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Research article

FLUCTUATIONS IN HEART RATE RESPONSE AND EXTERNAL DEMANDS RELATIVE TO GAME PERIOD IN RECREATIONAL FOOTBALL

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Abstract. *This study aimed to investigate fluctuations in external demands and heart rate (HR) response across two game periods (half-times) in recreational football players. Eighteen recreationally active, male college students (goalkeepers: n = 2; outfield players: n = 16; age: 20.9 ± 1.5 yr; height: 179.4 ± 5.0 cm; body mass: 76.9 ± 8.1 kg; fat mass: 15.3 ± 5.5%) participated in this study. Two sessions were used to administer 4-a-side small-side games (SSG). Differences in activity demands and HR response were analyzed using a paired sample t-test. The magnitude of the differences in each dependent variable was quantified with effect size (ES) analyses and interpreted as: trivial, <0.2; small, 0.2–0.59; moderate, 0.6–1.19; large, 1.2–1.99; very large, >2. An ES analysis showed, small to moderate, significant decreases in distance covered at 0-6.00 km·h^{-1} (ES = -0.54, small), 6.01-12.00 km·h^{-1} (ES = -0.99, moderate), 12.01-18.00 km·h^{-1}(ES = -0.66, moderate), >24 km·h^{-1} (ES = -0.72, moderate), total distance (ES = -0.91, moderate) and high-intensity accelerations (ES = -0.60, moderate) during the second rather than the first half. In addition, unclear significant decreases in HR_{mean}, and percentage of time spent working 81-90% HR_{max} were observed across two game periods. Our findings indicate game-related fatigue, whereby players demonstrated a consistent HR response across two game periods despite diminutions in activity demands during the second half. Similarities in HR response across two game periods might be due to the lower physical fitness of recreational players, eliciting slower HR recovery.*

Key words: *football, physical fitness, college students*

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INTRODUCTION

Traditionally, continuous aerobic activities such as brisk walking, running, and cycling have been used as a health-promoting type of training. However, recent meta-analysis has shown that high-intensity interval training and recreational football produces larger improvements in maximal oxygen uptake (indicator of cardiovascular fitness) than continuous moderate-intensity endurance running (Milanović, Pantelić, Čović, Sporiš, & Krustrup, 2015; Milanović, Sporiš, & Weston, 2015). However, recreational football has a higher potential to keep players motivated, while maintaining an intense level of activity, which is of paramount importance for health and fitness adaptation.

Recreational football in the form of small-sided games (SSG) has received attention by Danish researchers, leading to an increased number of investigations aimed at quantifying internal and external demands imposed on players (Randers, Brix, Hagman, Nielsen, & Krustrup, 2017; Randers, Nielsen, Bangsbo, & Krustrup, 2014; Randers et al., 2010; Randers, Ørntoft, Hagman, Nielsen, & Krustrup, 2018). It has been demonstrated that the intensity of recreational football SSG is affected by a range of factors, including player number (Randers et al., 2018), pitch size (Pantelić et al., 2019), boards (Randers et al., 2017), and regime of play (continuous vs. interval) (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011).

However, despite a growing interest, fluctuations in external demands and heart rate (HR) response across game periods remain un-described. Considering the link between work rates and fitness optimization, greater research attention should be directed toward quantification in internal and external demands across game periods. Assessing the external demands and HR response imposed on players relative to the game period allows an understanding of the distribution of physical and cardiovascular workload across games and potential accumulation of fatigue. Understanding of the fluctuations in work rate will assist players in having better control over training, and thus create a more efficient training process.

Hence, this study aimed to investigate the fluctuations in external demands and HR response across two game periods (half-times) in recreational football players.

METHODS

Participants

Eighteen recreationally active, male college students (goalkeepers: n = 2; outfield players: n = 16; age: 20.9 ± 1.5 years; stature: 179.4 ± 5.0 cm; body mass: 76.9 ± 8.1 kg; fat mass: 15.3 ± 5.5%) participated in this study. Written informed consent was obtained from all the participants after an explanation of the experimental design. All procedures were approved by the institutional Human Research Ethic Committee.

