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ORIGINAL RESEARCH

The relationship between heart rate responses and technical actions in 3-a-side small-sided games among young male football players

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Abstract

The purpose of this study was to investigate the relationship between heart rate (HR) responses and the technical actions of young male football players during 3-a-side small-sided games (SSGs). Twenty-four players (age: 17.42 ± 0.93 years, body height: 172.54 ± 6.21 cm, body mass: 64.19 ± 7.29 kg; fat percentage of body: 14.22 ± 3.62 %; VO_{2max}: 46.67±2.01 $ml.min^{-1}.kg^{-1}$) performed 3-a-side SSG consisting of four 3-minute bouts, separated by 2-minute passive rest intervals, during the 2022–2023 mid-season period. HR was continuously monitored throughout the SSGs, and the rating of perceived exertion (RPE) were recorded after each bout. The critical technical actions selected for analysis include total passes, one-touch passes, two-touch passes, and shots (both successful and unsuccessful). Pearson correlation analysis was performed to examine the relationship between physiological and technical variables. The significance level of the data was determined as $p<0.05$. A significant positive relationship was found only between one-touch and two-touch successful passes ($r = .442$; $p<0.05$). However, no significant relationship was found between other variables ($p>0.05$). In conclusion, this study demonstrated no clear relation between HR responses or RPE levels and the technical performance of young male football players in 3-a-side SSG. The 3-a-side SSG can simulate HR responses that mimic the physiological demands of match play, irrespective of technical actions. Therefore, this format may be recommended as an efficient tool for compensatory training to optimize game-like physiological loads in players with reduced match exposure, without compromising technical performance.

Introduction

Football is an intermittent team sport structured by alternating short-term high-intensity efforts and low-intensity recovery periods, during which players dynamically compete for space and time to gain an advantage against opponents (Rampinini et al., 2007). Players need to sustain quality and increase the number of high-intensity actions while also tolerating fatigue. Previous studies have reported that the maximum heart rate (HRmax) of young players during match play ranges from approximately 80% and 86% (Castagna et al., 2009). In addition, recent studies show that young football players (16-18 years) cover distances between approximately 10 km, and high-intensity actions (13-18 km/h) account for about 8.6-12% of the distance covered during the competition (Rebelo et al., 2014). However, performance in football is not solely determined by physical efforts. As emphasized by Soylu et al. (2022), football also relies on a combination of technical actions involving the ball (e.g., shooting, dribbling, passing, heading) and movements at various intensities. Considering all these, coaches must develop not only players' aerobic and anaerobic endurance but also their game-specific technical/tactical skills (Hazir et al., 2018; Köklü et al., 2015).

Small-sided games (SSGs) have emerged as an effective training method capable of simultaneously improving physical capacity and simulating technical-tactical demands. Consequently, SSGs have become increasingly popular in both research and applied football training (Dellal et al., 2011; Yılmaz, 2024). SSG is a time-efficient training method that allows working with the ball with fewer players on smaller pitch sizes and concurrently improves football-specific movement patterns, technical-tactical knowledge, and physical capacity under simulated game conditions (Arslan et al.,

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2020). For this reason, in contrast to traditional running-based aerobic capacity development methods, SSGs involve more suitable, enjoyable, and efficient outcomes in terms of goal-oriented training gain (Köklü et al., 2012). Because, running-based high-intensity interval training (HIIT) only contributes to the development of aerobic capacity (Billat et al., 2002) and high-intensity movements based on the anaerobic system, such as repetitive sprinting skills (Dellal et al., 2010). But it is thought to neglect other essential football components, such as technical and tactical skills, perceptual-cognitive skills, visual-auditory scanning, decision-making, and anticipating (Eniseler et al., 2017; Birinci et al., 2025a).

It is well reported that coaches can affect the technical and tactical performance and HR responses of SSGs' according to the purpose of training (Aguiar et al., 2013) by manipulating various factors such as pitch size (Aslan, 2013), the number of players (Köklü et al., 2011), work-to-rest ratio (Casamichana et al., 2013), coach encouragement (Birinci et al., 2025b), and rule modifications (Castillo et al., 2020). For instance, studies showed that increased pitch size of 1vs1 to 5vs5 SSGs (Owen et al., 2004) and decreased number of players (Köklü et al., 2011) resulted in increased HR responses and blood lactate accumulation in professional football players. Moreover, Dellal et al. (2011) showed that limiting the ball touches in SSGs will enhance technical and physical performance. Mallo & Navarro (2008) claimed that playing SSGs with goalkeepers changed the average intensity of exercise.

