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The effect of fatigue on shooting accuracy in basketball: Does performance change after fatigue as age increases?

El efecto de la fatiga en la precisión de tiro en el baloncesto: ¿Cambia el rendimiento después de la fatiga a medida que aumenta la edad?

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Abstract

The aims of this research were (a) to examine the effect of fatigue on shooting accuracy and rating of perceived exertion (RPE) in basketball, and (b) to compare the shooting accuracy and RPE after fatigue between age categories. 89 male basketball players from different age categories participated in the research. The 20 m shuttle run test was applied to create fatigue. RPE and shooting accuracy were measured before and after fatigue protocol. While there was no significant difference in shooting accuracy before and after fatigue in all age categories, RPE was significantly higher. Shooting accuracy quantitatively increased with age before fatigue (except U14). Shooting accuracy after fatigue was significantly different between the groups. As a result; although shuttle run was perceived as “hard-very hard” difficulty in basketball players, it did not create a fatigue that would significantly affect shooting accuracy. However, it was determined that the shooting accuracy after fatigue changed with increasing age. Therefore, this research presents important findings in terms of determining the age categories in which fatigue affects shooting performance in basketball.

Keywords
Shuttle run, free throw, VO_2max, throwing.

Resumen
Los objetivos de esta investigación fueron (a) examinar el efecto de la fatiga en la precisión del tiro y el índice de esfuerzo percibido (RPE) en baloncesto, y (b) comparar la precisión del tiro y el RPE después de la fatiga entre categorías de edad. Participaron en la investigación 89 jugadores masculinos de baloncesto de diferentes categorías de edad. Se aplicó la prueba de carrera de ida y vuelta de 20 m para crear fatiga. El RPE y la precisión de tiro se midieron antes y después del protocolo de fatiga. El RPE fue significativamente mayor, aunque no hubo una diferencia significativa en la precisión de tiro antes y después de la fatiga en todas las categorías de edad. La precisión de tiro aumentó cuantitativamente con la edad antes de la fatiga (excepto U14). La precisión de tiro después de la fatiga fue significativamente diferente entre los grupos. Como resultado; aunque la carrera de ida y vuelta se percibía como una dificultad "difícil-muy difícil" en los jugadores de baloncesto, no creaba una fatiga que afectara significativamente la precisión del tiro. Sin embargo, se determinó que la precisión de tiro después de la fatiga cambiaba con el aumento de la edad. Por lo tanto, esta investigación presenta hallazgos importantes en términos de determinar las categorías de edad en las que la fatiga afecta el rendimiento de tiro en baloncesto.

Palabras clave
Carrera de lanzadera, tiro libre, VO_2max, tiro.

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Introduction

Basketball is a high-intensity intermittent sport (Cengizel et al., 2022; Cengizel et al., 2022; Liveris et al., 2021) and includes activities that can cause acute and accumulated fatigue, such as sprint, jumping, and changing directions (Li et al., 2021c; Rupcic et al., 2015). Previous research shows that in a 40-minute basketball game, athletes cover a distance of 4500 to 6000 m (Erculj & Supej, 2009; Scanlan et al., 2011). On the other hand, basketball not only imposes a considerable strain and intensive movements on players, but also requires a high degree of accuracy (Erculj & Supej, 2009).

In basketball, the shooting is used as a scoring tool, and a good shooting requires basically accuracy as well as lower extremity patterns such as balance and jumping accompanying proper upper extremity movement (Chen et al., 2005). Some studies have reported that shooting accuracy can be negatively affected by different physiological loads (Erculj & Supej, 2009; Rupčić et al., 2020). As it is well known, shooting accuracy in basketball directly determines the outcome of a basketball game (Li et al., 2021b). In general, distance and velocity of shots and angle of releasing the ball are the three most important factors affecting shot accuracy (Chen et al., 2005).

