ASIS (Cm)	۲۴.۸۸ ± ۱.۶۵	۲۵.۵۰ ± ۱.۱۴	۲۹.۴۴ ± ۳.۴۱	۰.۰۰۱*
Knee Condyle Width (Cm)	۸.۴۴ ± ۰.۵۲	۹.۰۰ ± ۱.۰۰	۹.۷۷ ± ۰.۶۶	۰.۰۰۴*
Ankle Width (Cm)	۶.۸۳ ± ۰.۴۳	۶.۷۷ ± ۰.۴۴	۷.۷۷ ± ۰.۵۶	۰.۰۰۱*
Lower Limb Length (Cm)	۸۹.۸۸ ± ۳.۹۱	۹۳.۶۶ ± ۳.۸۲	۹۹.۳۵ ± ۳.۷۱	۰.۰۰۱*

Q Angle (degrees)	۹.۲۷ ± ۰.۸۷	۹.۵۵ ± ۰.۷۲	۹.۳۳ ± ۰.۹۰	۰.۷۶۰
Borg RPE	0.78±7.88	۷.۸۸ ± ۰.۷۸	۷.۸۸ ± ۰.۷۸	۱.۰۰۰

*The researchers considered a significance level of 0.05 (p ≤ 0.05).

In this section, the general characteristics of the test subjects are separately presented in (Table 1). The test results indicated homogeneity in individual features, such as age, angle Q, and Borg scale, across the three groups, while homogeneity was not observed in other variables across the three groups.

The Inferential and descriptive statistics (mean, standard deviation, and confidence interval) related to the variables of initial contact hip, maximum hip Flexion, valgus initial contact dominant foot, valgus initial contact non-dominant foot, valgus maximum knee flexion dominant foot, valgus maximum knee flexion non-dominant foot, initial contact knee, maximum knee flexion, initial contact ankle dorsiflexion and maximum ankle dorsiflexion for each group in the pre-test and post-test are presented in (Table 2).

Table 2: Mean and Standard Deviation of Research Variables Separated by Each Group

Variables		**Guard Group (9 individuals)**	**Forward Group (9 individuals)**	**Center Group (9 individuals)**	**All Participants (27 individuals)**	
	Time	Standard Deviation ± Mean	Standard Deviation ± Mean	Standard Deviation ± Mean	Standard Deviation ± Mean	Significant Meaning ANOVA
Initial Contact hip (degrees)	Pre-test	۱۳.۴۰ ± ۷.۸۷	۱۲.۲۸ ± ۶.۷۶	۹.۶۴ ± ۷.۰۶	۱۱.۷۷ ± ۷.۱۴	۰.۵۳۷
	Post-test	۱۶.۸۱ ± ۷.۰۱	۸.۷۵ ± ۵.۹۷	۱۱.۷۱ ± ۵.۲۹	۱۲.۴۲ ± ۶.۸۰	۰.۰۳۲*
Maximum hip Flexion (degrees)	Pre-test	۴۴.۵۶ ± ۲۴.۰۴	۴۷.۸۷ ± ۱۶.۲۶	± ۱۱.۵۹ ۴۴.۱۳	۴۵.۵۲ ± ۱۷.۴۲	۰.۸۹۱
	Post-test	۴۴.۹۷ ± ۲۱.۹۶	۵۱.۲۳ ± ۱۴.۵۰	۴۹.۱ ± ۱۳.۴۴	۴۸.۴۰ ± ۱۶.۶۰	۰.۷۳۶
Valgus Initial Contact Dominant Foot (degrees)	Pre-test	۲.۴۸ ± ۱.۷۷	۱.۲۴ ± ۱.۳۰	۲.۷۵ ± ۰.۸۲	۲.۱۶ ± ۱.۴۶	۰.۰۵۹
	Post-test	۲.۸۴ ± ۰.۶۱	۱.۵۴ ± ۲.۸۲	۳.۳۴ ± ۰.۷۳	۲.۵۷ ± ۱.۸۲	۰.۱۳۱
Valgus Initial Contact Non-Dominant Foot (degrees)	Pre-test	۳.۰۶ ± ۰.۴۳	۲.۰۳ ± ۲.۸۹	۲.۰۷ ± ۴.۱۳	۲.۹۳ ± ۲.۸۴	۰.۴۹۰
	Post-test	۲.۵۰ ± ۰.۸۰	۰.۶۶ ± ۲/۰۹	۱.۵۹ ± ۱.۹۰	۱.۵۸ ± ۱.۸۰	۰.۰۹۲
Valgus Maximum Knee Flexion Dominant Foot (degrees)	Pre-test	۹.۵۱ ± ۵.۶۸	۹.۱۴ ± ۱.۷۶	۹.۷۳ ± ۲.۸۳	۹.۴۶ ± ۳.۶۶	۰.۸۷۲
	Post-test	۱۰.۹۶ ± ۴.۶۰	۷.۶۱ ± ۱.۵۱	۱۱.۷۱ ± ۲.۹۳	۱۰.۰۹ ± ۳.۶۲	۰.۰۰۶*
Valgus Maximum Knee Flexion Non-Dominant Foot (degrees)	Pre-test	۶.۶۴ ± ۴.۶۷	۶.۹۱ ± ۲.۹۵	۴.۹۱ ± ۴.۶۲	۶.۱۵ ± ۴.۰۹	۰.۵۵۲
	Post-test	۹.۰۴ ± ۶.۳۸	۴.۲۵ ± ۲.۲۳	۸.۴۲ ± ۳.۴۲	۷.۲۴ ± ۴.۷۳	۰.۰۵۹

