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ORIGINAL SCIENTIFIC PAPER

The Association Between Heart Rate and Shooting Accuracy in Young Football Players

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Abstract

This study aimed to examine the accuracy of shots taken at various heart rate (HR) percentages resulting from increasing workload. Twenty-one male football players (age: 21.7 years) in amateur teams participated in the study. Athletes were asked to shoot at the center of the prepared target ten meters away before the test and at each level of the progressively increasing intensity exercise protocol (Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1)). At the end of each level, the distance of the shots to the center of the target and the areas of contact with the target was determined. During the test, HR was monitored and percentages of maximum HR (%HRmax) at each level were determined. The distance to the target and contact zones of the shots were compared depending on different percentages of %HRmax. It was observed that the increased HR due to the increased workload negatively affected the accuracy of the shots. In particular, the accuracy rate decreased significantly after 80% of the maximum HR compared with the resting HR (47-82%). Additionally, it was observed that the percentage of balls directed to the upper right corner increased as HR rose, with no shots targeting the center after the third level of Yo-Yo IR1 (%HRmax=~80%). Therefore, it can be concluded that a high HR impairs football accuracy. Consequently, football players should engage in workouts that enhance their ability to perform at a high HR, and coaches should design training programs in this vein.

Keywords: *football, heart rate, kinematic, shooting accuracy, performance analysis, physiological responses*

Introduction

Fatigue in soccer is considered a performance limiter affecting motor and perceptual processes (Almonroeder et al., 2020; Nuño et al., 2016). Due to significant metabolic changes, fatigue development can be observed during and towards the end of the game, resulting in a decrease in high-intensity activities (Bangsbo et al., 2007; Mohr et al., 2005). This negative effect often results in a reduced ability to perform game-specific actions (Mohr et al., 2005) due to physiological and metabolic causes that lead to decreased muscle strength capacity (Greig & Siegler, 2009) and impairments in coordination (Apriantono et al., 2006). Players are expected to perform well in these conditions despite fatigue, which has become an essential part of the game that can decrease coordination and athletic skill (Kellis et al., 2006; Lyons et al., 2006).

Shooting is the most studied soccer skill (Rodríguez-Lorenzo et al., 2015) and that is a decisive factor for scoring a goal in a match because 80.69% of goals are scored through this movement (Njororai, 2013). Soccer kicking performance depends on kicked ball velocity and accuracy (Vieira et al., 2018). Shooting accuracy is defined as the ability to direct the ball into a specific area. Accuracy is also a key element for scoring success in kicks, so improving shooting technique is a fundamental goal in improving soccer players' performance (Finnoff et al., 2002). The intermittent and high-paced nature of soccer can impose stress on players, making it challenging to take accurate shots (Young et al., 2010). Therefore, a significant advantage can be gained in situations that challenge the organism by knowing the physiological parameters that directly affect the game's outcome (Memmert et al., 2017). Studies have reported that shooting accuracy in soccer is negatively affected in relation to increased fatigue (Stone & Oliver, 2009). It was found that speed and accuracy of soccer-specific skills were signifi-

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cantly affected after a 45-minute soccer specific exercise that replicated half of a soccer match. When fatigued, the frequency of shots reaching the highest 5 points decreased by 47%, while the frequency of shots reaching the lowest 0 points increased by 85% (Radman et al., 2016; Stone & Oliver, 2009). In another study, exercise was found to affect shot accuracy (timing effect: p=0.035) and pass speed (timing effect: p=0.011), with shots made after exercise being 25.5±4.0% less accurate than those made before exercise (Russell et al., 2011). Radman et al. (2016) also reported that physiologic exertion above blood lactate >4 mmol/L resulted in a significant decrease in kicking accuracy (11-13%; p<0.05) compared with exercise performed at baseline or at intensities below the lactate threshold. They observed that light and moderate intensity exercise with blood lactate >4 mmol/L had no significant effect on kicking performance (Radman et al., 2016).

A common feature of previous studies is the examination of shot accuracy before and after fatigue. However, unlike these studies, the present research aims to investigate how shooting performance is influenced at different percentages of maximum heart rate (HR). Prior research has shown that jump shot accuracy declines when HR reaches 80% in adolescent basketball players (Padulo et al., 2018), while fatigue has been found to reduce ball speed and accuracy in experienced handball players (Nuño et al., 2016). In contrast, Juárez et al. (2011) reported no significant differences in maximal instep soccer kick test results among elite youth soccer players before and after reaching 80% HR following a 20-minute treadmill run (Juárez et al., 2011).