As in other sports, athletes face fatigue in basketball as well, and it has been reported that fatigue adversely affects athlete performance (Liveris et al., 2021). It is very crucial to examine the changes in the performance of the athletes with fatigue (Liveris et al., 2021), as further fatigue may result in an injury scenario (Verschueren et al., 2020). Fatigue can deteoriate performance, coordination (Emge et al., 2014) and players' technique (Kellis et al., 2006; Li et al., 2021a; Lyons et al., 2006). The fatigue accumulated as a result of the increase in physical activity intensity leads the athlete to internal cues, causing narrowing in perception and thus ignoring external cues related to the task. This results in a decrease in attention efficiency, and errors occur even in movements that can be done very easily (Schmidt & Wrisberg, 2008). In summary, the fact that the athlete has a focus problem due to fatigue affects the performance negatively, which is very important in shooting accuracy. Additionally, Verschueren et al. (2020) reported that acute fatigue can reduce the single leg postural control, ankle joint position

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sense and the strength of hamstring and quadriceps muscles, and this may increase the risk of injury.

Another factor to consider regarding fatigue is the age of the athletes. Although the age categories in basketball last two years, this age scale has a significant impact on most of the functional capacities of the athletes (Cengizel et al., 2022; Coelho e Silva et al., 2010). This current research is important in terms of examining fatigue responses among competing groups of different ages. Although there are studies examining the effect of fatigue on passing (Canlı et al., 2018; Li et al., 2021a) and shooting kinematics in basketball (Erculj & Supej, 2009; Li et al., 2021b; Slawinski et al., 2015), there are few studies examining the effect of fatigue on shooting accuracy (Chen et al., 2005; Mulazimoglu et al., 2017; Mülazımoğlu, 2012; Rupcic et al., 2015). Considering that fatigue has an effect on more than one performance parameter, evaluating fatigue effect on free throw performance according to age categories, and determining its effect on free throw success, which is of great importance for basketball can be effective way to develop new training methods, update existing training methods, and develop approaches that can reduce the effect of fatigue parameter on performance. Therefore, the aims of this current research were (a) to examine the effect of fatigue on shooting accuracy and rating of perceived exertion (RPE) in basketball, and (b) to compare the shooting accuracy and RPE after fatigue between age categories.

Material and Methods

Participants

A total of 89 male basketball players from different age categories and played in the same club participated in this cross-sectional comparative research voluntarily (U12 n=35, U14 n=34, U16 n=20, U18 n=10, Table 1). The study protocol was explained to all players before the study and written informed consent were collected from their parents. Inclusion criteria for the study were (a) being a male basketball player between the ages of 10 and 18 (b) participating regularly in training for the last two years (c) participating in competitions. Exclusion criteria were (a) having had any musculoskeletal injury or surgery in the last six months (b) having

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chronic respiratory or circulatory system disease (c) incomplete or incorrect application of the test protocol. Participants were trained 3 times per week (90min/training session) and usually competed once per week. The study was performed in accordance with the Declaration of Helsinki and approved by the Local Ethics Committee (Research Code: 2021-805).

Table 1. Characteristics of the participants

	U12	U14	U16	U18
Age (years)	10.7±0.5	12.4±0.5	14.2±0.4	16.0±0.0
Age of experience (years)	4.1±1.3	4.9±1.7	6.7±2.3	9.1±1.5
Body height (cm)	152.5±8.8	163.4±8.9	179.4±6.0	182.3±6.4
Body mass (kg)	44.7±10.1	52.9±9.5	68.6±11.2	73.9±12.5
VO_2max (ml.kg/min)	50.1±3.4	47.9±3.8	49.1±2.9	51.7±5.1

Data are presented as mean ± SD.

Study Protocol

The testing protocol was completed in one day for all athletes. All participants were familiarized in one session one week before measurements. All measurements were performed in the training halls of the athletes between 17:00 and 19:00. After the characteristics of the participants (chronological age, age of experience, body height, body mass) were determined, shooting accuracy, fatigue protocol, and shooting accuracy were measured, respectively. RPE was questioned before and after the fatigue protocol.