Experimental design

This study was conducted over a 3-week period across five sessions. The first session was used to familiarize the participants with the testing procedures, as well as each of the football SSG formats. During the second and third session, anthropometric measures were taken for each participant [using a multi-frequency bioelectrical impedance analyzer (InBody 770, Biospace Co. Ltd, Seoul, Korea) and portable stadiometer (Seca 220, Seca Corporation, Hamburg, Germany)], followed by the 30-15 Intermittent Fitness Test (Buchheit, 2010) to determine maximal heart rate (HR_{max}). The remaining two sessions were used to administer 4-a-side SSG. Specifically, half of the participants completed the football SSG during the first week, while the remaining participants completed it the following week. Two goalkeepers participated in each session. Goalkeepers were not included in the final data set, given their restricted movement requirements (Randers, Andersen, Rasmussen, Larsen, & Krustrup, 2014). The participants completed a standardized warm-up [moderate-intensity jogging (4 min), static and dynamic stretching (4 min), and accelerative running bouts (2 min)], followed by 2 x 20-min periods of recreational football SSG with a 5-min half-time break and a 5-min cool-down following game completion. The participants were permitted to consume water ad libitum between two periods and following games. Data collected during the warm-up, half-time break, and cool-down periods were not included for analysis. Sessions were conducted at the same time of day (10:00-11:00 h) to avoid any effect of circadian rhythm on the measured variables (Pavlović et al., 2018). All testing sessions were performed on the same indoor football court. The pitch size of all the SSG was fixed at 40 x 20 m with consistent goal sizes (2 m high x 3 m wide). A single standard-size football was used in each SSG.

Heart rate monitoring

HR was continuously recorded at 1-s intervals using a Polar Team Pro System (Polar Electro, Kempele, Finland) whereby the participants had HR monitors affixed to their chest at the level of the xiphoid process. HR responses were presented relative to individualized HR_{max}. All HR data were stored by HR monitors throughout the SSG and transferred to an iPad (A1822; Apple; California, USA) using the Polar Pro Team dock (Polar Electro, Kempele, Finland). Data were then exported to Microsoft Excel (v15.0; Microsoft Corporation; Redmond, WA, USA) to calculate the time spent in the following HR-mediated intensity zones: <70%HR_{max}, 71-80%HR_{max}, 81-90%HR_{max}, and 91-100%HR_{max}. Mean and peak HR responses were also determined.

Activity demands

The activity demands were measured using portable GPS devices (10 Hz, Polar Team Pro, Kemple, Finland). The 10 Hz GPS technology was previously determined as reliable and valid for assessing team sport movement profiles (Nikolaidis, Clemente, van der Linden, Rosemann, & Knechtle, 2018). The following movement categories and velocities were used in the current study (Puente, Abián-Vicén, Areces, López, & Del Coso, 2017): standing/walking <6 $km \cdot h^{-1}$; low-speed running 6.01-12 $km \cdot h^{-1}$; moderate-speed running 12.01-18 $km \cdot h^{-1}$; high-speed running 18.01-24 $km \cdot h^{-1}$; and maximal-speed running >24 $km \cdot h^{-1}$. The frequency of accelerations and decelerations were measured using accelerometers within the Polar Team system sampling at 200 Hz (Polar Team Pro, Kemple, Finland). Default zones set by the manufacturer were used to categorize acceleration/deceleration intensities as: low, 0.5-0.99 $m \cdot s^{-2}$; medium, 1-1.99 $m \cdot s^{-2}$; and high, >2 $m \cdot s^{-2}$.

