THE EFFECTS OF A CONSTANT SPRINT-TO-REST RATIO AND RECOVERY MODE ON REPEATED SPRINT PERFORMANCE

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ABSTRACT
Abt, G, Siegler, JC, Akubat, I, and Castagna, C. The effects of a constant sprint-to-rest ratio and recovery mode on repeated sprint performance. J Strength Cond Res 25(6): 1695–1702, 2011—It is unclear if a constant sprint-to-rest ratio allows full performance recovery between repeated sprints over different distances. This is important for the development of sprint-training programs. Additionally, there is conflicting evidence on whether active recovery enhances sprint performance. Three repeated sprint protocols were used (22 × 15, 13 × 30, and 8 × 50 m), with each having an active and passive recovery. Each trial was conducted with an initial sprint-to-rest ratio of 1:10. Repeated sprints were analyzed by comparing the first sprint to the last sprint. For the 15-m trials, there were no significant main effects for recovery or time and no significant interaction. For the 30-m trials, there was no main effect for recovery, but a main effect for time ($F_{[1,10]} = 15.995, p = 0.003$; mean difference = 0.20 seconds, 95% confidence interval [CI] = 0.09–0.31 seconds, $d = 1.4$ [large effect]). There was no interaction of recovery and time in the 30-m trials. For the 50-m trials, there was no main effect for recovery, but a main effect for time ($F_{[1,10]} = 34.225, p = 0.0002$; mean difference = 0.39 seconds, 95% CI = 0.24–0.55 seconds, $d = 1.3$ [large effect]). There was no interaction of recovery and time in the 50-m trials. The results demonstrate that a 1:10 sprint-to-rest ratio allows full performance recovery between 15-m sprints, but not between sprints of 30 or 50 m, and that recovery mode did not influence repeated sprint performance.

KEY WORDS training, high-intensity, maximal

INTRODUCTION
Repeated sprints are performed by team sport athletes during training and playing and involve sprints interspersed with periods of submaximal activities such as standing, walking, or jogging. Despite a number of studies examining the effect of different recovery durations on the development of peak power output or sprint performance (2,6), no study has examined the effect of a constant sprint-to-rest ratio on sprint performance over various distances or durations. The relationships between sprint duration and the sprint-to-rest ratio have important implications for the development of sprint-training programs. For example, it has been advised that for the development of sprinting speed in soccer players, short sprints should be performed with rest periods “long enough for the muscles to recover to near resting conditions” to allow a maximal effort in each subsequent sprint (4). Bangsbo (4) suggested that recovery between sprints should be greater than 5 times the sprint duration, although recovery of 3 times the sprint duration (11) and 6 times the sprint duration (12) have also been used. For the development of speed endurance, Bangsbo (4) recommended that longer sprints should be performed with a sprint-to-rest ratio of 1:1 (which would progressively decrease muscle phosphocreatine [PCr] and pH), so that players become progressively fatigued. Alternatively, Reilly (31) suggested that for speed-endurance training, “the rest period between bouts should be about four to five times the exercise duration to allow recovery to take place.” However, Gaitanos et al. (16) reported that 30-second rest was not enough time to recover from a 6-second sprint (1.5 sprint-to-rest ratio), which led to decrements in both peak and mean power output of 33 and 27%, respectively. Moreover, Dawson et al. (13) reported that 3 minutes after the completion of a 5 × 6-second repeated sprint protocol with a 30-second recovery between sprints (1:4 sprint-to-rest ratio), PCr had recovered to only 84% of the pre-exercise value. Although longer recovery periods per se have been shown to promote recovery and subsequent performance relative to shorter recovery periods (5), there is little evidence to support the sprint-to-rest ratio
Sprint-to-Rest Ratio and Performance

recommendations provided by authors such as Bangsbo (4) and Reilly (31).