The 20 m shuttle run test was applied to create fatigue. The Course Navette of 20 meter shuttle run test is a maximum 20-stage shuttle run that is used to measure aerobic endurance in children besides the athletes. The participants were asked to run for 20 meters in a specified area while following the pace of the given signals. The running speed steadily increased after a slow start. From a starting speed of 8.5 km/h, the frequency of the running rhythm rises by 0.5 km/h per minute. The participants were instructed to position in the 2 m-area at the ends of the 20 m-area for every "beep" voice they heard, with the test ending when they missed the signal 2 times. An estimated VO_2max was determined based on the number of shuttles obtained (Gürses & Akalan, 2018; Léger et al., 1988).

VO_2max (ml.kg/min)= 31.025 + 3.238speed – 3.248age +0.1536speed x age

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Before and after the fatigue protocol, basketball players were asked to perform 10 free throws from the free throw line (4.2m). After each shot, one of the researchers passed the ball to the athlete for the next free throw from the baseline (5.80m). Shooting accuracy was calculated as successful free throws divided by attempted free throws. RPE was assessed using the Borg Scale (0-10), modified by Foster et al. (2001) before and after the fatigue protocol.

Data Analysis

Statistical analysis was conducted via Sigma Plot 11.0 (Systat Software, Inc., San Jose, USA). software. The normality of the data distribution was evaluated using Shapiro-Wilk test. Means and standard deviations of the variables were calculated for descriptive statistics. Confidence intervals (95%CI) were presented with mean and standard deviations in the table. Paired sample t-test was used for comparisons of shooting accuracy and RPE before and after fatigue within the group.

One-way analysis of variance was used to determine the differences between age categories, and All Pairwise Multiple Comparison Procedures (Holm-Sidak method) were applied to determine between which groups the differences occurred. Effect sizes for one-way analysis of variance was classified using the partial eta squared (η^2) according to following scale: trivial = <0.01, small = 0.01, medium = 0.06, large = >0.14 (Cohen, 1988). The significance level was set as 0.05.

Results

VO_2max shows a quantitative increase with age except for the U14 age group (Table 1).

Before vs. after fatigue comparison

While there was no significant difference in shooting accuracy in all age categories before vs. after fatigue comparison, RPE was significantly higher ($p<0.001$).

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Table 2. RPE and shooting accuracy of basketball players in pre- and post-fatigue protocol

	RPE					Shooting accuracy				
	Pre-fatigue		Post-fatigue		p	Pre-fatigue		Post-fatigue		p
	mean±SD	95%CI	mean±SD	95%CI		mean±SD	95%CI	mean±SD	95%CI	
U18	0.3±0.4	0.1-0.5	6.7±2.4	5.2-8.2	.001	44.0±19.0[c]	32.2-55.8	48.0±22.0[b,c,d]	34.4-61.6	.462
U16	0.5±0.8	0.1-0.9	5.5±1.5[c,d]	4.8-6.2	.001	34.5±21.9	24.9-44.1	26.5±16.6[a]	19.2-33.8	.202
U14	0.3±0.4	0.2-0.4	7.0±2.0[b]	6.3-7.7	.001	26.8±16.6[a]	21.2-32.4	28.8±16.7[a]	23.2-34.4	.345
U12	0.4±0.4	03.-0.5	7.3±1.9[b]	6.7-7.9	.001	31.7±13.6	27.2-36.2	31.1±17.5[a]	25.3-36.9	.867

Data are presented as mean ± SD (95%CI). CI: Confidence interval. RPE: Rating of perceived exertion, Within-group significance was shown in the p-columns. Significant differences between groups are shown as a, b, c, d. a: Significant difference with U18, b: Significant difference with U16, c: Significant difference with U14, d: Significant difference with U12.

