Title

Physiological, perceptual and performance responses associated with self-selected versus standardized recovery periods during a repeated sprint protocol in elite youth football players: A preliminary study

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Running head

Repeated sprinting and self-selected recovery

Authorship

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Abstract

Purpose: To examine the physiological and perceptual responses of youth footballers to a repeated sprint protocol employing standardized and self-selected recovery. ***Methods:*** Eleven male participants (13.7 ± 1.1 years) performed a repeated sprint assessment comprising 10 x 30 m efforts. Employing a randomized crossover design, repeated sprints were performed using 30 s and self-selected recovery periods. Heart rate was monitored continuously with ratings of perceived exertion (RPE) and lower body muscle power measured 2 min after the final sprint. The concentration of blood lactate was measured at 2, 5 and 7 minutes post sprinting. Magnitude of effects were reported using effect size (ES) statistics $\pm 90\%$ confidence interval and percentage differences. Differences between trials were examined using paired student *t*-tests ($p < 0.05$). ***Results:*** Self-selected recovery resulted in *most likely* shorter recovery times (57.7%; ES 1.55 ± 0.5; $p < 0.01$), a *most likely* increase in percentage decrement (65%; ES 0.36 ± 0.21; $p = 0.12$), *very likely* lower heart rate recovery (-58.9%; ES -1.10 ± 0.72; $p = 0.05$), and *likely* higher blood lactate concentration ($p = 0.08$-0.02). Differences in lower body power and RPE were *unclear* ($p > 0.05$). ***Conclusion:*** Self-selected recovery periods compromise repeated sprint performance.

Introduction

Repeated sprint protocols that employ standardized work to rest ratios have been studied in youth footballers (2,23,13) and are related to the physical demands of match play (2). This notwithstanding, published data suggests that repeated sprint protocols use a greater number of sprints and longer recovery durations than those observed in competitive match play (4).

Repeated sprint performance is affected by the length of recovery period afforded between efforts (1,23). For example, recovery duration during 6 x 40 m sprints was inversely related to the rate of fatigue and blood lactate concentration after exercise. These results suggest short recovery periods during repeated sprint tasks would be detrimental to performance, possibly through an increased physiological load and exercise-induced acidosis. Despite the evidence suggesting that short recovery periods are detrimental to performance in repeated sprint sequences, these actions are prevalent during match play of youth footballers (4). Adopting self-selected recovery periods during repeated sprint protocols might therefore present a way of assessing athletes that more closely replicates the non-uniform recovery periods during match play.

Repeated sprint tasks utilizing self-selected recovery periods have been examined in adults who demonstrate a different physiological response to those reported in youths. For example, peak blood lactate concentration after repeated and single sprints is lower in boys compared with men (9), a difference in part explained by reduced release from the active musculature (26) and a lower muscle mass in boys (27).

Boys also exhibit an enhanced ability to preserve performance across multiple sprints with shorter recovery periods than in adults (26). These data support the notion that boys rely predominantly on aerobic energy provision, even during high-intensity maximal effort exercise (27). Given the differences in how adults and children respond to high intensity exercise, the adoption of work to rest ratio's designed for adults might over-estimate the time required to recover between sprints performed by young athletes.

Repeated sprint exercise provides an effective stimulus for enhancing aerobic capacity in young footballers (10). Individualizing the intensity of activity bouts has been advocated during sport specific high-intensity aerobic training (17) and linear running drills (7). However, as yet, the individualization of recovery periods for repeated sprint practices has yet to be explored. Allowing young athletes to select their own between-sprint recovery periods might enable individualization of this type of training such that the physiological response is optimized for adaptation. Accordingly, the aim of the present study was to determine the physiological, perceptual and performance outcomes associated with a repeated sprint assessment in youth footballers utilizing both a self-selected and a standardized between sprint recovery period.