There is evidence to suggest that full performance recovery from brief sprints (15 m, ~3 seconds) can be achieved with only 30-second recovery (3). Balsom et al. (3) studied the physiological responses to repeated 15-, 30-, and 40-m sprints when separated by 30 seconds of passive rest. These authors reported no significant decrease in sprinting performance from the first sprint to the last sprint in the 15-m trial, whereas decrements in performance were observed during the 30- and 40-m trials. This suggests that a sprint-to-rest ratio of approximately 1:10 might allow sufficient recovery between 15-m sprints to maintain performance. However, the sprint-to-rest ratio did not remain at 1:10 for the 30- and 40-m trials as the recovery duration was held constant at 30 seconds. Therefore, it is unclear if a 1:10 sprint-to-rest ratio will provide a similar rate and magnitude of recovery for longer sprint distances. Unfortunately, there have been very few studies that have examined the effect of a constant sprint/exercise-to-rest ratio (10,25,28,29,32), and all but one of these studies (25) used exercise intensities (~400 W; 17.5–22.0 km·h⁻¹; 120–150% V̇O₂max) that are below those which would be considered a sprint. In the only study similar to the current investigation, Little and Williams (25) published a research note examining the effect of sprint duration and exercise-to-rest ratios on sprint performance in professional soccer players. These authors reported significant decreases in sprint performance when using a 1:4 sprint-to-rest ratio compared with a 1:6 sprint-to-rest ratio over the same distance. Although the study by Little and Williams (25) sheds light on the effect of a constant sprint-to-rest ratio on sprint performance, the absolute sprint-to-rest ratios used (1:4 and 1:6) did not allow full performance recovery (which is recommended for the development of speed [4,7,31,38]) and is the focus of our investigation.

Although the primary governing factors regulating the performance of repeated sprints are the sprint intensity, sprint duration, and recovery duration, there is also evidence showing that the recovery mode may be important (6,9). For example, Bogdanis et al. (6) reported that active recovery performed between 2 30-second maximal-intensity sprints resulted in a higher power output in the second sprint compared with the use of passive recovery (603 vs. 589 W, respectively [effect size = 0.9]). Conversely, Castagna et al. (9) recently reported that active recovery between sprints of much shorter duration (30 m/~6 seconds) resulted in a decreased sprint performance compared to a passive recovery. In this case, the passive recovery mode resulted in a lower total sprint time compared to the active recovery mode (60.6 ± 1.6 vs. 62.2 ± 3.0 seconds, respectively [ES = 0.7]). As such, there may be an interaction between recovery mode and duration of sprint that is worthwhile investigating.

Clearly, studies examining the sprint-to-rest ratio and associated recovery modes are needed. Although changes in the metabolic responses to repeated sprints are important, the changes in performance with repeated sprints are of equal importance from an applied perspective. Consequently, the aim of this study was to examine the changes (if any) in repeated sprint performance over 3 distances (15, 30, and 50 m), with either active or passive recovery, when the initial sprint-to-rest ratio was held constant at 1:10 across all trials. We hypothesized that a 1:10 sprint-to-rest ratio would allow full performance recovery over a sprint distance of 15 m but not over distances of 30 and 50 m.

METHODS

Experimental Approach to the Problem

A repeated measures design was used with all players completing all experimental conditions. Three repeated sprint protocols were used (22 × 15, 13 × 30, and 8 × 50 m), with each having an active recovery and passive recovery condition. This resulted in 6 trials for each player. Each trial for a player was separated by a minimum of 3 days and a maximum of 7 days. The number of sprints completed was set at 22, 13, and 8 so that the total sprint time was approximately equal for all protocols (~60 seconds). We chose to use this research design as the study is examining the effect of increased sprint distance while maintaining the sprint-to-rest ratio. The distances were chosen to represent typical sprint distances that might be used in a team sport setting. Although some authors suggest that repeated sprint protocols should consist of 8 sprints or less (15), we chose to use a higher number to replicate specific repeated sprint training (12) as opposed to repeated sprint testing. Trial order was randomized to avoid learning or training effects. There were 6 dependent variables (first sprint; last sprint; blood pH; blood lactate; blood bicarbonate; base excess [BE]). The rationale for using the first and last sprints is discussed later in the Statistical Analyses section. We measured blood pH, lactate, bicarbonate, and BE to help explain any effect of the changes in sprint-to-rest ratio over the 3 distances.

