

Assessment of the body response to specific fatigue exercise protocol SAFT90 in U16 soccer players

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Background: SAFT90 is a specific multidirectional fatigue protocol that imitates the internal and external load of soccer match-play. **Objective:** The aim of the study was to evaluate the impact of SAFT90 on lactate production, heart rate (HR) and rate of subjective perceived exertion (RPE) expressed by Borg scale (6–20). **Methods:** Fourteen male elite junior soccer players (age 15.9 ± 0.2 years, stature 180.8 ± 5.5 cm, body mass 69.8 ± 5.8 kg, body fat $8.1 \pm 3.2\%$, $\text{VO}_{2\text{max}}$ 57.6 ± 4.7 ml·kg⁻¹·min⁻¹, maximum heart rate 192.8 ± 4.6 beats·min⁻¹) participated in this study. Lactate concentration, HR and RPE were monitored during specific fatigue exercise protocol SAFT90. **Results:** Results of HR showed mean values of 153 ± 15 beats·min⁻¹, mean blood lactate concentration was 1.9 ± 0.5 mmol·L⁻¹. A mean value of RPE was 11.0 ± 1.4 that corresponds to “fairly light” exercise. No significant change was found between consecutive SAFT90 stages for HR and lactate concentration. For Borg scale, there were significant increases between stages 20 min and 45 min and between stages 70 min and 90 min. Change between stages 45 and 70 min was not significant. **Conclusions:** In respect to study results, we suggest that specific fatigue protocol SAFT90 applied in U16 soccer players appears to be insufficient in terms of exercise intensity to achieve comparable lactate concentration, HR and RPE values with a soccer match.

Keywords: exercise field-testing, external and internal load, lactate, heart rate, rate of perceived exertion, soccer performance

Introduction

Soccer as the most popular game in the world is played by men and women throughout all age categories and levels. During 90 min of a soccer match, adult players cover a distance of 10–12 km (Di Salvo et al., 2007). Previous studies have reported the distance 6–8 km in elite youth soccer players (U12–U16) while older players (U16) covered significantly higher total distances than U12 (Harley et al., 2010; Stølen, Chamari, Castagna, & Wisløff, 2005). Game performance is characterized by alternating short intervals of high or low intensity. Intervals of high intensity are typically interspersed by passive or active recovery periods. During a soccer match, the level of heart rate (HR) is close to anaerobic threshold, usually 80–90% of maximal HR (Dellal et al., 2010; Stølen et al., 2005). Due to

the duration, intermittent features and requirements of the game, aerobic capacity with emphasis on strength, speed and specific movement skills are considered important in terms of successful performance (Maly, Sugimoto, Izovska, Zahalka, & Mala, 2018; Stølen et al., 2005). Although aerobic metabolism dominates, to perform crucial actions as jumps, short sprints, duel plays etc. require anaerobic energy release. A review of Stølen et al. (2005) involving both junior and senior soccer teams, reported the mean blood lactate concentration during a soccer match ranged between 2–10 mmol·L⁻¹. However, Lehnert et al. (2018) presented post-test blood lactate concentration of 1.72 ± 0.32 mmol·L⁻¹ and a moderate rate of perceived exertion (RPE). The previous findings showed higher blood lactate concentration in the first half of a soccer match (Bangsbo, 2007; Stølen et al., 2005). In male soccer $\text{VO}_{2\text{max}}$ ranges from 50–75 ml·kg⁻¹·min⁻¹ according to age and playing position (Botek, Krejčí, McKune, & Klimešová, 2016; Semjon, Botek, Svozil, & McKune, 2016; Soyul, Korkmaz Eryilmaz, Polat, & Aydoğan, 2017; Stølen et al., 2005).