Statistical analysis

Data analyses were performed using IBM SPSS software (v25.0, IBM Corporation; Armonk, NY, USA). Normality of all data was confirmed with the Shapiro-Wilk test. Mean ± standard deviation was calculated for each outcome measure. Differences in HR and activity demands were analyzed using a paired sample t-test. The magnitude of differences in each dependent variable was quantified with effect size (ES) analyses and interpreted as: *trivial*, <0.2; *small*, 0.2–0.59; *moderate*, 0.6–1.19; *large*, 1.2–1.99; *very large*, >2 (Hopkins, Marshall, Batterham, & Hanin, 2009). An effect was deemed *unclear* if the confidence intervals overlapped the threshold for substantial positive and negative values (±0.20 standardized units) (Hopkins et al., 2009).

RESULTS

Mean ± standard deviation HR responses and external load variables relative to game period are presented in Table 1. The paired T-test showed statistically significant differences across two game periods for external demands (total distance, distance covered at 0-6.00 $km \cdot h^{-1}$, 6.01-12.00 $km \cdot h^{-1}$, 12.01-18.00 $km \cdot h^{-1}$, >24 $km \cdot h^{-1}$ and acceleration >2 $m \cdot s^{-2}$) and HR response (HR_{mean}, <70%HR_{max}, 81-90%HR_{max}). Effect size analysis showed *small* to *moderate*, significant decreases in the distance covered at 0-6.00 $km \cdot h^{-1}$ (ES = -0.54, *small*), 6.01-12.00 $km \cdot h^{-1}$ (ES = -0.99, *moderate*), 12.01-18.00 $km \cdot h^{-1}$ (ES = -0.66, *moderate*), >24 $km \cdot h^{-1}$ (ES = -0.72, *moderate*), total distance (ES = -0.91, *moderate*) and high-intensity accelerations (ES = -0.60, *moderate*) during the second than the first half. In addition, *unclear* significant decreases in HR_{mean}, and percentage of time spent working 81-90%HR_{max} were observed across two game periods.

Table 1 Internal and external load variables relative to the game period in recreational football players (n = 16).

Outcome measure	Two game periods: 1st half	2nd half	Effect size (95% CI)	Interpretation	*p* value
HR response					
HR_{mean} ($beats \cdot min^{-1}$)	168.7±13.3	165.6±13.2	-0.23 (-0.92 to 0.47)	*unclear*	**0.04**
HR_{mean} (%HR_{max})	82.1±7.9	80.7±8.0	-0.18 (-0.87 to 0.52)	*unclear*	**0.04**
<70%HRmax	13.0±26.1	17.1±26.4	0.16 (-0.54 to 0.85)	*unclear*	**0.03**
71-80%HRmax	22.4±16.3	27.2±15.7	0.30 (-0.40 to 0.99)	*unclear*	0.10
81-90%HRmax	48.2±24.6	39.4±22.5	-0.37 (-1.06 to 0.33)	*unclear*	**0.02**
91-100%HRmax	16.4±22.7	16.4±26.8	0.00 (-0.69 to 0.69)	*unclear*	0.98
External demands					
Distance covered					
0-6.00 $km \cdot h^{-1}$	828.1±82.4	775.7±110.5	-0.54 (-1.23 to 0.18)	*small*	**0.01**
6.01-12.00 $km \cdot h^{-1}$	452.7±157.1	296.9±156.9	-0.99 (-1.70 to -0.23)	*moderate*	**0.00**
12.01-18.00 $km \cdot h^{-1}$	193.7±133.3	122.1±76.8	-0.66 (-1.35 to 0.07)	*moderate*	**0.05**
18.01-23.99 $km \cdot h^{-1}$	83.6±99.6	40.6±28.1	-0.59 (-1.28 to 0.13)	*small*	0.10
>24 $km \cdot h^{-1}$	32.6±41.5	10.4±12.6	-0.72 (-1.42 to 0.01)	*moderate*	**0.04**
Total distance	1590.5±423.5	1245.7±323.9	-0.91 (-1.62 to -0.16)	*moderate*	**0.01**
Acceleration categories					
0.50-0.99 $m \cdot s^{-2}$	97.4±32.4	112.9±40.1	0.43 (-0.29 to 1.11)	*unclear*	0.11
1.00 – 1.99 $m \cdot s^{-2}$	115.4±24.2	119.9±28.1	0.17 (-0.53 to 0.86)	*unclear*	0.46
>2 $m \cdot s^{-2}$	24.7±15.5	17.3±8.1	-0.60 (-1.29 to 0.12)	*moderate*	**0.03**
Total acceleration	237.4±45.4	250.1±61.7	0.23 (-0.47 to 0.92)	*unclear*	0.31
Deceleration categories					
0.50-0.99 $m \cdot s^{-2}$	104.2±30.9	113.4±44.4	0.24 (-0.46 to 0.93)	*unclear*	0.22
1.00 – 1.99 $m \cdot s^{-2}$	116.7±27.5	123.4±30.4	0.23 (-0.47 to 0.92)	*unclear*	0.33
>2 $m \cdot s^{-2}$	26.7±16.3	20.6±12.1	-0.42 (-1.11 to 0.29)	*unclear*	0.10
Total deceleration	247.6±48.2	257.4±64.7	0.17 (-0.53 to 0.86)	*unclear*	0.37