The aim of this study was to examine the shooting accuracy at varying heart rates after intermittent running. In addition, the relationship between HR and shot accuracy rate was also examined. The hypothesis of this study is that there is a significant association between HR levels and shooting accuracy in football players, reflecting the influence of physiological responses on performance outcomes.

Method

Participants

Twenty-one male football players (mean age: 21.7 years, height: 174.9 cm, body weight: 68.1 kg) from amateur football teams in Sakarya, Turkey, participated in the study. All participants were free of musculoskeletal injuries in the past six months and met the requirements to perform the test. Before the study, the participants were informed about the study and signed a voluntary consent form. The athletes were instructed to eat 2 hours before the study and not to take stimulants such as caffeine before the tests. Ethical approval for this study was obtained from the Ethical Committee of Sakarya University of Applied Sciences (Approval Number: 16.11.2023-E.105539).

Study design

The Yo-Yo IR1 test (Figure 1) was applied to the soccer players participating in the study as an exercise protocol of increasing intensity. The athletes were asked to perform 3 free throws from a distance of 10 m to a target (Figure 2), which was 2 m x 3 m in size and 50-50 cm in diameter with a red color at the midpoint, at the end of each level during the test. During the test, heart rates were recorded with a HR monitor and at the same time, the shots to the target were recorded with a camera.

Test Procedures

Each athlete was given an appointment at the scheduled time and before the measurements, the players were given 10 shots at the target to familiarize them with the test. Afterwards, a special warm-up protocol including 7 min of general warm-up (running), 3 min of dynamic stretching and 5 min of free throw shooting was applied by an experienced coach. After the warm-up protocol, the players were asked to shoot at the goal from a distance of 10 meters. During this shot, the heart rate of the soccer players' %HRmax=~45%. Then, the Yo-Yo IR1 test began, where players were asked to shoot at levels 1 and 5 (5 shots in total). The data from 6 shots, including rest, were analyzed for the analysis. During the test, the shots to the target were recorded with a camera (iPhone 11 pro) that can record images at a frequency of 240 fps in slow motion mode. The distance in meters from the target to the point of contact of the ball and the area of the target divided into 5 sections were determined by Tracker 6 video analysis and modeling tool. Heart rates were continuously recorded with a HR monitor (Polar H10, Finland) during the test.

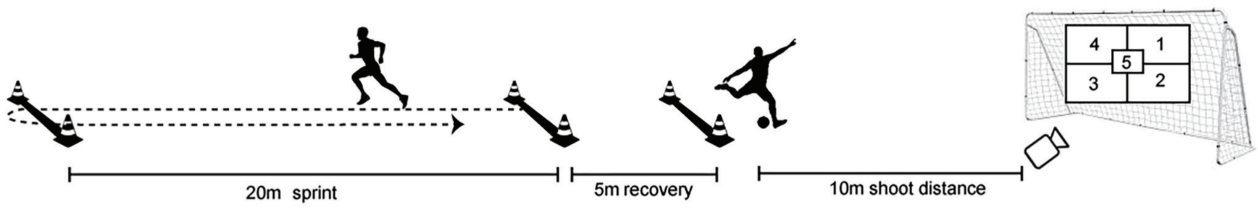

FIGURE 1. Test Protocol (Yo-Yo testing process and shooting).

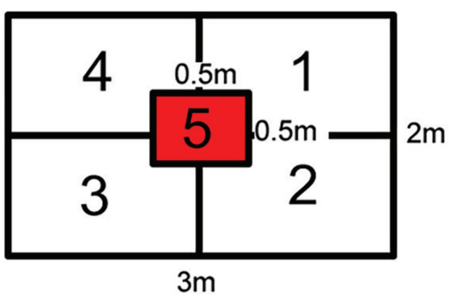

FIGURE 2. The target area where the shooting takes place.