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Another factor influencing soccer performance is somatic profile. Not only body height varies between soccer positions considerably, also body fat percentage varies from 7 to 12% among national senior soccer teams (Ademović, 2016; Reilly & Williams, 2003). Semjon et al. (2016) reported that different playing positions require specific somatic characteristics. The crucial elements of soccer performance are regularly tested to evaluate the physical performance or effectiveness of training programs (Dragijsky, Maly, Zahalka, Kunzmann, & Hank, 2017; Svensson & Drust, 2005). Exercise field tests such as Yo-Yo test, INTER test, single-sprint test, multi-sprint test or laboratory tests (e.g., maximal aerobic power) do not imitate the overall soccer performance and real soccer conditions (Aandstad & Simon, 2013; Svensson & Drust, 2005). SAFT90 was created according to time-motion data analysis of 2007 English Championship Level matches and it imitates internal and external load of match-play (Barett, Guard, & Lovell, 2013; Small, McNaughton, Greig, & Lovell, 2010). SAFT90 is a shuttle running agility course with an intermittent exercise demand. SAFT90 takes 90 min and players cover 10.78 km, 1,350 changes in direction, and 1,269 changes of pace (Small et al., 2010). According to Small et al. (2010) the players performing SAFT90 cover 3.36 km by walking, 5.58 km by jogging, 1.50 km by striding, and 0.34 km by sprinting. There is still a lack of studies examining and comparing the physiological response of SAFT90 with data from real soccer matches. The main aim of this study was to assess the response of selected internal body load indicators such as lactate, HR, and RPE to SAFT90 exercise protocol in male youth soccer players.

Methods

Participants

Fourteen male elite junior soccer players (age 15.9 ± 0.2 years, stature 180.8 ± 5.5 cm, body mass 69.8 ± 5.8 kg, body fat $8.1 \pm 3.2\%$; $\text{VO}_{2\text{max}}$ 57.6 ± 4.7 $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, maximum heart rate 192.8 ± 4.6 $\text{beats} \cdot \text{min}^{-1}$) playing first Czech junior league, took part in the study. Prior to testing, all tested participants were informed about the testing procedures and the aim of the research. All participants were asked to complete a health questionnaire to reassure they are free of any health problems. The day before testing, participants were not exposed to any exhaustive activity. The research was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Physical Culture, Palacký University Olomouc. The participation in this

research was voluntary and all participants were asked to submit the consent of the legal guardian and sign informed assent with the testing procedure.

Anthropometrical measurement

A week before the exercise protocol, the participants underwent anthropometric measurements. The anthropometrical data were determined using bioimpedance analysis (Tanita BC-418 MA, Tanita, Tokyo, Japan).

Maximal running test

In order to obtain $\text{VO}_{2\text{max}}$ and maximum heart rate (HR_{max}), all participants underwent maximal running test on treadmill (Lode Valiant, Lode, Groningen, Netherlands). The maximal running test was performed a week before the exercise protocol.

Exercise protocol

Immediately before 90 min of SAFT90 exercise protocol the participants completed 15 min warm-up. SAFT90 included a 20 m long course consisted of four positioned navigation poles. The exercise protocol consisted of following locomotion activities, standing, walking, jogging, running and sprinting. The intensity and activity during the test were directed by a CD player. The SAFT90 was divided into two 45 min half-times with 15 min passive rest after the first half-time. All monitored parameters were recorded prior the testing and in 20th, 45th, 70th minute of the protocol (excluding 15 min rest time) and immediately after the end of the protocol. The protocol was performed outdoors on concrete pitch at the air temperature of 20–22 °C.

Heart rate monitoring

HR was measured in periods of 5 s by Polar HR monitor RS800 (Polar, Kempele, Finland). All participants wore watches and chest straps. After the testing, the HR data were imported into the Polar ProTrainer 5 (Polar, Kempele, Finland) software. HR values at pre-determined times were exported using the software.