Understanding how such manipulations influence physiological and technical outcomes can assist coaches to integrate the SSGs into their training programs, manage training load effectively, and align technical skill development with training objectives. Therefore, the aim of this study was to investigate the relationship between HR responses and the technical performance of young male football players in 3-a-side SSG. We hypothesized that there would be a relation between HR responses and technical actions in 3-a-side SSG format in young football players.

Methods

Participants

24 male young football players (age: 17.42 ± 0.93 years, body height: 172.54 ± 6.21 cm, body mass: 64.19 ± 7.29 kg; fat percentage of body: % 14.22 ± 3.62; VO_{2max}: 46.67±2.01 ml.min-1.kg-1) voluntarily participated in this study during the 2022–2023 mid-season period. All the subjects (sports background of at least 4 years and a training workload of at least 4 days/week) were chosen from the same team competing in a U-18 development league. Before signing the informed consent form, subjects and parents were informed of the research procedures, benefits, and risks. This study was approved by the Research Ethics Committee of Uludag University (2023-1/29) and was conducted in accordance with the Declaration of Helsinki.

Experimental Approach

A pretest-posttest design was used to investigate the relation between HR responses and the technical actions of youth football players in 3-a-side SSG. SSG groups (3vs3) were determined according to the rankings in the Yo-Yo Intermittent Recovery Test Level-1 (YYIRT-1) to avoid the difference because of the fitness levels.

SSG sessions were conducted in the morning (11.00-12.00) to have similar chronobiological characteristics on a natural grass pitch during the mid-season training period. Players were advised to avoid high-intensity exercise within 48 hours, be prohibited from drinking alcohol or coffee within 24 hours, and get at least 7-8 hours of sleep before the SSG intervention. During the study, the players were informed to continue their normal dietary and habitual lifestyle.

Procedures

The intervention consisted of 2 visits for each participant. The intervention procedure is summarized in Figure 1. In the first visit, the body weight and body fat percentage were measured with the bioelectrical impedance measurement (BC-418, Tanita, Tokyo, Japan). After the anthropometric measurements, resting HR were taken for each player. Then, a reliable (Krustrup et al., 2003) and acoustically progressive YYIRT-1 test was conducted following the procedures outlined by Bangsbo et al., (2008) to assess aerobic capacity on a natural grass pitch. After the test, the estimated VO_{2max} was calculated using the following formula:

"VO_{2max} = 36.4 + (0.0084 × covered distance in YYIRT-level 1)."