Age category comparison

While shooting accuracy increases quantitatively with increasing age before the fatigue protocol (excluding U14), U14 players have significantly lower shooting accuracy than U18 players (U18 vs. U14, t=2.802, F=4.487, η^2=0.098 [medium], p=0.006, Figure 1). As the age increased, there were significant differences between the groups in shooting accuracy after the fatigue protocol (U18 vs. U16, t=3.171, F=3.366, η^2=0.065 [medium], p=0.002; U18 vs. U14, t=3.045, F=4.219, η^2=0.109 [medium], p=0.003; U18 vs. U12, t=2.685, F=3.987, η^2=0.119 [medium], p=0.009). RPE was significantly different between groups after fatigue protocol (U16 vs. U14, t=2.777, F=1.217, η^2=0.001 [trivial], p=0.007; U16 vs. U12, t=3.430, F=2.133, η^2=0.002 [trivial], p<0.001).

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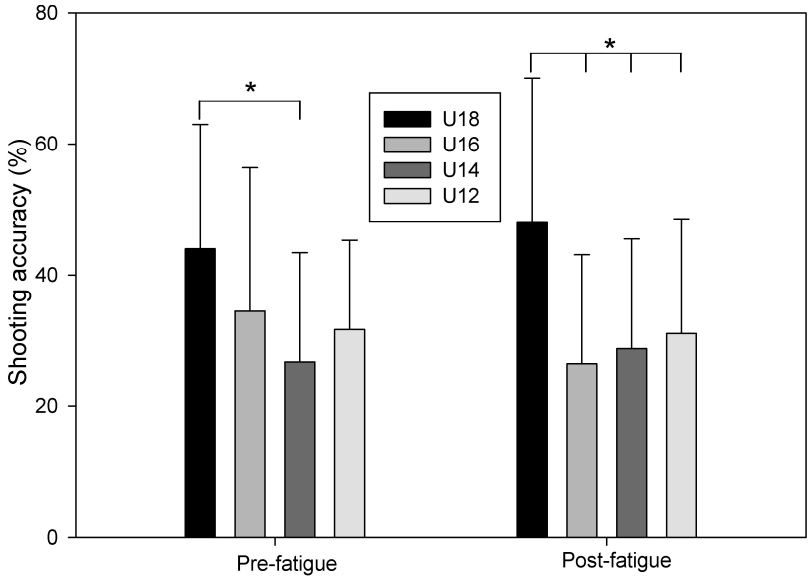

Figure 1. Comparison of shooting accuracy between age categories in basketball players.

Discussion

In this study, it was aimed to determine the effect of fatigue on shooting accuracy in basketball and whether there is a difference in shooting accuracy after fatigue with age. Our hypothesis was that fatigue will cause a decrease in shooting accuracy and shooting accuracy will increase as age increases. The most important findings of the study were that fatigue does not change shooting accuracy, but shooting accuracy responses differ significantly between age categories after fatigue.

While shooting accuracy was not found to be significantly different after fatigue protocol in all age categories (pre- vs. post-test comparison), RPE was significantly higher as expected. Although it is well known that fatigue affects players' performance, it is seen in previous studies that there are differences in shooting kinematics after fatigue, but shooting accuracy is not affected which is similar to this current study. In basketball, fatigue affects shooting kinematics, especially ball trajectory, lower and upper extremity joint angles, and body center of mass (Erculj & Supej, 2006, 2009; Slawinski et al., 2015). Generally, there is no