Blood lactate sampling

Blood lactate level was determined using Lactate Scout+ analyser (EKF Diagnostics, Cardiff, United Kingdom). Capillary blood samples were taken from fingertip. Before each sample, the finger was cleaned in order to make the area clean and free of sweat. The skin was punctured using lancet and the first blood drop was wiped away, while the second drop was analyzed.

Rate of perceived exertion

At predetermined times the participants were asked to rate their perceived level of exertion using scale

developed by Borg (Borg, 1982). All participants were familiarized with the Borg scale before the testing. The scale ranged from 6 (no exertion at all) to 20 (maximum exertion). The degree of subjective exertion was expressed both in numbers and in verbal terms on A4 paper. RPE was scored immediately after the end of the protocol.

Statistical analysis

Data are expressed as the mean \pm *SD*. An analysis of variance (ANOVA) for repeated measures was used to evaluate changes in the SAFT90 stages including the baseline level. When the omnibus effect of time was significant, Fisher's LSD post-hoc test was performed to evaluate changes between consecutive SAFT90 stages. A planned contrast with weights (-4, 1, 1, 1, 1) was created to evaluate change between the baseline value and pooled mean of all SAFT90 stages. For all tests, the statistical level was set at $\alpha = .05$.

The effect size was calculated as Cohen's *d*. The following threshold values for effect size were adopted (Hopkins, Marshall, Batterham, & Hanin, 2009): < 0.2 (trivial), ≥ 0.2 (small), ≥ 0.6 (moderate), ≥ 1.2 (large), ≥ 2.0 (very large), and ≥ 4.0 (extremely large). Statistical analysis was performed using STATISTICA (Version 12.0; StatSoft, Tulsa,

OK, USA) and MATLAB (Version 8.4; MathWorks, Natick, MA, USA).

Results

Means and *SDs* of HR, lactate concentration, and Borg scale at baseline and during SAFT90 stages are depicted in Table 1 and showed in Figure 1. Statistical significances and effect sizes of changes between baseline and SAFT90 stages are provided in Table 1. HR during SAFT90 stages was 153 ± 15 beats \cdot min⁻¹, $79.4 \pm 8.3\%$ of HR_{max}.

The pooled mean of all SAFT90 stages was significantly increased compared to the baseline value for all studied variables, namely HR, lactate concentration, and the Borg scale. The effect size was extremely large for HR and very large for Borg scale, while for lactate concentration was only small. No significant change was found between consecutive SAFT90 stages for HR and lactate concentration and effect sizes were trivial or small. For the Borg scale, there were significant increases between stages 20 min and 45 min and between stages 70 min and 90 min with moderate effect sizes. Change between stages 45 and 70 min was not significant with trivial effect size.

Table 1

Results of statistical analysis of heart rate, lactate concentration, and Borg scale at baseline and during SAFT90 stages

Variable/stage	Mean \pm <i>SD</i>	$\Delta \pm 95\%$ CI	<i>p</i>	<i>d</i>	Effect size
Heart rate (beats \cdot min ⁻¹)					
Baseline	93 \pm 6	59 \pm 8 ^a	< .001 ^a	4.39 ^a	Extremely large
20 min	154 \pm 14				
45 min	155 \pm 15	1 \pm 5 ^b	.615 ^b	0.10 ^b	Trivial
70 min	150 \pm 14	-5 \pm 5 ^b	.057 ^b	-0.38 ^b	Small
90 min	152 \pm 16	2 \pm 5 ^b	.459 ^b	0.15 ^b	Trivial
Lactate concentration (mmol \cdot L ⁻¹)					
Baseline	1.6 \pm 0.2	0.2 \pm 0.2 ^a	.043 ^a	0.29 ^a	Small
20 min	2.1 \pm 1.1				
45 min	1.7 \pm 0.6	-0.4 \pm 0.6 ^b	.149 ^b	-0.53 ^b	Small
70 min	1.8 \pm 1.1	0.1 \pm 0.6 ^b	.821 ^b	0.08 ^b	Trivial
90 min	1.8 \pm 0.5	0.0 \pm 0.6 ^b	.900 ^b	-0.05 ^b	Trivial
Borg scale					
Baseline	6.4 \pm 0.5	4.6 \pm 0.8 ^a	< .001 ^a	3.08 ^a	Very large
20 min	10.1 \pm 1.7				
45 min	11.1 \pm 1.2	1.0 \pm 0.8 ^b	.014 ^b	0.66 ^b	Moderate
70 min	10.9 \pm 1.9	-0.1 \pm 0.8 ^b	.717 ^b	-0.09 ^b	Trivial
90 min	11.9 \pm 1.7	1.0 \pm 0.8 ^b	.014 ^b	0.66 ^b	Moderate