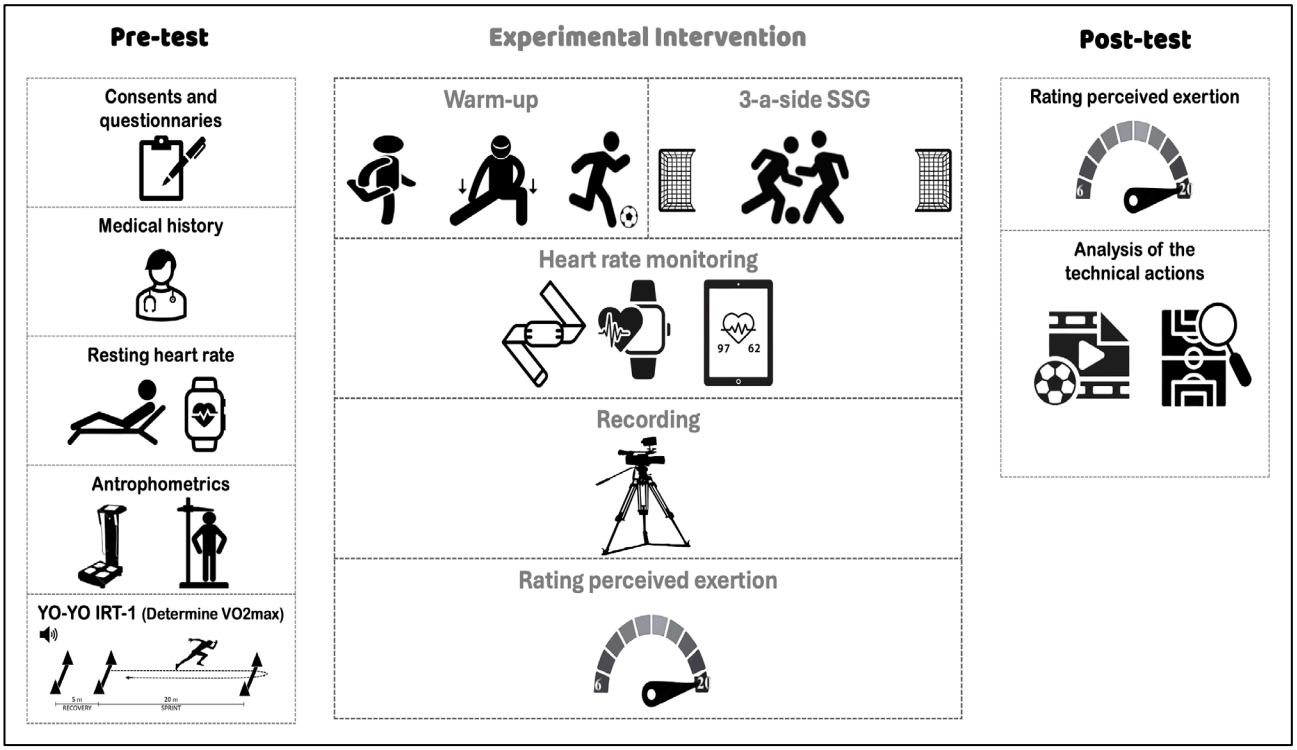

Figure 1. Experimental design. *HR: Heart Rate; HRmax: Maximal Heart Rate; RPE: Rating of Perceived Exertion; VO_{2max}: Maximum Oxygen Consumption; YYIRT-1; Yo-Yo Intermittent Recovery Test Level-1.*

Table 1
The features of 3-a-side small-sided game (SSG).

3-a-side SSG format	
Number of the bouts	4
Bout duration (min)	3
Resting duration (min)	2
Grid size (length X width) (m)	34 X 26
Total grid area (m^2)	884
Grid ratio (length: width)	1.31: 1
Ratio per player (grid total area): m^2	1: 147
Small goals	Yes (1.0 X 1.0 m)
Coach encougarement/feedback	Yes
Rules	A maximum of three consecutive touches of the ball, no offside

In the second visit, a 20-minute warm-up (jogging, dynamic stretching, and football-specific actions) was performed under the supervision of the expert strengt and conditioning coach. Then players performed 3-a-side SSG consisting of 4 bouts, each lasting for 3 minutes (Table 1). The passive recovery time between bouts was 2 minutes between all the bouts for a particular SSG session. The rating of perceived exertion (RPE, assessing for physical fatigue) scale was also reported by players after each bout of SSGs. Players were allowed to drink water during all recovery periods of the SSGs.

An HR monitor (Polar M430, Kempele, Finland) was used. The technical actions of the players were recorded by using a high-definition video camera (Canon LEGRIA HF R806, Tokyo, Japan). Then, critical both successful and unsuccessful technical actions such as pass, one touch pass, two touch pass and shot were analyzed by UEFA A licensed experienced football coaches (Y.Z.B) using a special football analysis program (eAnalyze Soccer: Espor Digital, Ankara, Turkey).

Statistical Analysis

Arithmetic mean and standard deviation analyses were performed for information such as the research group's height, weight, and BMI. Skewness and kurtosis values were examined to determine whether the data were normally distributed. It has been determined that the values are in the range of -1.5 and +1.5. Pearson correlation analysis was performed to examine the

relationship between continuous variables. The significance level of the data was determined as $p<0.05$. SPSS 26 statistical program was used for the analysis of the data.