Subjects

Eleven recreational soccer players competing at the university level volunteered to participate in the study. The study was conducted during the months of May and June, which was at the end of their season. As such, players were training 2 times per week and playing 1 match per week. Before participation, all players were provided with both verbal and written explanations of all experimental procedures. Written informed consent was obtained from all players before their participation. The study was approved by the University Ethics Committee and conformed to the Declaration of Helsinki.

Procedures

Sprint Trials. Each trial was conducted with an initial sprint-to-rest ratio of 1:10. The rest duration for each trial was based on a final warm-up sprint completed 3 minutes before the start of the trial (explained below). For example, if a player took 2.6 seconds to sprint 15 m in the final warm-up sprint before the start of the trial, his or her recovery time
between each sprint would be 26 seconds, irrespective of the time required to complete a given sprint during the protocol.

All sprints were performed in an indoor hall with a synthetic multipurpose sports floor. To accommodate the length of the 50-m trials, participants ran through a large door onto an outside area with a tartan surface. Approximately 7 m of each 50-m trial was run on this tartan surface. All trials for a given player were completed at approximately the same time of the day, within a window of ±1 hour. Players were instructed to refrain from eating or drinking caffeine for 3 hours before each trial. Before each trial, participants performed a 10-minute warm-up consisting of cycling on a Monark cycle ergometer for 5 minutes at 75 W, followed by a specific sprint warm-up consisting of running, dynamic stretches, and 3 run-throughs of the distance to be sprinted. Each sprint run-through was performed at a self-selected pace, but participants were instructed to complete each sprint at approximately 50, 75, and 100% maximal sprint speed. The recovery interval between these sprint run-throughs was self-selected, but participants were instructed to begin the next effort when you feel you have recovered from the previous sprint. After the third sprint run-through, there was a 3-minute passive recovery period before the start of the sprint trial.

Participants started each sprint 30 cm behind the first timing gate (17) (SmartSpeed, Fusion Sport, Brisbane, Australia) and were required to sprint maximally through to the finish gate. Strong verbal encouragement was provided during all trials. In the active recovery trials, players were required to decelerate as quickly as possible (before a line marked 10 m from the finish gate) and then jog (~8 km·h⁻¹) back to the start of the next sprint, upon which they remained stationary until the start of the next sprint. In the passive recovery trials, the timing gates were repositioned to minimize the distance and therefore the amount of activity between sprints. To achieve this, players were required to decelerate as quickly as possible (before a line marked 10 m from the finish gate) and then walk slowly to the next starting gate which was stationed 2 m to the side of the 10-m line and then remain stationary until the next sprint.

Figure 1. The progressive changes in sprint performance across all trials. There were no significant decreases from the first to the last sprint in either 15-m trials but large decreases in sprint performance in the 30- and 50-m trials. There was no effect of recovery mode on sprint performance over any distance.
All blood samples were obtained aseptically via capillary finger sticks. To analyze blood pH, bicarbonate ($HCO_3^-$), and BE, whole blood was collected in a balanced heparin 200-μL blood gas capillary tube. The sample was immediately analyzed for blood gas concentrations and acid–base balance using a clinical blood gas analyzer (ABL77 Blood gas and electrolyte analyzer, Radiometer Ltd, Crawley, West Sussex, United Kingdom). Whole blood lactate (La) samples (25 μL) were collected in Microvette CB300 tubes (300-μL capacity) containing lithium heparin and fluoride. A lysing agent was used during the subsequent and immediate analysis, added to buffer fluid according to manufacturers instructions (YSI 2300 stat plus glucose–lactate analyzer, YSI inc., Yellowsprings, OH, USA).