Initial Contact knee (degrees)	Pre-test	۱۷.۴۵ ± ۸.۶۱	۱۳.۵۱ ± ۵.۹۰	۱۲.۵۳ ± ۴.۵۹	۱۴.۵۰ ± ۶.۶۹	۰.۲۶۴
	Post-test	۱۷.۵۴ ± ۷.۹۵	۱۷.۲۰ ± ۵.۷۶	۱۲.۲۱ ± ۳.۰۸	۱۵.۶۵ ± ۶.۲۲	۰.۰۵۶
Maximum knee Flexion **(degrees)**	Pre-test	۶۶.۶۰ ± ۱۰.۰۴	۶۰.۹۱ ± ۶.۳۸	۶۴.۶۵ ± ۶.۹۲	۶۴.۰۵ ± ۸.۰۰	۰.۳۲۱
	Post-test	۶۰.۹۱ ± ۸.۵۹	۶۲.۵۷ ± ۹.۵۹	۶۰.۸۰ ± ۸.۸۶	۶۱.۴۲ ± ۸.۷۱	۰.۸۹۷
Initial Contact Ankle Dorsiflexion (degrees)	Pre-test	۴۱.۸۴ ± ۵.۲۱	۴۵.۰۰ ± ۹.۳۴	± ۱۲.۲۰ ۵۱.۲۶	۴۶.۰۳ ± ۹.۸۵	۰.۱۱۶
	Post-test	۳۴.۳۱ ± ۱۴.۵۲	۳۸.۳۲ ± ۱۰.۰۷	± ۱۰.۳۸ ۴۳.۳۰	۳۸.۶۴ ± ۱۱.۹۷	۰.۲۹۰
Maximum Ankle Dorsiflexion (degrees)	Pre-test	۲۱.۷۳ ± ۸.۵۰	۲۱.۱۴ ± ۷.۱۸	۲۵.۳۱ ± ۴.۱۷	۲۲.۷۲ ± ۶.۸۵	۰.۳۹۳
	Post-test	۲۲.۹۱ ± ۱۰.۱۴	۱۷.۱۵ ± ۵.۷۲	۲۰.۹۳ ± ۵.۵۵	۲۰.۳۳ ± ۷.۵۶	۰.۲۶۹

*The researchers considered a significance level of 0.05 ($p \leq 0.05$).

Table 2 presents the descriptive statistics (mean and standard deviation) for the research variables, separated for each group. The results of the test showed significant differences in the post-test Initial Contact hip and post-test Maximum Dominant Foot Valgus patterns among the three groups. However, the researchers did not observe any significant differences in other variables across the three groups.

Table 3 displays the results of the two-way analysis of variance for the means of the variables of hip, knee, and ankle joint angles.