Results

Table 2 demonstrates the mean values of the HR responses (173.67±5.05 bpm) and technical action performances (number of successful passes: 23.79 ± 1.95, number of unsuccessful passes: 3.12 ± 1.42, number of successful passes with one touch: 3.50 ± 1.25, number of successful passes with two touches: 3.54 ± 1.06, number of successful shots 3.54 ± 1.06, the number of successful shots: 3.13 ± 1.03, number of successful passes with one touch: 3.50 ± 1.25) of youth football players during 3-a side SSG.

Table 3 demonstrates the relation of participants' HR responses, RPE scores, and the number of successful passes, unsuccessful passes, successful one-touch passes, two-touch successful passes, successful shots, and unsuccessful shots. As the table indicates, there was a significant positive relationship between only one-touch and two-touch passes ($r = .442$; $p<0.05$). However, no significant relationship was found between other variables ($p>0.05$).

Discussion

This study investigated the relationship between HR responses and the technical performance of young football players during 3-a-side SSGs. The findings revealed that using 3-a-side SSGs significantly increased internal load indicators such as HR and RPE, closely mimicking the physiological demands of official match play. However, no clear association was found between technical actions and HR or RPE responses.

These findings are in line with previous research. For instance, Fanchini et al. (2011) examined the effects of different bout durations (2, 4, and 6 minutes) on exercise intensity (HR and RPE) and technical actions in male football players. They reported that while exercise intensity varied with bout duration, technical actions remained unaffected. Similarly, Moreira et al. (2016) showed that technical performance (goal attempts, tackles, interceptions, passes, pass effectiveness, and individual ball possession) was maintained during 5-a-side SSG (2 x 8 minutes with 3 minutes of passive rest) in youth players, without compromising physical performance. In support of these findings, Soylu et al. (2022) investigated technical performances, psychophysiological responses and

Table 2
Physiological and technical responses of participants during 3-a-side SSG.

	Variables	Mean ± SD
Physiological Responses	HR (beat.min^{-1})	173.67 ± 5.05
	RPE (score)	14.50 ± 1.89
Technical Actions	Successful pass (number)	23.79 ± 1.95
	Unsuccessful pass (number)	3.12 ± 1.42
	One-touch successful pass (number)	3.50 ± 1.25
	Two-touch successful pass (number)	3.54 ± 1.06
	Successful shot (number)	3.13 ± 1.03
	Unsuccessful shot (number)	1.96 ± 0.95

HR: Heart Rate; RPE: Rating of Perceived Exertion; SD:Standart deviation.

Table 3
The relation of participants' physiological responses and technical actions.

	HR	RPE	SP	UP	SP^1	SP^2	SS	US
HR	1	-.146	-.227	-.042	-.213	-.216	.183	-.039
RPE		1	-.194	-.073	.129	-.076	-.078	-.133
SP			1	.119	.364	.119	.164	-.005
UP				1	-.134	.011	.136	-.156
SP^1					1	.442*	.050	.091
SP^2						1	.133	-.148
SS							1	-.391
US								1

HR: Heart rate; RPE: Rating of Perceived Exertion; SP: Successful Pass; SP^1: One-touch Successful Pass; SP^2: Two-touch Successful Pass; SS: Successful Shot; UP: Unsuccessful Pass; US: Unsuccessful Shot.

kinetimatic profiles of young football players across different SSG formats (2vs2, 3vs3, 4vs4) conditions with and without mental fatigue. They observed that technical performance was only negatively affected under mental fatigue conditions, despite similar HR values (174.5 ± 4.8 bpm) to those observed in the current study. Likewise, Farhani et al. (2022) compared %HR peak, blood lactate, RPE, and technical-tactical performance in 4vs4 and 3vs3 SSGs with different bout durations (1x12min, 2x6min, 3x4min) in adult players. Interestingly, continuous format (1x12) resulted in higher successful pass rates and lower ball losses, despite increased physiological strain, suggesting that technical performance can be maintained—or even improved—under higher internal loads depending on the bout structure.