Heart Rate Measurement

HR were recorded with a Polar H10 HR monitor during the test. According to the max HR values determined by the formula 220-age, %HRmax values were calculated. The Yo-Yo IR1 test was used to determine percentages of maximum HR and to measure shooting accuracy after running. After arriving at the starting line (B) and getting ready, the athlete started running with the instruction (beep) coming from the audio file recorded by means of a sound bomb. At the second beep, they reached the return line (C) at the end of 20 m and ran another 20 m back to the starting line (B) before the third beep. After each running level, the athletes had an active rest period of 10 seconds in a 5m wide area. When the athletes reached the B line at the end of each level, they walked or jogged to the A line at the end of the active rest period area and then took a shot with located ball at the A line towards the target 10 meters away. As soon as the shots were completed, they returned to the B line and continued to the next level with a beep. The initial speed for the test was 10.0 km/h and then increased to 12 km/h (second level), 13 km/h (third and fourth levels) and then 13.5 km/h (fifth level) (Bangsbo et al., 2008). The test continued in this way until level 5. Athletes were instructed not to start running before the beep, to run the entire distance and to reach each line before or during the beep. The test was terminated if the subjects failed to reach the finish lines on time twice or at the point of exhaustion, and the distance traveled was recorded and reported as the test result (Bangsbo et al., 2008).

Determining the Distance to the Target

The shots to the target were recorded using an iPhone (11 pro) mobile phone capable of recording images at a frequency of 240 fps in slow motion mode. The images were analyzed using Tracker 6 video analysis and modeling tool. During the analysis, the distance to the target from the point of contact of the ball was determined in meters and which part of the target each ball went to, which was divided into 5 sections.

Statistical Analysis

Statistical analyses were performed using the SPSS (version 24 IBM Corporation, NY, USA). Normality of data distribution was determined by the Shapiro–Wilk test. A one-way within-participant's repeated-measures analysis of variance (ANOVA) was used for HR values and Friedman test for shooting accuracy. Eta squared (η^2) was calculated as a measure of effect size for ANOVA and Kendall's W for Friedman Test. The thresholds for small, medium and large effects were 0.01, 0.06 and 0.14, respectively. Multiple pairwise comparisons were used when there were significant differences between the values. The Pearson product-moment correlation coefficient was calculated between HR and shooting accuracy, and the variables were expressed as values with a 95% confidence interval (CI). The correlation was interpreted as follows: an r between 0 and 0.3, was considered small; 0.31–0.49, moderate; 0.5–0.69, large; 0.7–0.89, very large; and 0.9–1, near perfect for predicting the relationship (Hopkins, 2000). Linear regression analysis was used to determine whether the HR values predicted the shooting accuracy scores. All data are presented as mean ± standard deviation with 95% confidence interval. The alpha level was accepted at $p<0.05$.

Results

Detailed descriptive information of the young football players can be found in Table 1.

The analysis confirmed the differences in HR values (%HRMax) obtained during the YoYo IR1 test ($F=894.478$, $p<0.001$, $\eta^2=0.978$) (Table 2). There was a significant difference of distances from the center over the % HRmax levels ($X^2=21.408$, $p=0.001$, $\eta^2=0.20$) (Table 2).

Table 1. Descriptive statistics for the physical characteristics and training status of participants (n=21)

Age (year)	Mass (kg)	Height (cm)	BMI (kg/m²)
21.7± years (18-22)	68±7 (58-86)	175±7 (165-185)	22±1 (21-24)

Note. Data are expressed as means ± standard deviations (min-max); BMI - body mass index.

Table 2. Comparison of distances from the center of the shootings at different levels

Times	%HRmax	Distances (m)		X²	p	ES
	Mean ± SD	Mean ± SD	min-max			
Rest	44.83±2.31	0.45±0.22	0.11-0.97	21.408	0.001**	0.20
Level-1	63.33±5.05	0.52±0.29	0.19-1.36			
Level-2	71.54±5.27	0.50±0.26	0.21-1.36			
Level-3	79.49±5.28	0.66±0.30	0.10-1.45			
Level-4	83.93±5.62	0.68±0.32	0.27-1.56			
Level-5	86.90±5.20	0.82±0.35	0.29-1.70			

Note. ** - p<0.01; ES - Effect size.

Pairwise comparisons revealed a significant difference between Rest - Level 5 (82.22%, p=0.001) and between Level 2 - Level 5 (64%, p=0.034) in the distance from the center. When the rest was compared with the Level 1 and Level 2, it was found that there was a change of about 11% to 15%. However, at the Level 3, when the HR reached an average of 80%, it was found that the central distance changed 47% with compared to the resting state. In addition, level 4 and level 5 were 51.11% and 82.22% distorted, respectively, compared with the resting condition. The results show that ~80% HR max is an important threshold value for the deterioration of shooting accuracy compared to the baseline (Figure 3).