**Statistical Analyses**

Repeated sprint performance was analyzed by comparing the first sprint to the last sprint within each distance to compare our results against those reported by Balsom et al. (3), who analyzed their results using this method. Although we acknowledge that direct measures such as the total sprint time or mean sprint time are recommended (26), we could not use these because we were comparing different protocols with different sprint durations (15 m–2.6 seconds; 30 m–4.5 seconds; 50 m–72 seconds). Percentage decrement was also not used because of its poor reliability (26). Before data analysis, the assumptions for conducting parametric analyses were examined and found to be plausible. To compare the first sprint and the last sprint within each distance, a repeated measures analysis of variance (ANOVA) with factors of recovery (active, passive) and time (first sprint, last sprint) was conducted for each distance. After the detection of main effects or interactions from the ANOVA, pairwise comparisons were adjusted using a Sidak correction. The dependent variables of (a) blood pH; (b) blood lactate; (c) $HCO_3^-$; and (d) BE were analyzed with a repeated measures ANOVA, with factors of sprint distance (15, 30, 50 m) and recovery (active, passive). After the detection of main effects or interactions from the ANOVA, pairwise comparisons were adjusted using a Sidak correction. All data are presented as mean ± SD. The significance level was set at $p < 0.05$. When significant differences are stated, the mean difference plus the 95% confidence interval (95%CI) of the mean difference are provided. The Cohen effect size ($d$) and a qualitative interpretation of $d$ are also provided, which were calculated and interpreted as recommended by Hopkins (21). Briefly, Hopkins (21) suggests that the effect size be interpreted as 0–0.19 (trivial), 0.20–0.59 (small), 0.60–1.19 (moderate), 1.20–1.99 (large), 2.0+ (very large). The repeated-measures ANOVA was conducted using the Statistical Package for the Social Sciences (SPSS) Version 15 (SPSS Inc.) and the assumptions of normality were examined with Minitab Version 15 (Minitab Inc., State College, TX, USA).

**RESULTS**

**Repeated Sprints**

**First Vs. Last Sprint.** Individual sprint data are displayed in Figure 1. For the 15-m trials, there were no significant main effects for recovery ($F[1,10] = 0.791, p = 0.395$) or time ($F[1,10] = 4.642, p = 0.057$) and no significant interaction ($F[1,10] = 0.028, p = 0.871$). For the 30-m trials, there was no main effect for recovery ($F[1,10] = 0.629, p = 0.446$), but a main effect for time ($F[1,10] = 15.995, p = 0.003$; mean difference = 0.20 seconds, 95% CI = 0.09–0.31 seconds, $d = 1.4$ [large effect]). There was no interaction of recovery and time in the 30-m trials. For the 50-m trials, there was no main effect for recovery ($F[1,10] = 0.897, p = 0.366$), but a main effect for time ($F[1,10] = 34.225, p = 0.0002$; mean difference = 0.39 seconds, 95% CI = 0.24–0.55 seconds, $d = 1.3$ [large effect]). There was no interaction of recovery and time in the 50-m trials.

**Blood Acid–Base Response**

**Preprint.** There were no significant differences between trials before the start of the sprints for any of the acid–base variables ($pH: F[2,16] = 2.11, p = 0.15$; La: $F[2,14] = 0.90, p = 0.43$; $HCO_3^- : F[2,16] = 1.65, p = 0.22$; BE: $F[2,16] = 1.38, p = 0.28$; Table 1).

**Postprint.** All data are displayed in Table 2. There were significant main effects for distance for pH ($F[2,14] = 26.87; p < 0.001$); La ($F[2,16] = 39.70; p < 0.001$); $HCO_3^-$ ($F[2,18] = 42.79; p < 0.001$) and BE ($F[2,18] = 58.79; p < 0.001$). Post hoc comparisons revealed significantly lower pH at 50 m

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**Table 1. Blood acid–base measures prior to each sprint trial.**

<table>
<thead>
<tr>
<th>Distance</th>
<th>pH</th>
<th>Blood lactate (mmol·L$^{-1}$)</th>
<th>HCO$_3^-$ (mmol·L$^{-1}$)</th>
<th>Base excess (meq·L$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Active</td>
<td>Passive</td>
<td>Active</td>
<td>Passive</td>
</tr>
<tr>
<td>15 m</td>
<td>7.409 ± 0.009</td>
<td>7.390 ± 0.004</td>
<td>1.3 ± 0.2</td>
<td>1.0 ± 0.1</td>
</tr>
<tr>
<td>30 m</td>
<td>7.397 ± 0.007</td>
<td>7.400 ± 0.009</td>
<td>1.2 ± 0.2</td>
<td>1.3 ± 0.2</td>
</tr>
<tr>
<td>50 m</td>
<td>7.406 ± 0.005</td>
<td>7.397 ± 0.008</td>
<td>1.3 ± 0.1</td>
<td>1.1 ± 0.1</td>
</tr>
</tbody>
</table>