Methods

Subjects

Sample size was estimated *a priori* using G*Power (11). Estimations were based on changes in blood lactate concentrations of 6.5 mmol·l^{-1} reported after variable

recovery durations in youth footballers (23), which yielded an effect size of 1.2 alongside an α level of 0.05 and a power $(1 - \beta)$ of 0.8. Accordingly, eleven male elite youth footballers (age 13.7 ± 1.1 years; 0.1 ± 1.3 years from peak height velocity [PHV] (22); stature 164.8 ± 11.5 cm; mass 52.9 ± 16.2 kg) from the same professional academy took part in the study. Written informed consent was obtained from the participants and their legal guardians before data collection. All players competed in their countries' top tier of competition and had been involved in regular and organized training for at least 12 months. Training comprising three technical, two conditioning and one competitive match that totalled ~10 hours per week. The study received institutional ethics approval and all procedures conformed to the Declaration of Helsinki.

Study protocol

Using a randomized crossover design, participants completed two repeated sprint protocols with either self-selected or standardized between sprint recovery periods. Measures of muscle function were obtained before and after the repeated sprint protocol along with measures of heart rate, rating of perceived exertion and blood lactate concentration. Both conditions were performed in the early evening (ambient temperature: $14.8 \pm 2.8°C$; relative humidity: $71 \pm 6.8\%$; wind speed: 11.4 ± 5.2 km/h) before normal squad training on an artificial synthetic surface with six days between each condition.

Lower limb muscle power

Participants performed a countermovement jump (CMJ) for assessment of lower limb muscle power (W) using a portable force platform (Force Platform, Ergotest Innovation, Porsgrunn, Norway) connected to a laptop (Dell Inspiron 9100, Dell, United Kingdom). Participants performed two practice jumps before collecting data from a third jump using commercially available software (MuscleLab 4020e, Ergotest Innovation) and taken for analysis. Participants were instructed to flex their knees to approximately 120 degrees before jumping as high as possible with their hands remaining on their hips. The landing and takeoff positions for jumps were assumed to be the same, with any jumps that deviated from the stated procedure repeated. Lower body power measurements were repeated 2 minutes after the final sprint. The CMJ has been shown to be reliable in the assessment of lower body power in youth football players (21,29).

Repeated sprint protocol

Participants performed 10 x 30 m maximal sprints interspersed by either 30 s recovery or a self-selected recovery period. Before the self-selected trial participants were instructed to allow sufficient recovery to maintain a maximal effort in each sprint equal to their fastest single 30 m effort, these instructions were adapted from previous work (15). There was no further instruction or communication during the trial. All sprints were initiated from a standing start 0.5 m behind the first timing gate that marked the point at which participants returned to after each effort. Sprint timings

were recorded using electronic timing gates (Smartspeed, Fusion Sport, Australia) placed at zero and 30 m. Outcome variables of fastest sprint time, mean sprint time, total between sprint recovery time and percentage decrement (100 x (total sprint time/ideal sprint time) -100) were calculated afterwards. These variables have been shown to be appropriate measures of repeated sprint performance (14).

Internal responses

During each condition participants were fitted with a heart rate monitor positioned around the chest (Polar, Oy, Finland) to record maximum heart rate and heart rate recovery during between sprint intermissions. Heart rate recovery was defined as the beats per minute differential between the peak HR attained after each sprint and at the recommencement of exercise. This method has been used elsewhere to assess recovery in youth footballers (5). Whole blood capillary samples were obtained from the fingertip at 2, 5 and 7 min after the final sprint for the assessment of blood lactate concentration. Samples were refrigerated and analyzed within 30 min of collection using a commercially available bench top analyzer (Biosen C Line, Germany) with a TEM of 0.42%.

Ratings of perceived exertion (RPE) was collected 2 min after the final sprint, immediately before the blood sample collected at the same time interval. A Borg 15 point scale (3) was used which participants had been habituated with before data collection.

Statistical analysis

Differences between the trials were examined using paired student *t*-tests (SPSS Inc, Chicago, IL, USA) with the level of significance set at $p < 0.05$. Effect sizes (ES), ±90% confidence limits, relative change (in percentages) expressed as the transformed (natural logarithm) and magnitude based inferences were also calculated for all physiological and performance outcome measures. Threshold probabilities for a substantial effect based on the 90% confidence limits were <0.5% *most unlikely*, 0.5-5% *very unlikely*, 5-25% *unlikely*, 25-75% *possibly*, 75-95% *likely*, 95-99.5% *very likely*, and >99.5% *most likely*. Thresholds for the magnitude of the observed change for each variable were determined as the between participant SD x 0.2, 0.6 and 1.2 for a small, moderate and large effect, respectively. Effects with confidence limits across a likely small positive or negative change were classified as unclear (18).