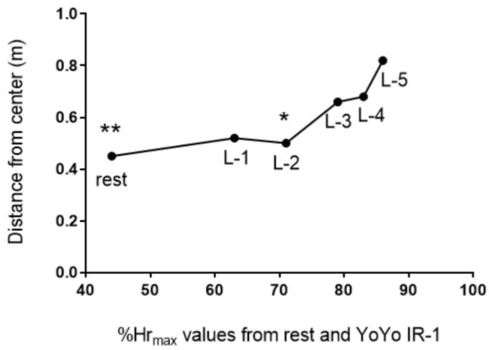

FIGURE 3. Examining the distances from the center of the shootings at different % HRMax values. Note. ** - significantly (p<0.01) lower than the Level 5; * - significantly (p<0.05) lower than Level 5.

Figure 4 shows a moderate correlation between shooting accuracy and HR (r=0.387, 95% CI=0.226-0.525). Linear regression analyses showed that HR was a significant predictor of shooting accuracy (R^2=14% explained variance).

Figure 5 shows that, in the resting state, 48% of the shots were collected in the upper left corner and 14% in the center, while at increasing levels, the proportion of balls going to the upper right corner increased and after the third level there were no hits in the center area.

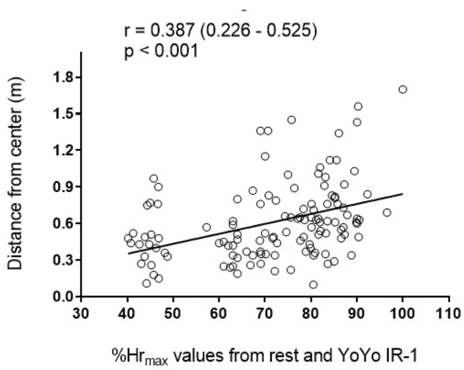

FIGURE 4. Scatter plots for HR (%) and shooting accuracy (m) and linear regression line with 95% CI

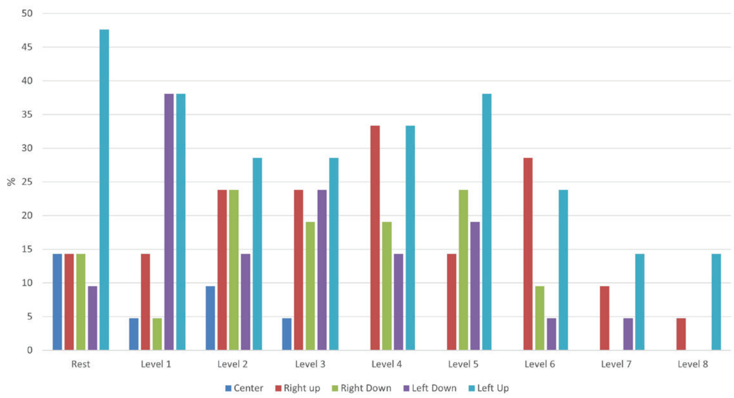

FIGURE 5. Hit zones of shots at rest and at each level of the Yo-Yo IR1 test.

Discussion

The aim of this study was to examine the accuracy of shots at different heart rates at rest and during the YoYo IR1 test. The study showed that shot accuracy was negatively affected as HR increased and there was a moderate positive correlation between them. It was also found that during an average HR of 80%, a significant deterioration in shot accuracy occurred compared to the resting state (approximately between 47%-82%).

In the study, while HRMax was around 44.83% at rest, it increased to 82.22% at the end of Level 5. It was found that the increase in HR impaired shot accuracy and especially from ~80% HR, shot accuracy deteriorated by ~47% compared to resting HR. The findings suggest that there is a negative interaction between HR and shot accuracy. In addition, it was observed that in the resting state, 48% of the shots were collected in the upper right corner and 14% in the center, while at increasing levels, the proportion of balls going to the upper left corner increased and after the third level, there were no shots to the center.

A review of the literature revealed that shooting accuracy (Coutts et al., 2009; Hill-Haas et al., 2010; Kelly & Drust, 2009; Nuño et al., 2016) and passing ability (Rampinini et al., 2008) are negatively affected with increasing fatigue in soccer players. Rampinini et al. (2008) reported that fatigue during a match and after relatively short periods of high-intensity intermittent activity had a negative effect on short passing ability in young soccer players. It is stated that the decrease in technical proficiency due to fatigue is related to the fitness status of the athletes (Rampinini et al., 2008). In a study examining the effects of fatigue on soccer skills performed during a simulated soccer match, it was found that shots made after exercise were 25.5% less accurate than those made before exercise, and passes in the last 15 minutes were 7.8% slower than those in the first 15 minutes (Russell et al., 2011).