On the other hand, some studies present contrasting results. For example, Aslan (2013) reported that smaller pitch sizes may increase the number of unsuccessful passes compared to larger ones. In contrast, a study by Clemente et al., (2019) showed that in 3-a side games can enhance the number of individual technical actions due to the greater frequency of on-ball and off-ball involvements. Considering the nature of 3-a-side SSGs, which require players to perform continuous actions under high HR conditions, we hypothesized that a relationship would exist between physiological load and technical execution. However, the findings of this did not support this hypothesis. While internal load increased significantly, technical actions appeared to be independent of HR and RPE responses. In this study, players' positions were not categorized when evaluating technical actions. However, Owen et al. (2011) emphasized that different playing positions may require distinct technical demands. Therefore, the lack of positional differentiation might have obscured potential relationships between HR variability and spesific technical actions.

Another explanation for our findings could be the inherent nature of 3-a-side SSGs. Despite inducing high training intensities, SSGs provide frequent ball contacts per player, potentially allowing players to compensate for unsuccessful technical actions through repeated opportunities. This may help maintain overall technical performance, regardless of internal load. Additionally, our SSG regimes might not have been long enough to induce technical fatigue. Supporting this, Beato et al., (2014) suggested a significant decline in technical performance typically occurs only after extended play durations, such as beyond four sets of 4 minutes.

The mean HR observed in our study (173.67 ± 5.05 bpm) is comparable to values reported in previous literature on 3-a-side SSGs, which typically elicit HR responses between 173 and 184 bpm-within the range observed during official match play (150-180 bpm) in young players (Capranica et al., 2001; Strøyer et al., 2004). Brandes et al. (2012) reported a mean HR of 184.1 ± 6.8 bpm during 3-a-side SSGs in elite youth footballers, concluding that this format is appropriate for football-specific aerobic conditioning. Similarly, Aşçı (2016) showed that HR responses during 3-a-side SSGs (177.1 ± 7.3 bpm) were significantly higher than during official matches, suggesting their use for high-intensity conditioning. Likewise, Köklü and Alemdaroğlu (2016) demonstrated that 3-a-side SSGs elicit higher %HRmax and RPE scores compared to 2- to 4-a-side formats, making them effective for developing anaerobic performance.

In contrast to these findings, Li et al. (2022) found no significant differences in blood lactate or mean HR (157 ± 17 bpm) between 3v3, 5v5, and 8v8 SSGs in elite youth players. Similarly, Gómez-Carmona et al. (2018) showed that 6-a-side SSGs with match-like rules involving goalkeepers generated physiological responses comparable to official matches.

These discrepancies across studies may stem from variations in SSG design parameters. Key influencing factors include pitch size (Gantois et al., 2023), number of ball contacts (Dellal et al., 2010), positional roles (Dellal et al., 2012), different formats (Yılmaz & Soylu, 2024) and participant characteristics such as age, experience and competitive level (Clemente & Sarmento, 2020). Such methodological differences likely contribute to the inconsistencies in physiological and technical responses observed in the literature.

The present findings offer practical insights for coaches aiming to structure SSGs that optimize both technical and physiological outcomes in youth football. However, some limitations must be acknowledged. The main limitation is the small sample size needed to be sufficiently large to generalize the results. Another limitation is the the absence of positional categorization may have masked position-specific technical trends). The final limitation of this study, participants spanned a wide age range (16–18 years), which could have influenced their workload capacity and response to SSG formats. Indeed, López-Fernández et al. (2020) highlighted that training loads vary across age groups in youth football. Therefore, future studies should consider increasing sample size, matching age groups,

and accounting for positional differences to better explore the interaction between physiological demands and technical performance in SSG contexts.

Conclusion

This study demonstrated no significant relationship between HR responses or RPE levels and the technical performance of young male football players during 3-a-side SSG. However, the 3-a-side SSG elicited internal load responses, particularly HR values, that closely mimic the physiological demands of official match play, irrespective of technical actions. Therefore, 3-a-side SSG may serve as a practical compensatory training tool for players with limited match time. It allows for the optimization of training load under game-like physiological conditions without negatively affecting technical performance.

Authors' Contribution

Study Design: S.P., Y.Z.B. ; Data Collection: S.P., Y.Z.B; Statistical Analysis: S.P., Y.Z.B; Manuscript Preparation: S.P., Y.Z.B; Funds Collection: S.P., Y.Z.B.

Ethical Approval

The study was approved by the Uludag University Faculty of Medicine Clinical Research Ethics Committee (01.11.2023-2023-1/29) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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