Results

Repeated sprint performance

The standardized recovery trial was *most likely* longer in total duration ($p < 0.01$), with *possibly* shorter total sprint duration ($p = 0.03$) and *most likely* greater total recovery time ($p < 0.01$) compared to the self-selected recovery condition, respectively. The fastest and average sprint times were *possibly* faster ($p = 0.06$ and $p = 0.02$ respectively) whilst percentage decrement was *most likely* lower ($p = 0.12$) in the standardized compared to the self-selected recovery condition, respectively (Table 1).

Individual responses for percentage decrement and fastest sprint time are shown in Figures 1a and b with average recovery duration and sprint speed in the self-selected recovery condition and sprint times for both conditions in Figure 2.

Comparisons between sprint speed during repetitions 2-10 and the initial sprint in the standardized recovery condition were all *trivial* (ES < 0.12). In the self-selected recovery condition, when compared to sprint one; sprints 2 and 6 were *possibly* slower (sprint 2, 1%; ES 0.19 ± 0.29; sprint 5 1.5%; ES 0.29 ± 0.48), sprints 3, 4, 7 and 9 were *likely* slower (sprint 3, 3.1%; ES 0.59 ± 0.35; sprint 4, 2.4%; ES 0.46 ± 0.37; sprint 7, 3.2%; ES 0.6 ± 0.62; sprint 9, 3.0%; ES 0.56 ± 0.59) whilst sprint 5 was *very likely* slower (4.4%; ES 0.83 ± 0.42). Comparisons between sprint 1 and sprints 8 and 10 were *unclear*.

INSERT FIGURE 1 NEAR HERE

Variability in self-selected recovery periods

The duration of recovery taken between sprints when compared to the first intermission was *possibly* longer for recovery periods 2, 8 and 9 (recovery 2, 13.9%; ES 0.36 ± 0.42; recovery 8, 18%; ES 0.45 ± 0.47; recovery 9, 15.9%; ES 0.4 ± 0.65), *likely* longer for recovery periods 4, 6 and 7 (recovery 4, 17.9%; ES 0.45 ± 0.35; recovery 6, 24.3%; ES 0.59 ± 0.44; recovery 7, 27.7%; ES 0.67 ± 0.44) and *very likely* longer for recovery 5 (26.2%; ES 0.63 ± 0.31). There were *unclear* differences between recovery periods 1 and 3

INSERT FIGURE 2 NEAR HERE

Internal responses

The magnitude of between sprint heart rate recovery was *very likely* lower (p = 0.05)

and peak heart rate *possibly higher* (p = 0.01) in the self-selected compared to

standardized recovery condition whilst blood lactate concentration was *likely* higher

compared to the standardized recovery condition at 2 (Δ 1.82 mmol^{-1}; p = 0.08), 5 (Δ

1.25 mmol^{-1}; p = 0.02) and 7 minutes (Δ 1.14 mmol^{-1}; p = 0.04). *Unclear* differences

were reported for RPE (p > 0.05) (Table 1).

INSERT TABLE 1 NEAR HERE

Lower body muscle power responses

There was a *most likely trivial* increase in lower body power from pre to post-

assessment (1268.8 $\pm$ 408.4 cf. 1308.6 $\pm$ 458.3 W; 2.1%; ES = 0.06 $\pm$ 0.09; p > 0.05)

in the standardized recovery condition and self-selected condition (1285.5 $\pm$ 385.7 cf.

1299.5 $\pm$ 396.7 W; 0.7%; ES 0.02 $\pm$ 0.07; p > 0.05). Furthermore, *most likely trivial*

differences (p = 0.15) in post exercise lower body power were observed between

standardized and self-selected recovery conditions (Table 1).

Discussion

The present study compared the physiological and perceptual responses to a repeated sprint assessment that utilized both self-selected and standardized recovery periods in elite youth footballers. The fastest and average sprint speed was *possibly* slower whilst percentage decrement was *most likely* higher in the self-selected compared to standardized recovery condition. There were *likely* lower magnitudes of heart rate recovery, *possibly* higher peak heart rate and *very likely* higher blood lactate concentrations in the self-selected recovery condition.