Kellis et al. (2006) reported a significant decrease in ball speed (24.69 m/s -21.78 m/s) and a negative effect on shooting performance at the fatigue level induced by a 90-minute exercise protocol with rest interval. This finding was explained by changes in neuromuscular system function and force generating capacity due to fatigue (Kellis et al., 2006). In another study examining the effect of fatigue on shooting biomechanics in soccer, it was concluded that fatigue resulted in a significant decrease in the shooting speed of the ball (Lee, 2018). Stone and Oliver (2009) found that dribbling speed and shooting accuracy were negatively affected after 45 minutes of exertion with soccer-specific skills (Stone & Oliver, 2009). Ferraz et al. (2012) reported that kicking speed in soccer players decreased significantly with fatigue. In our study, it was found that in the YoYo IR1 test, from level 3 (Hrmax=~80%) onwards, approximately 47% of the kicking accuracy was impaired compared to the resting state. Therefore, it can be said that the fatigue that occurs at high tempo with an increase in HR may reduce the shooting success in soccer (Ferraz et al., 2012).

In addition, it has been reported that shooting is affected according to HR velocity variations in sports dominated by intermittent running such as basketball. Ardigo et al. (2018) found that three-point shooting performance in basketball players did not differ significantly at 50% of max HR according to the resting state, but it changed statistically significantly at ~80% (Ardigò et al., 2018). Padulo et al. (2018) reported that the HR of adolescent basketball players did not impair jump shot accuracy in the resting state and at 50%, but when it reached 80%, jump shot accuracy was impaired (Padulo et al., 2018). In our study, it was found that a similar percentage of HR velocity dramatically impaired shooting accuracy. They recommended that three-point shooting drills in basketball can result in higher accuracy during the game if they are performed at moderate to high HR velocity in order to maintain efficiency during the game (Ardigò et al., 2018). Similarly, in soccer, it is thought that high intensity training can contribute positively to the positions that may occur during the match. This specific training can enable players at all levels of the game to better cope with the demands of the game on the pitch and maintain a higher standard of play (Lyons et al., 2006).

In contrast to these studies, there are also studies in the literature that state that fatigue does not directly affect shot accuracy (Ferraz et al., 2019; Royal et al., 2006). However, the most striking finding in these studies is that professional or more expert athletes and amateur or novice athletes have different responses to fatigue. Uygur et al. (2010) suggested that high-level athletes are able to cope with the potentially detrimental effects of fatigue when performing coordinated movements such as free throws (Uygur et al., 2010). Another study found that elite athletes are better able to cope with changing conditions such as physiological stress and overcome the negative effects of high physiological arousal (McMorris & Graydon, 1996). Finally, another study reported that fatigue through repetitive sprinting had no effect on kicking accuracy in a Spanish professional women's soccer club (Torreblanca-Martinez et al., 2020).

There were some limitations in this study, the first being that the intermittent running test was terminated at level 5. The reason for this was to directly examine the effect of soccer-specific HR variations on shooting. Nevertheless, future research could examine the effects of longer levels of running on shooting accuracy. Another limitation was that blood lactate levels were not directly measured. Since there was no direct measurement, the energy threshold of the soccer players could not be determined. Therefore, physiologically, only the effect of the HR variable could be examined. Despite all these limitations, the study showed that HR has a direct effect on one of the most important actions in soccer, which is shooting accuracy.

Conclusion

This study confirms that HR plays a critical role in soccer shot accuracy, with significant declines observed when heart rates exceed 80% of HRmax. Elevated heart rates not only reduce precision but also influence shot placement, reducing attempts at central targets and increasing the likelihood of shots deviating toward the upper right corner. These findings emphasize the importance of preparing players for high-intensity match conditions by integrating targeted drills into training programs. Specifically, practicing various shot techniques under elevated heart rate conditions and monitoring players' HR during training can enhance their ability to maintain accuracy in competitive scenarios. Such tailored training approaches can improve resilience, precision, and overall performance in high-stress match environments.

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Conflict of Interest

The authors declare no conflicts of interest related to this work.

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