Note. Δ = difference between the baseline value and the pooled mean of all SAFT90 stages (^a) or difference between this stage and the preceding stage (^b); CI = confidence interval; *p* = significance of contrast (^a) or significance of Fisher's LSD post-hoc test (^b); *d* = Cohen's effect size; ^acomparing the baseline value and the pooled mean of all SAFT90 stages; ^bcomparing this stage with the preceding stage.

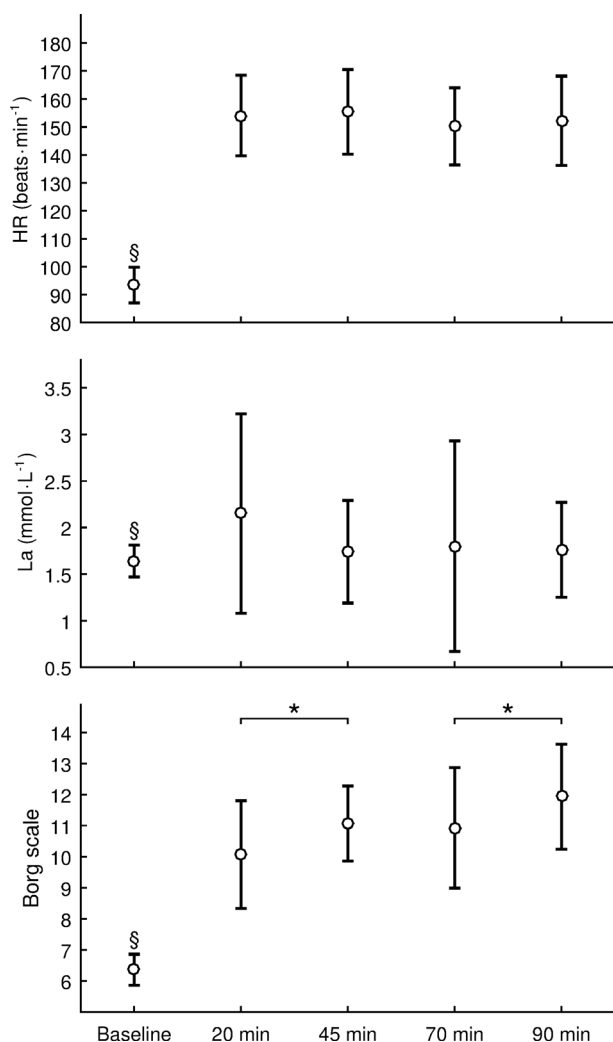


Figure 1. Means and SDs of heart rate (HR), lactate concentration (La), and Borg scale at baseline and during SAFT90 stages. *significant difference between two means ($p < .05$, Fisher's LSD post-hoc test); \$significant contrast comparing the baseline value and the pooled mean of all SAFT90 stages ($p < .05$).

Discussion

The aim of this study was to assess the body response to the standardized fatigue protocol SAFT90 in U16 soccer players. The main findings of this study revealed lower values in HR, lactate production and RPE when compared to common values observed in youth soccer players during the match play.