Key performance determinants of repeated sprint ability are high sprinting speeds and fatigue resistance (15), which were likely compromised when self-selected recovery periods were used in the present study. The performance decrements in the self-selected recovery condition can be attributed, in part, to the shorter recovery time. Adults have been shown to take longer recovery periods between sprints when completed under self-selected conditions (24) than would be employed in protocols with the same number of sprint repetitions and distances. Our findings with youth football players are therefore in contrast to those reported in adults. Despite having autonomy over between sprint recovery duration, youth players seemed unable to maintain sprint performance by effectively manipulating recovery duration. With the exception of sprint six, the sprint time during repetitions three to seven were *likely* or *very likely* slower than sprint one in the self-selected condition. These slower sprint speeds coincided with between sprint recovery periods *likely* and *very likely* longer than the first recovery period.

Running performance has previously been reported to be impaired when schoolchildren paced their effort on a target time compared to distance (6). It has

therefore been proposed that children struggle to interpret the interaction between space, distance and time until the formal intelligence phase of their cognitive development occurs, which is between 14 and 18 years of age (25). Given the age of participants in the present study, it is plausible that they might not have acquired the ability to prospectively regulate recovery duration in line with the demands of the assessment given the temporal rather than spatial nature of this task. As cognitive development was not measured in the present study, further work is required to understand how this variable might affect performance in tasks requiring the regulation of recovery duration.

Blood lactate concentration was higher at 2, 5 and 7 min after the self-selected recovery condition, and given the slower sprint time is likely the result of shorter between sprint recovery periods. Disturbances in metabolic homeostasis have been found to increase supraspinal fatigue by inhibiting central drive and afferent signals from the active musculature (16). The central mechanism hypothesis might explain the reduced sprint time and increased percentage decrement in the self-selected recovery condition. Studies investigating self-selected recovery periods have used adult participants and not reported blood lactate concentrations (8,15,24), making comparisons with the current data difficult. Adolescents have been shown to produce less lactate than their adult counterparts in short, high-intensity intermittent tasks (9,26). Therefore, where elevated acidosis and an elevated physiological load is an intended outcome, (19), our data suggest that self-selected recovery periods might be warranted.

Possible higher peak heart rate values and a very likely reduced magnitude of heart rate recovery were observed in the self-selected compared to standardized recovery condition. When viewed in combination with a likely higher percentage decrement in the self-selected recovery condition, heart rate recovery seems an inappropriate method for assessing readiness to recommence short term, high-intensity repeated sprint exercise in youth populations (8).

Despite the differences in heart rate and blood lactate concentration, RPE were similar between conditions. The relationship between RPE, HR and blood lactate has been established in intermittent activities (12,20), with evidence to suggest that increases in the physiological response elevates perception of effort. These findings have been confirmed in youth populations. However, our results suggest that in repeated sprint assessments of a short but high intensity nature, RPE might not be sensitive, in youth footballers at least, to changes in performance and physiological load.

Although there were likely differences in running performance and internal load between conditions, no changes in lower body muscle power were detected. These findings are consistent with those reported for youth football players following a training micro cycle with significant variation in running distance and speed (21). The greater propensity for aerobic metabolism and lower absolute work during high intensity exercise in youths, along with a reduced muscle mass when compared to adults (27), might explain why lower body power was unaffected in the present study. Our results might also support the assertion that field based measures are unable to identify small yet meaningful changes in the force generating capacity of muscle (21). The observation is particularly relevant since reductions in maximal

voluntary force were detected after only two sprints when using laboratory methods (16).

Whilst the benefits of individualizing exercise intensity are well understood, standardized recovery periods are still commonly employed. In the present study five participants actually demonstrated a lower percentage decrement in the self-selected recovery condition (Figure 1a). Of these five participants only two recorded between sprint recovery periods in excess of 30 s (five recovery intermissions above 30 s, maximum of 36 s and two intermissions above 30 s, maximum of 33 s), whilst two participants performed their fastest sprint in the self-selected recovery protocol (Figure 1b). Accordingly, these data suggest that standardized between sprint recovery periods might not always be the most effective way of programming repeated sprint exercise or in assessing the ability of young athletes to resist fatigue during such exercise.