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**Blood Acid–Base Balance.** All blood samples were obtained aseptically via capillary finger sticks. To analyze blood pH, bicarbonate ($HCO_3^-$), and BE, whole blood was collected in a balanced heparin 200-μL blood gas capillary tube. The sample was immediately analyzed for blood gas concentrations and acid–base balance using a clinical blood gas analyzer (ABL77 Blood gas and electrolyte analyzer, Radiometer Ltd, Crawley, West Sussex, United Kingdom). Whole blood lactate (La) samples (25 μL) were collected in Microvette CB300 tubes (300-μL capacity) containing lithium heparin and fluoride. A lysing agent was used during the subsequent and immediate analysis, added to buffer fluid according to manufacturers instructions (YSI 2300 stat plus glucose–lactate analyzer, YSI inc., Yellowsprings, OH, USA).

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**Statistical Analyses**

Repeated sprint performance was analyzed by comparing the first sprint to the last sprint within each distance to compare our results against those reported by Balsom et al. (3), who analyzed their results using this method. Although we acknowledge that direct measures such as the total sprint time or mean sprint time are recommended (26), we could not use these because we were comparing different protocols with different sprint durations (15 m–2.6 seconds; 30 m–4.5 seconds; 50 m–72 seconds). Percentage decrement was also not used because of its poor reliability (26). Before data analysis, the assumptions for conducting parametric analyses were examined and found to be plausible. To compare the first sprint and the last sprint within each distance, a repeated measures analysis of variance (ANOVA) with factors of recovery (active, passive) and time (first sprint, last sprint) was conducted for each distance. After the detection of main effects or interactions from the ANOVA, pairwise comparisons were adjusted using a Sidak correction. The dependent variables of (a) blood pH; (b) blood lactate; (c) $HCO_3^-$; and (d) BE were analyzed with a repeated measures ANOVA, with factors of sprint distance (15, 30, 50 m) and recovery (active, passive). After the detection of main effects or interactions from the ANOVA, pairwise comparisons were adjusted using a Sidak correction. All data are presented as mean ± SD. The significance level was set at $p < 0.05$. When significant differences are stated, the mean difference plus the 95% confidence interval (95%CI) of the mean difference are provided. The Cohen effect size ($d$) and a qualitative interpretation of $d$ are also provided, which were calculated and interpreted as recommended by Hopkins (21). Briefly, Hopkins (21) suggests that the effect size be interpreted as 0–0.19 (trivial), 0.20–0.59 (small), 0.60–1.19 (moderate), 1.20–1.99 (large), 2.0+ (very large). The repeated-measures ANOVA was conducted using the Statistical Package for the Social Sciences (SPSS) Version 15 (SPSS Inc.) and the assumptions of normality were examined with Minitab Version 15 (Minitab Inc., State College, TX, USA).
than at 15 m (mean difference = 0.10; 95% CI = 0.08–0.13; p < 0.001; d = 1.8 [large effect]) and 30 m (mean difference = 0.07; 95% CI = 0.04–0.09; p < 0.001; d = 1.2 [large effect]), respectively. Blood lactate significantly increased as the distance increased (50–15 m: mean difference = 5.01 mmol L⁻¹; 95% CI = 3.71–6.31 mmol L⁻¹; p < 0.001; d = 1.6 [large effect]; 50–30 m: mean difference = 2.60 mmol L⁻¹; 95% CI = 1.09–4.11 mmol L⁻¹; p = 0.001; d = 0.9 [moderate effect] and 30–15 m: mean difference = 2.12 mmol L⁻¹; 95% CI = 0.89–3.35 mmol L⁻¹; p = 0.001; d = 0.8 [moderate effect]). HCO₃⁻ and BE were significantly different between all distances (HCO₃⁻ from 50 to 15 m: mean difference = 4.96 mmol L⁻¹; 95% CI = 4.02–5.89 mmol L⁻¹; p < 0.001; d = 1.7 [large effect]; 50–30 m: mean difference = 2.78 mmol L⁻¹; 95% CI = 1.93–3.62 mmol L⁻¹; p < 0.001; d = 1.2 [large effect] and 30–15 m: mean difference = 2.00 mmol L⁻¹; 95% CI = 0.99–3.00 mmol L⁻¹; p < 0.001; d = 1.8 [large effect]; and BE from 50 to 15 m: mean difference = 7.06 meq L⁻¹; 95% CI = 5.73–8.39 meq L⁻¹; p < 0.001; d = 1.8 [large effect]; 50–30 m: mean difference = 4.25 meq L⁻¹; 95% CI = 2.95–5.55 meq L⁻¹; p < 0.001; d = 1.7 [large effect] and 30–15 m: mean difference = 2.59 meq L⁻¹; 95% CI = 1.41–3.76 meq L⁻¹; p < 0.001; d = 0.7 [moderate effect]).