DISCUSSION

This study aimed to investigate fluctuations in HR response and external demands across two game periods in recreational football players. No research has explored fluctuation in distance covered and HR response relative to the game period, despite providing an understanding of the distribution of cardiovascular and physical workload across games and potential accumulation of fatigue. The results showed that recreational players complete a greater overall external workload (total distance, distance covered at 0-6.00 km·h^{-1}, 6.01-12.00 km·h^{-1}, 12.01-18.00 km·h^{-1}, >24 km·h^{-1}, and acceleration >2 m·s-2) during the first than the second half, while the HR response remain unchanged.

Small to *moderate*, statistically significant reductions in distance covered at 0-6.00 km·h^{-1} (ES = -0.54, *small*), 6.01-12.00 km·h^{-1} (ES = -0.99, *moderate*), 12.01-18.00 km·h^{-1} (ES = -0.66, *moderate*), >24 km·h^{-1} (ES = -0.72, *moderate*) and total distance (ES = -0.91, *moderate*) were observed with SSG progression. In contrast, Jones, West, Crewther, Cook, and Kilduff (2015) reported non-significant differences between two game periods for distance measures in professional rugby players. The reduced aerobic fitness of recreational players compared to professional rugby players might underpin these differences. In addition, these disparities may be due to variations in competition settings (recreational vs. official). Nevertheless, Jones et al. (2015) identified significant decreases in player load, cruising and striding with game progression. Overall, differences in activity data were evident relative to the game period, with players experiencing declines in external demands across two game periods.

In addition to activity distance data, time-related reduction in high intensity accelerations were also observed. These trends concur with those observed in the rugby league and football (Akenhead, Hayes, Thompson, & French, 2013; Jones et al., 2015). Previously, diminutions of accelerations and decelerations with game progression in adult soccer players have been reported (Akenhead et al., 2013). Similarly, temporal analysis in the rugby league displayed significant differences in player load and acceleration/deceleration significantly declining throughout each half (Jones et al., 2015). Decreases in activity demands are likely underpinned by peripheral fatigue-related mechanisms which have been shown to reduce the rate of force development and maximal force production compared to baseline levels (Rahnama, Reilly, Lees, & Graham-Smith, 2003; Thorlund, Aagaard, & Madsen, 2009). The current study provides further evidence regarding attenuation of acceleration demands during game-play.