Strengths and Limitations

This is the first study to compare performance during repeated sprints separated by either self-selected or standardized recovery periods in elite standard youth football players. Our results suggest that whilst performance is likely compromised with the use of self-selected recovery periods, some individuals might perform better under these conditions. Furthermore, self-selected recovery periods induced likely increases in physiological load that might be advantageous when using repeated sprint type activities as a conditioning method (10,19). Further research should focus on how

cognitive development and physical maturation impacts on the ability of young athletes to self-pace their activities during intermittent high intensity exercise.

This study is not without limitations, brought about by conducting research with young athletes in a professional training environment. Differences in physical maturity might have affected the results whilst employing shorter standardised recovery periods similar to that used elsewhere during repeated sprint protocols (28) might have led to a different response than observed herein. Both factors should be considered limitations in the present study. While the statistical power calculation was based on a difference in blood lactate concentration of 6.5 mmol/L, the actual difference in blood lactate concentration between the self-selected and standardized recovery bouts was only 1-2 mmol/L. Consequently future research with larger sample sizes and shorter recovery intermissions during repeated sprinting in young athletes is needed.

Summary

Peak and mean sprint speed along with percentage decrement during a repeated sprint task are likely compromised by the use of self-selected between effort recovery periods in youth footballers. The decrements in performance were accompanied by higher blood lactate concentrations after exercise, higher peak heart rate and a lower magnitude of between sprint heart rate recovery. Both RPE and lower body power showed no differences between conditions. Where the aim of repeated sprint training is to maintain performance across each repetition, self-selected between effort recoveries are not advised in youth team sport athletes. Self-selected recovery periods

might provide a useful alternative to standardized rest periods for certain individuals and where the intention is to increase physiological load.

Table I: Repeated sprint performance and internal load responses for standardized and self-selected recovery duration conditions. Values are mean ± SD. *Indicates statistical significance (p < 0.05).

	Standardized recovery	Self-selected recovery	% change; effect size (ES) ± 90% CI
Total duration (min)	5.31± 0.04	3.78 ± 0.8*	43.1%; ES 1.64 ± 0.89
Total sprint duration (s)	48.73 ± 2.55	49.9 ± 3.0*	2.3%; ES 0.4 ± 0.3
Average recovery duration (s)	30.0 ± 0.0	19.7 ± 5.6*	57.7%; ES 1.55 ± 0.5
Fastest sprint (s)	4.71 ± 0.3	4.78 ± 0.3	1.4%; ES 0.23 ± 0.21
Mean sprint time (s)	4.87 ± 0.3	4.98 ± 0.3*	2.3%; ES 0.4 ± 0.29
Percentage decrement (%)	3.4 ± 1.5	4.3 ± 2.7	65%; 0.36 ± 0.21
Internal load responses			
Peak heart rate (b·min^{-1})	180 ± 12	183 ± 10	1.8%; ES 0.24 ± 0.4
Recovery heart rate (b·min^{1})	9 ± 6	4 ± 4	-58.9%; ES -1.10 ± 0.72
RPE (6-20).	12.8 ± 1.	12.8 ± 1.7	0.4%; ES 0.04 ± 0.46
Blood lactate conc. (mmol·l^{-1})			
2 min	7.05 ± 2.2	8.87 ± 2.6	21.5%; ES 0.9 ± 0.7
5 min	5.93 ± 2.1	7.18 ± 2.1	24.6%; ES 0.51 ± 0.35
7 min	6.04 ± 1.6	7.18 ± 2.0	18.3%; ES 0.58 ± 0.41
Lower body power – 2 min post final sprint (W)	1308.6 ± 458.3	1299.5 ± 396.7	-2.6%; ES -0.07 ± 0.12

Figure 1a and 1b – Individual responses in percentage decrement (a) and fastest sprint (b) after standardized and self-selected recovery conditions.

Figure 2a and b – Sprint durations during standardized (SD) and self-selected (SS) recovery trials (a) and between sprint recovery durations during the self-selected recovery trial (b).

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