Lactate is the final metabolite product of anaerobic carbohydrates breakdown (Brooks, Fahey, & Baldwin, 2004) that plays important role in high-intensity actions in soccer play such as repeated sprints (Stølen et al., 2005). An increased blood lactate concentration is associated with the elevated H^+ ions that decrease pH and consequently inhibit both ATP production,

and muscle contractions (Brooks et al., 2004). One of the factors influencing lactate clearance is VO_{2max} that plays an important role in recovery and aerobic performance (Tomlin & Wenger, 2001). In male soccer players, VO_{2max} may range from 50–75 $ml \cdot kg^{-1} \cdot min^{-1}$ according to age and playing position (Semjon et al., 2016, Soyal et al., 2017; Stølen et al., 2005). Signorelli, Perim, Santos, and Araujo (2012) found young soccer players (17–22 years old) having VO_{2max} of 62.7 ± 6.1 $ml \cdot kg^{-1} \cdot min^{-1}$. Comparable values reported Tønnesen, Hem, Leirstein, Haugen, and Seiler (2013) in their two decades study of professional soccer players in Norway. Due to the fact that VO_{2max} is age-related, we need to highlight that the data for the creation of SAFT90 was collected from matches of adult soccer players while we tested U16 players. Botek et al. (2016) reported relatively stable VO_{2max} (~ 59 $ml \cdot kg^{-1} \cdot min^{-1}$) in professional soccer players up to 30 years of age. It then decreases by $\sim 5\%$ (~ 3 $ml \cdot kg^{-1} \cdot min^{-1}$) in the following nine years possibly due to a gain in body weight.

In our study, we found a significant increase in lactate concentration in 20th minute of the testing protocol compare to baseline. In the following sampling-times we found a non-significant decrease. An average blood lactate concentration in the second part of the SAFT protocol was found at 1.8 ± 0.7 $mmol \cdot L^{-1}$ while VO_{2max} of our participants was 57.6 ± 4.7 $ml \cdot kg^{-1} \cdot min^{-1}$. Small (2008) previously found lactate values of 4.7 $mmol \cdot L^{-1}$ and of 4 $mmol \cdot L^{-1}$ after the first half and the second half of the SAFT90 in semi-professional soccer players at the age of 22 ± 4 years, and equal VO_{2max} to our study (57.6 ± 5.1 $ml \cdot kg^{-1} \cdot min^{-1}$). Due to the same VO_{2max} values to our study, we suggest that higher lactate concentration might be explained by anthropometric characteristics of the players. The anthropometrics differences related to age in soccer players are discussed later in this manuscript. The higher lactate values reported by Small (2008) are comparable to lactate values assessed during soccer match by Russell, Benton, and Kingsley (2014) who reported values of 5.0 ± 0.7 $mmol \cdot L^{-1}$ in the final 15 min of the match in ten British male soccer players (age 15.6 ± 0.2 years, VO_{2max} 58.4 ± 0.8 $ml \cdot kg^{-1} \cdot min^{-1}$). Lactate ranging from 3.24 to 4.62 $mmol \cdot L^{-1}$ found Aslan et al. (2012) who examined players (VO_{2max} 51.76 ± 4.18 $ml \cdot kg^{-1} \cdot min^{-1}$) of different playing positions. In the review of Stølen et al. (2005) all included studies reported average blood lactate concentration after the second half of the match-play ranged between 2.5 and 10 $mmol \cdot L^{-1}$ in elite and 1st division players throughout different age categories. Based on lactate concentrations and VO_{2max} values reported in this part of our discussion we suggest that lower values of lactate production in the present study

might be explained by insufficient applied exercise intensity. This suggestion is supported by HR values mentioned in the following paragraph.