There were no main effects for recovery (active or passive) for pH (F[2,17] = 2.22; p = 0.18) or La (F[2,18] = 4.13; p = 0.08). Conversely, HCO₃⁻ and BE were significantly lower in the passive condition (mean difference in HCO₃⁻ = 0.5 mmol L⁻¹; 95% CI = 0.1–1.1 mmol L⁻¹; p = 0.045; d = 0.2 [small effect] and mean difference in BE = 0.9 meq L⁻¹; 95% CI = 0.0–1.7 meq L⁻¹; p = 0.039; d = 0.2 [small effect]). Distance × recovery interactions were not significant for any of the blood variables (pH: F[2,14] = 0.25; p = 0.78; La: F[2,16] = 0.16; p = 0.85; HCO₃⁻: F[2,18] = 0.97; p = 0.97; BE: F[2,18] = 0.19; p = 0.083).

### Discussion

The main research question posed by this study was whether a sprint-to-rest ratio of 1:10 allows full performance recovery when repeating sprints over 10, 30, and 50 m. The results of our study show that 15 m sprints with a 1:10 sprint-to-rest ratio can be repeated without a significant decrement in performance, which is in agreement with the findings of Balsom et al. (3). However, when the distance was increased to 30 and 50 m, we observed large decreases in sprint performance between the first and the last sprints. This would suggest that for distances >15 m (~2.6 seconds) a sprint-to-rest ratio of >1:10 is needed if full performance recovery is required between sprints.

Although we found no statistically significant difference between the first and last sprints in the 15-m trials, there was still a decrement (0.07 seconds), which approached statistical significance (p = 0.057). We used a sprint-to-rest ratio of 1:10, but perhaps a sprint-to-rest ratio of 1:12 is required for complete performance recovery. This is close to the 1:11.5 sprint-to-rest ratio used by Balsom et al. (3) who reported...
Sprint-to-Rest Ratio and Performance

only a 0.01-second decrease from the first to last sprint over 15 m. Recently, van Someren (38) suggested that for maximal efforts ≤15 seconds, a sprint-to-rest ratio of 1:10 would allow repetition of bouts. However, the results of our study suggest that the recommendations made by van Someren (38) and others such as Bangsbo (4) and Reilly (31) are underestimations and should probably be revised.