Variables	Source of Variation		Total Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F	Significance Level
Initial Contact Hip	Between groups	group	۲۴۳.۸۱۸	۲	۱۲۱.۹۰۹	۱.۹۹۱	۰.۱۵۹
	Within groups	time	۵.۶۷۱	۱	۵.۶۷۱	۰.۱۹۶	۰.۶۶۲
	interaction	group* time	۱۲۲.۰۸۹	۲	۶۱.۰۴۵	۲.۱۱۰	۰.۱۴۳
Maximum Knee Flexion	Between groups	group	۲۱۰.۱۲۳	۲	۱۰۵.۰۶۲	۰.۱۷۵	۰.۸۴۱
	Within groups	time	۱۱۲.۰۹۰	۱	۱۱۲.۰۹۰	۶.۸۴۸	۰.۰۱۵*
	interaction	group* time	۴۶.۴۰۷	۲	۲۳.۲۰۴	۱.۴۱۸	۰.۲۶۲
Initial Contact Knee	Between groups	group	۲۳۸.۷۵۸	۲	۱۱۹.۳۷۹	۱.۷۷۶	۰.۱۹۱
	Within groups	time	۱۷.۹۱۱	۱	۱۷.۹۱۱	۱.۵۵۵	۰.۲۲۴
	interaction	group* time	۴۳.۸۲۷	۲	۲۱.۹۱۴	۱.۹۰۳	۰.۱۷۱
Maximum Knee Flexion	Between groups	group	۳۶.۴۰۷	۲	۱۸.۲۰۴	۰.۱۴۹	۰.۸۶۳
	Within groups	time	۹۳.۰۸۹	۱	۹۳.۰۸۹	۴.۱۷۸	۰.۰۵۲

	interaction	group* time	۱۳۱.۹۴۰	۲	۶۵.۹۷۰	۲.۹۶۱	۰.۰۷۱
Valgus Initial Contact Dominant Foot	Between groups	group	۲۷.۰۳۸	۲	۱۳.۵۱۹	۵.۱۲۵	۰.۰۱۴*
	Within groups	time	۲.۳۲۳	۱	۲.۳۲۳	۱.۰۷۷	۰.۳۱۰
	interaction	group * time	۰.۲۱۱	۲	۰.۱۰۶	۰.۰۴۹	۰.۹۵۲
Valgus Initial Contact Non-Dominant Foot	Between groups	group	۱۹.۲۹۳	۲	۹.۶۴۷	۱.۱۲۷	۰.۳۴۰
	Within groups	time	۸.۷۲۸	۱	۸.۷۲۸	۳.۰۳۵	۰.۰۹۴
	interaction	group* time	۲.۱۴۹	۲	۱.۰۷۴	۰.۳۷۴	۰.۶۹۲
Valgus Maximum Knee Flexion Dominant Foot	Between groups	group	۵۵.۱۶۳	۲	۲۷.۵۸۱	۱.۳۰۸	۰.۲۸۹
	Within groups	time	۵.۴۱۵	۱	۵.۴۱۵	۱.۳۲۱	۰.۲۶۲
	interaction	group* time	۳۲.۳۰۱	۲	۱۶.۱۵۱	۳.۹۴۱	۰.۰۳۳*
Valgus Maximum Knee Flexion Non-Dominant Foot	Between groups	group	۴۶.۰۳۴	۲	۲۳.۰۱۷	۰.۶۸۹	۰.۵۱۲
	Within groups	time	۱۵.۸۷۶	۱	۱۵.۸۷۶	۵.۱۶۲	۰.۰۳۲*
	interaction	group* time	۹۷.۱۸۳	۲	۴۸.۵۹۱	۱۵.۷۹۹	۰.۰۰۱*
Initial Contact Ankle Dorsiflexion	Between groups	group	۷۷۵.۶۴۶	۲	۳۸۷.۸۲۳	۲.۱۸۶	۰.۱۳۴
	Within groups	time	۷۳۷.۴۱۱	۱	۷۳۷.۴۱۱	۱۴.۵۷۳	۰.۰۰۱*
	interaction	group* time	۳.۸۴۳	۲	۱.۹۲۱	۰.۰۳۸	۰.۹۶۳
Maximum Ankle Dorsiflexion	Between groups	group	۱۵۸.۸۸۹	۲	۷۹.۴۴۵	۰.۹۵۷	۰.۳۹۸
	Within groups	time	۷۷.۵۲۰	۱	۷۷.۵۲۰	۳.۹۴۰	۰.۰۵۹
	interaction	group* time	۸۶.۶۵۶	۲	۴۳.۲۸۲	۲.۲۰۰	۰.۱۳۳

*The researchers considered a significance level of 0.05 ($p \leq 0.05$).