HR has widely been used as an indicator of exercise intensity in many studies. This is based on the fact that there is a linear relationship between HR, work rate and oxygen consumption (Arts & Kuipers, 1994). HR is a simple and available device to monitor exercise intensity. In the present study average HR during SAFT protocol was 153 ± 15 beats \cdot min⁻¹ ($\sim 79\%$ HRmax) while its dynamic was in accordance with the dynamic of lactate concentration. A significant increase in HR compared to baseline values was recorded in the 20th minute of SAFT90 and then a non-significant decrease was found during the rest of the testing protocol. The most previous studies dealing with soccer demonstrated values above 80% of HRmax (Capranica, Tessitore, Guidetti, & Figura, 2001; Henderson, Cook, Kidgell, & Gastin, 2015). Coelho et al. (2016) tested 44 players U17 and U20 who were monitored during 29 official soccer matches. The average values of all monitored participants ranged between 80% and 85% of HRmax in the first and the second half of the soccer match. Even higher values between 85% and 95% HRmax found Veale and Pearce (2009) and Aslan et al. (2012). Authors dealing with SAFT90 reported an average HRmax between 82.2% and 83.3% (Barrett et al., 2013; Small, 2008).

Whereas the data for SAFT90 were obtained from matches of adults (Small, McNaughton, Greig, & Lovell, 2010), in the present study we tested youth soccer players. The lower values of both lactate concentrations and HR might be partly explained by different VO_2max values and anthropometric characteristics of adults and junior soccer players. Anthropometrics characteristic particularly body mass, influence VO_2max . Botek et al. (2016) found the differences up to 10 kg between adults (20–39 years old) and youth (17–19.9 years old) professional soccer players. In the same study, authors found differences in the average percentage of body fat between 8.7% (17–19 years old) and 12.5% (30–39 years old). The lower (7%) and homogenous values of fat content confirmed Arroyo, Gonzalez-de-Suso, Sanchez, Ansotegui, and Rocandio (2008). Also, Sever and Zorba (2017) showed considerable differences in body height and body mass between soccer players under 16 and over 17 years old. Body mass can play an important role in the change of direction, acceleration or deceleration.

RPE is an important indicator of an individual's degree of physical strain (Borg, 1982). It has been studied in many different kinds of exercises in both the laboratory and the field conditions as well as in many different groups of individuals, both healthy

and diseased. Borg, Hassmén, and Lagerström (1987) and Zinoubi, Zbidi, Vandewalle, Chamari, and Driss (2018) found approximately linear increases in HR and RPE. The average rate of RPE in the present study was 11.0 ± 1.4 . This value demonstrates a “fairly light” exercise. Although our results demonstrate significant increase in RPE at the 45th min compared to the 20th min, and the 90th min compared to the 70th min, based on previous results we suggest that elevated RPE values at the end of each half period might reflect more mental exertion (fatigue) because RPE changes were not followed by cardiovascular and/or metabolic response. The study of junior soccer players of Aslan et al. (2012) showed average RPE 11.48 ± 1.28 in the 1st half and 13.64 ± 1.28 in the 2nd half of a match. However, these values correspond to “fairly light” and “somewhat hard” exercise.

Although it seems that SAFT90 does not stimulate metabolism enough, it has been shown that SAFT90 induces muscular changes and influence muscular performance (Jones, Ryan, & Todd, 2015). Lehnert et al. (2018, 2017) did not find significant changes in muscular control however, they reported impaired absolute leg stiffness and relative leg stiffness after SAFT90.

One limitation of this study might be the lack of information about our participants' lactate, HR and RPE values from soccer match play. As well concrete surface used in the current study could affect current participants. Another limitation includes the lack of neuromuscular tests. We also suggest including control group and cross-sectional design for better indication of the results.

Conclusions

Taken together, both objective and subjective internal load indicators showed that values of SAFT90 for our male elite junior soccer players, did not represent exercise with sufficient intensity to cause required physiological and psychometric response. Hence, to replicate the fatigue response of soccer match play, we recommend for highly trained youth soccer players a fatigue protocol with a more demanding activity profile.

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Conflict of interest

There were no conflicts of interest.

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