Despite diminutions in external load, the HR response remained unchanged, with *unclear* differences between two game periods. No research has measured HR response relative to the game period in recreational football players. Our findings indicate game-related fatigue, whereby players demonstrated a consistent HR response across two game periods despite diminutions in activity demands during the second half. Similarities in the HR response across two game periods might be due to lower physical fitness of recreational players, resulting in slower HR recovery. In addition to the HR response, many physiological measures might underpin the onset of fatigue such as muscle glycogen depletion, temperature elevation, inadequate resynthesis of phosphocreatine and adenosine trisphosphate and muscle damage. However, given the limitation in data acquisition methods, further research is needed to fully elucidate the physiological fatigue-related mechanisms.

Throughout the current study, some limitations were recognized. First, activity categories were quantified using generalized speed thresholds. Therefore, future studies should quantify activity data in an individualized manner relative to each player's maximal sprint velocity. Second, multi-directional running, cuts, shuffling demands were not quantified and should be considered when interpreting the present data, given this activity may constitute a considerable portion of movements in football SSG. Third, given the influence of the playing level (Dellal, Hill-Haas, Lago-Penas, & Chamari, 2011) on player responses during game-play our findings are not transferable to elite and sub-elite football players.

CONCLUSION

In conclusion, the first playing bout imposed greater overall external workload (total distance, distance covered at 0-6.00 $km \cdot h^{-1}$, 6.01-12.00 $km \cdot h^{-1}$, 12.01-18.00 $km \cdot h^{-1}$, >24 $km \cdot h^{-1}$, and acceleration >2 $m \cdot s^{-2}$) on recreational football players, while HR response remained unchanged. Shorter playing bouts should be considered for administration providing the opportunity for recovery and improved game activity workload.

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FLUKTUACIJE U SRČANOJ FREKVENCIJI I SPOLJAŠNJIM ZAHTEVIMA U ODNOSU NA PERIOD IGRE U FUDBALU

Cilj ove studije bio je da se istraže fluktuacije u spoljašnjim zahtevima i srčanoj frekvenciji kroz periode igre kod fudbalera rekreativaca. Osamnaest rekreativno aktivnih studenata muškog pola (golmani: n=2; igrači: n=16; starost: 20.9 ± 1.5 god.; visina: 179.4 ± 5.0 cm; telesna masa: 76.9 ± 8.1 kg; masna masa: 15.3 ± 5.5%) je učestvovalo u ovoj studiji. Dve sesije su korišćene za igru 4 na 4. Razlike u spoljašnjim zahtevima i srčanoj frekvenciji analizirane su t-testom zavisnih uzoraka. Veličina razlike u svakoj zavisnoj varijabli je kvantifikovana efektom (ES – effect size) i interpretirana kao: trivijalna, <0.2; mala, 0.2–0.59; umerena, 0.6–1.19; velika, 1.2–1.99; veoma velika,> 2. Analiza veličine efekta pokazala je mala do umerena, značajna smanjenja u predjenoj distanci brzinom 0-6.00 km·h^{-1} *(ES = -0.54, mala), 6.01-12.00 km·h*$^{-1}$ *(ES = -0.99, umerena), 12.01-18.00 km·h*$^{-1}$ *(ES = -0.66, umerena), > 24 km·h*$^{-1}$ *(ES = -0.72, umerena), ukupnoj distanci (ES = -0.91, umerena) i visoko intenzivnim ubrzanjima (ES = -0.60, umerena) u drugom poluvremenu u odnosu na prvo. Pored toga, uočeno je nejasno značajno smanjenje srčane frekvencije i procenat vremena provedenog u radu 81-90%*HR_{max} *kroz periode igre. Nalazi studije ukazuju na umor uzrokovan igrom, pri čemu su igraču pokazali konzistentnu srčanu frekvenciju uprkos smanjenju spoljašnjih zahteva tokom drugog poluvremena. Sličnosti u srčanoj frekvenciji kroz periode igre mogle bi biti posledica manje fizičke spremnosti rekreativnih igrača, izazivajući sporiji oporavak srčane frekvencije.*

Ključne reči: *fudbal, fizička spremnost, studenti univerziteta*