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consensus in studies examining the effect of fatigue on shooting accuracy. In young male basketball players, a significant decrease was observed in shooting accuracy only after chest press in free throw, 2-point (2P) and 3-point (3P) shots performed after fatigue was created with chest press and wrist curl protocols (In the chest press protocol, pre and post shooting accuracies are respectively; free throw: 72.7±13.6 vs. 52.7±16.9, 2P: 56.7±13.0 vs.46.5±12.4, 3P: 40.0±10.9 vs. 30.6±10.9, $p<0.05$) (Chen et al., 2005). In another study with young male basketball players (n=13), a significant decrease was found in the shooting performance before and after fatigue created by the Yo-Yo Intermittent Recovery test (pre-test= 12.62 ± 3.02 vs. post-test 10.54 ± 2.96, $p<0.001$) (Mulazimoglu et al., 2017). In contrast, Rupcic et al. (2015) reported that shooting accuracy did not change in basketball after fatigue, but shooting speed and the angle of entry of the ball into the basket differed significantly. However, it is not possible to generalize the result because the research was conducted on only one male basketball player. In another study conducted on relatively more participants (n=8, male basketball players), significant differences were obtained in kinematic parameters (decrease in hip joint angle and increase in shoulder joint angle) after a fatigue protocol that included sprints and jumps, but shot accuracy was not accompanied (3P%: 43.7 ± 21.6 % vs. 41.4 ± 18.9 %; $p=0.8$). In support, at the maximum fatigue level (HR: 197 bpm, La: 9.7 mmol/L), it was noted that the accuracy of the shot was not affected by fatigue, and kinematic changes were observed (Erculj & Supej, 2006). In another previous research also clearly demonstrate changes in the shooting technique's kinematics as a consequence of moderate and, in particular, heavy fatigue (Erculj & Supej, 2009). Perhaps the fatigue protocols applied in our research and previous studies may not have created in-competition fatigue scenarios, or it can be thought that in the absence of other parameters (i.e. pressure, probability of winning or losing, spectators, environment, etc. that affect shooting accuracy in the competition environment) the shooting accuracy may not change. Although there was no significant difference in the in-group comparison before and after fatigue, we obtained inconsistent shooting accuracy responses in different age groups after fatigue (quantitative increase in shooting accuracy in U18 and U14

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and decrease in U16 and U12 after fatigue). These findings may be related to the development or alteration of motoric and cognitive features in the specified age groups.

Shooting accuracy responses after fatigue in the comparison between age categories are quite interesting. Shooting accuracy of U18 basketball players before (U18 vs. U14, η^2=0.098 [medium], p=0.006) and after fatigue is significantly higher (U18 vs. U16 η^2=0.065 [medium], p=0.002; U18 vs. U14 η^2=0.109 [medium], p=0.003; U18 vs. U12 η^2=0.119 [medium], p=0.009). While the lowest shooting accuracy before fatigue was in U14, it was observed in U16 athletes after fatigue. The RPE responses were the lowest at U16 after fatigue and significantly different from the U14 and U12 (U16 vs. U14 η^2=0.001 [trivial], p=0.007; U16 vs. U12 η^2=0.002 [trivial], p<0.001). U16 RPE responses can be interpreted as a decrease in body awareness due to rapid growth, but the lowest shooting accuracy after fatigue may offer us important clues about rapid physical growth and physiological adaptation.

Conclusions

As a result, although there is no significant difference in shooting accuracy before and after fatigue created by shuttle run in different age groups, shooting accuracy and RPE responses after fatigue differ in comparison between age groups. U16 basketball players have the lowest shooting accuracy and RPE after fatigue. To our knowledge, no previous study has yet examined the effect of fatigue on shooting accuracy across this wide range of age categories. In this study, the lack of fatigue in competition conditions and the number of participants were considered as limitations. Despite the limitations reported above, this article fills the gap in the contemporary sports science literature in terms of examining the shoot accuracy responses of fatigue in different age categories in basketball. In order to minimize the deterioration in the technical skills, these different shooting accuracy responses in age categories should be considered. However, although shuttle run is perceived as "hard-very hard" in basketball players, it was determined that it did not create a fatigue that would significantly affect free throw performance, and shooting accuracy changed after fatigue as age increased. Therefore, it is recommended to apply different protocols or competition-like drills/tests in investigating how technical elements are affected after fatigue in basketball players. It is important for the coaches

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to know what kind of changes occurs in which age groups, in order to increase the performance of the teams.

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