DISCUSSION

The current study examined the impact of fatigue on the lower limb kinematics of basketball players who have dynamic knee valgus patterns in different positions. In this study, fatigue did not significantly affect the hip joint angle in the guard, forward, and center groups. However, it did produce a significant outcome on the knee joint angle within the guard group, resulting in a decrease. We observed no significant effect in the forward and center groups. Additionally, the ankle joint angle (initial contact) differed between the guard and forward groups, showing an increase in the ankle initial contact angle after fatigue in the guard group and a decrease in the forward group.

Furthermore, the results of this test did not reveal a significant difference in the knee joint angle among the guard, forward, and center groups. These findings suggest that fatigue-induced changes in lower limb kinematics are more pronounced in the knee joint, particularly in individuals with dynamic knee valgus patterns, highlighting the importance of considering specific player positions in assessing the impact of fatigue on biomechanics.

In this regard, Hollman and collaborators (2012) explored the effects of hip extensor fatigue on lower limb kinematics during landing. The research results indicated that there were no statistically significant changes in pelvis and knee kinematics, suggesting that the kinematics of the thigh and knee joints did not alter after fatigue intervention [32]. Lucci and colleagues (2011) after conducting two fatigue protocols on 36 female soccer players, concluded that the knee and hip mechanics significantly changed after both fatigue protocols [30]. The researchers used short-term functional and non-functional fatigue specifically for football in their study. At the time, we chose a 40-minute full basketball game as the fatigue protocol in the present research, which could be one reason for the thigh joint angle not changing. Additionally, the fatigue protocols by Lucci and colleagues (2011) were short-term and may not be directly applicable to a real basketball game.

Using an ISOKINETIC fatigue protocol, Thomas and colleagues (2010) conducted a study titled "Fatigue of Quadriceps and Hamstring and Its Effect on Thigh and Knee Mechanics" on 25 healthy men and women. They found a significant reduction in knee flexion angle after fatigue induced by ISOKINETIC dynamometer contractions [33]. Khazaee and associates (2021) looked at the impact of lower extremity fatigue on adult soccer players' knee joint kinematics during landing maneuvers in another study. In this study, ten male adult football players were involved. While other kinematic variables did not indicate significant changes from the pre-test to the post-test, the results did reveal a substantial momentary flexion difference. One of the kinematic alterations was a decrease in momentary flexion, which is thought to be a predictor of ACL injury after landing [34]. The observation that fatigue led to reduced knee flexion, specifically in the guard group, while not effecting the forward and center groups, may indicate the varying levels of activity and responsibilities among these positions during an entire basketball game. Guards, given their roles, such as advancing the ball against defenders, frequently engaging with opponents, and creating opportunities for passing, may experience more dynamic movements. They often possess the ball during offensive plays, involving sudden changes in direction, rotations, and quick maneuvers. Since one foot is typically stationary during these actions while the other foot undergoes rotation, change of direction, or pivoting against defenders, guards might be more prone to fatigue.

Another factor contributing to the absence of changes in thigh joint angle in the present study could be the development of less fatigue in the thigh muscles. In other words, players in this study might have adapted to the fatigue conditions or experienced less fatigue in their thigh muscles, potentially due to conditioning or acclimatization to fatigue-inducing activities.

Results from the present study demonstrated that fatigue did not have a significant effect on knee joint angle (initial contact dominant/non-dominant foot) in all three groups: guard, forward, and center. However, researchers observed in the results of this test that fatigue had a significant impact on the knee joint angle (maximum flexion dominant foot) in the center group, causing an increase. In contrast, it did not affect the forward and guard groups. Additionally, fatigue had a significant impact on, the knee joint angle (maximum flexion non-dominant foot) in all three groups, leading to an increase. While knee joint angles (initial contact dominant/non-dominant foot) showed no significant differences among the guard, forward, and center groups, there was a meaningful difference in the knee joint angle (maximum flexion dominant foot) between the center and forward groups. Specifically, the center group experienced a more pronounced increase in the valgus angle in the dominant foot. The effect of fatigue on the valgus angle of the non-dominant foot was also significant in all three groups, with the guard and center groups experiencing an increase and the forward group showing a decrease. It seems that the reason only the center group experienced a rise in valgus angle in both legs could be the type of tasks these players perform during basketball games. Centers typically execute their highest landing jumps in the paint area and under the basket using a two-foot jump. This has led to fatigue on both dominant and non-dominant legs. Chappell et al. (2005) conducted a study titled “The Effect of Fatigue on Knee Kinematics and Kinetics During Stop-Jump Tasks in Collegiate Athletes.” They used videography and force plates to analyze knee joint angles and movements during landing. They found that both male and female groups exhibited increased valgus movements and decreased knee flexion angles during fatigue-induced landings [35]. The results of the current study somewhat align with the research by Carcia et al. (2005), where they reported that fatigue of the hip abductors increased the abduction angle (valgus) of the knee in the frontal plane [36]. The present study is consistent with the findings of Smith et al. (2009). In their research on the impact of fatigue and gender on knee movement in the frontal plane, they reported no significant differences between females and males in all variables. They concluded that fatigue led to a change in the knee angle in the frontal plane toward valgus alignment [37].

The results of the current study indicate that fatigue had a significant effect on the ankle joint angle (initial contact) in the forward and center groups, resulting in a reduction in the ankle dorsiflexion angle. However, this effect was not observed in the guard group. Additionally, fatigue had a significant effect on the ankle joint angle (maximum flexion) in the center group, causing a reduction. In contrast, it did not impact the guard and forward groups. The test results showed no significant difference in the ankle joint angle (initial contact and maximum flexion) among the three groups: guard, forward, and center. In this context, Boyas et al. (2013) conducted a study titled “The Effect of Plantar Flexor Fatigue on Postural Sway, Lower Extremity Joint Angles, and Postural Strategies During Single-Leg Stance,” showing that fatigue in the plantar flexors of the ankle leads to changes in joint angles, primarily associated with a reduction in ankle dorsiflexion [38]. Zhang et al. (2022) conducted a study titled “The Impact of Fatigue on the Kinematics, Kinetics, and Muscular Activities of the Lower Extremities During Walking.” The results demonstrated that fatigue induces changes in the angles of the ankle, knee flexion, and hip flexion, leading to a reduction in the plantar flexion angle of the ankle [39]. Wild et al. (2017) conducted a study titled “Biomechanics of the Lower Limbs and Trunk After Fatigue in Irish Dancers.” The findings indicated that fatigue results in a decrease in plantar flexion of the ankle [40].

CONCLUSION

In summary, the results of this research demonstrate that fatigue due to a real basketball game did not lead to a change in the ankle joint angle between players from all three groups. However, there was a notable kinematic disturbance in the lower limbs of the guard group during landing, characterized by a smoother knee joint and a more excellent, valgus pattern in the non-dominant leg compared with pre-fatigue conditions. In the center group, players landed with reduced ankle plantar flexion and a more fantastic, valgus pattern in both legs than pre-fatigue. Therefore, fatigue had only a minimal effect in the forward group, where it did not affect the sagittal plane angles of the hip, knee, and ankle but resulted in a further increase in a valgus pattern in the non-dominant leg. The increased valgus angle in the non-dominant leg in the guard and forward groups might be related to the three-step movement in basketball and the commonly observed increased knee valgus angle during both-feet landings in basketball players. Still, more extended sample sizes and longer investigations are needed to draw more precise results.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Conflict of interests

The authors declared no conflict of interest.

Data Availability Statement

Data will not be available at request.

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اثر یک برنامه خستگی بر کینماتیک مفاصل اندام تحتانی در بازیکنان بسکتبال دارای نقص داینامیک والگوس زانو در پست‌های مختلف

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چکیده:

پایداری پویای مفصل زانو ممکن است تحت تاثیر شروع خستگی متابولیک در حین شرکت در ورزش قرار گیرد که می‌تواند خطر آسیب دیدگی زانو را افزایش دهد. پژوهش حاضر با هدف اثر یک برنامه خستگی بر کینماتیک مفاصل اندام تحتانی در بازیکنان بسکتبال دارای نقص داینامیک والگوس زانو در پست‌های مختلف انجام شد. در این مطالعه ۲۷ بازیکن بسکتبال دارای نقص داینامیک والگوس زانو در ۳ گروه گارد (میانگین سن= ۱۹/۷۷±۲/۶۸سال، میانگین قد=۱۷۷±۴سانتی متر و میانگین وزن= ۶۳/۴۰±۵/۱۰ کیلوگرم) فوروارد (میانگین سن= ۲۰/۲۲±۲/۹۰ سال، میانگین قد=۱۸۷±۴ سانتی متر و میانگین وزن= ۷۶/۸۰±۲/۹۴ کیلوگرم) و سنتر (میانگین سن= ۲۲/۳۳±۳/۲۷سال، میانگین قد=۱۹۹±۴ سانتی متر و میانگین وزن=۹۸/۸۴±۱۸/۴۲ کیلوگرم) و در دامنه سنی ۱۶ تا ۲۶ سال به صورت غیرتصادفی هدفمند انتخاب شدند. برای ارزیابی زوایای اندام تحتانی در دو صفحه ساجیتال و فرونتال از تصویربرداری توسط دو دوربین دیجیتال در فاصله ۳۶۶ سانتی متری و با ارتفاع ۱۰۵ سانتی متری نسبت به آزمودنی قرار گرفت و آزمودنی‌ها سه پرش کانتر را انجام دادند. تحلیل آن با استفاده از نرم‌افزار کینوا انجام شد. در این پژوهش پروتکل خستگی ۴۰ دقیقه بازی بسکتبال بود که به صورت قانونی و با در نظر گرفتن تمامی وقت‌های استراحت انجام شد. جهت مقایسه میانگین متغیرهای پژوهش از آزمون‌های تجزیه و تحلیل واریانس مختلط (۲*۳)، تجزیه و تحلیل واریانس یکراهه و تعقیبی بونفرونی استفاده شد. تمام آزمون فرضیات در سطح معناداری برابر یا کوچکتر از ۰/۰۵ انجام شد. نتایج نشان داد که اعمال پروتکل خستگی به هنگام فرود در صفحه ساجیتال، باعث کاهش معنی‌دار در زاویه حداکثر فلکشن زانو در گروه گارد (p= ۰/۰۳۵)، اینیشیال کانتکت مچ پا در گروه فوروارد (p= ۰/۰۴۴) و اینیشیال کانتکت مچ پا در گروه سنتر (p= ۰/۰۱۶) و همچنین کاهش حداکثر پلانتارفلکشن مچ پا در گروه سنتر (p= ۰/۰۱۸)، شده است. در صفحه فرونتال نیز پروتکل خستگی باعث افزایش زاویه والگوس حداکثر فلکشن زانو در پای غالب در گروه سنتر (p= ۰/۰۳۹) و پای غیرغالب در هر ۳ گروه گارد (p= ۰/۰۱۹)، فوروارد (p= ۰/۰۰۲) و سنتر (p= ۰/۰۰۹) شده است. در مقایسه بین گروهی، اینیشیال کانتکت مفصل ران در گروه گارد با فوروارد (p= ۰/۰۳۱) و والگوس حداکثر فلکشن پای غالب گروه فوروارد با سنتر (p=۰/۰۴۱) تفاوت معناداری وجود داشت، اما در دیگر زوایا تفاوت معناداری مشاهده نشد. بر اساس نتایج پژوهش حاضر، خستگی عملکردی مورد استفاده در این تحقیق بر برخی از متغیرهای مفاصل اندام تحتانی آزمودنی‌ها اثرگذار بوده است. در صفحه فرونتال، زاویه والگوس پای غالب و غیرغالب در گروه سنتر و زاویه والگوس پای غیر غالب در هر سه گروه افزایش داشته است. علت آن می‌تواند حرکت لی آپ در بسکتبال باشد، که بازیکنان گارد و فوروارد به فور در حین بازی انجام می‌دهند. زیرا در لی‌آپ آخرین پایی که از زمین جدا می‌شود، پای غیرغالب بازیکنان می‌باشد که همین امر فشار بیشتری به پای غیر غالب می‌آورد. از طرفی

بازیکنان گروه سنتر پرش و فرود را بیشتر به صورت جفت پا در زیر حلقه و در منطقه پینت برای ریباند انجام می‌دهند، که می‌تواند باعث افزایش زاویه والگوس در هر دو پا شود.

واژگان کلیدی: داینامیک والگوس زانو، کینماتیک، خستگی، بسکتبال