There is an assumption that full performance recovery is required for the development of speed (4,7,31,38), despite no experimental evidence to support this. In this study, although we have shown that a 1:10 sprint-to-rest ratio does not allow full performance recovery over 30 and 50 m, this does not mean that such a protocol will not improve speed. Dawson et al. (12) studied the effects of a 6-week sprint-training program on muscle metabolism and sprint performance over 10 and 40 m. Sprint distances in the training program ranged from 30 to 80 m with the sprint-to-rest ratio starting at 1:6 and reducing to 1:4 toward the end of the 6 weeks. After training, these authors reported no significant improvement in 10-m sprint time but a significant 2.4% improvement in 40-m sprint time. Linossier et al. (24) also studied the effects of short sprints on sprint performance and muscle metabolism, but used a higher 1:11 sprint-to-rest ratio. Participants completed 7 weeks of sprint training consisting of 5-second cycle ergometer sprints interspersed with a 55-second recovery. Based on the results of this, a 1:11 sprint-to-rest ratio with 5-second sprints is unlikely to allow full performance recovery between sprints. Despite this, the authors reported a 26% increase in peak power and a 16% increase in total work during a 30-second Wingate test. The results reported by Dawson et al. (12) and Linossier et al. (24) would suggest that complete recovery between sprints is not required for improvements in sprint performance to occur. Future studies need to address the often-suggested requirement of complete performance recovery for the improvement of sprint performance (4,7,31,38), particularly over very short distances such as 15–30 m. There is also a need for future training studies to provide a physiological justification for the sprint-to-rest ratio used, which Dawson et al. (12), Linossier et al. (24), nor other sprint-training studies (20) have done.

Although we have based our conclusions on an analysis of the first and last sprints, there are conflicting views as to which method is the most appropriate for the analysis of repeated sprints. As Glaister et al. (17,18) have shown, the interpretation of repeated sprint data is largely dependent on the formula used. Although Glaister et al. (17,18) concluded that the percentage decrement formula as originally used by Fitzsimons et al. (15) was the most valid and reliable measure of sprinting fatigue, Oliver (26) recently criticized the use of percentage decrement and other fatigue index measures because of their poor reliability. Although the percentage decrement method has been used extensively in the literature (8,9,15,23), Oliver (26) suggested that direct measures of sprint performance such as the total sprint time or mean sprint time were better measures of repeated sprint performance. As stated in our method, we could not use the total sprint time or mean sprint time as we were comparing different protocols with different distances and sprint durations. Although we agree with Oliver (26) that a direct measure of repeated sprint performance is preferable, we used the first and last sprints in part to compare our data with that reported by Balsom et al. (3). Balsom et al. (3) did not report limits of agreement or typical error for their analysis method; however, they did report that there were no significant differences between the first 15 m of each protocol when measured on different days, suggesting that performance over that distance was reproducible. Although the validity and reliability of using first and last sprints as measures of repeated sprint performance might suffer from the ‘pacing’ phenomenon, Spencer et al. (35) reported the typical error for the first and last sprints of a 6 × 30-m repeated sprint ability test as 0.9 and 1.5%, respectively. These typical error values are substantially better than those previously reported for percentage decrement (22,27,30).

Consequently, we are confident that the analysis of repeated sprint performance using the first versus last sprint in the context of the present research question is appropriate. Although we did not collect muscle samples in this study, the changes observed in sprinting performance are interesting in light of the previously reported changes in PCr and pH. The changes in PCr are important because previous studies have shown that power output is closely related to PCr concentration (5,33). However, for repeated sprints, the resynthesis of PCr is equally as important. It would be expected that the half-time for PCr resynthesis after very short sprints of 15 m would be shorter than the 21–22 and >170 seconds for the fast and slow components reported by Harris et al. (19), although we are unaware of any studies that have measured this. That said, as no significant decrement in 15-m performance was observed in this study, it would seem that complete PCr resynthesis might not be required for sprinting performance to be maintained. The recovery duration in the 15-m trials was ~26 seconds, which would allow about 50–80% PCr resynthesis (13,19). Moreover, Dawson et al. (13) reported that repeated sprints resulted in lower PCr and a longer PCr resynthesis time compared with a single sprint, which would provide further evidence that PCr resynthesis was probably not complete between 15-m sprint efforts. However, this assertion needs to be shown experimentally before a conclusive statement can be made.

For the 30- and 50-m conditions, it is most probable that PCr resynthesis was not complete between sprints, given their sprint times of ~4.5 and ~70 seconds and recovery times of ~45 and ~70 seconds, respectively. Although the sprinting performance observed in the 30- and 50-m trials is probably related to PCr concentration within the muscle, the greater magnitude of change observed in blood pH after these trials compared to the 15-m trials would suggest that blood acid–base balance also played a role. The blood acid–base response follows a similar
profile to that of the performance decrement, with significantly greater levels of acidosis observed after the longer sprints (30 and 50 m; Table 2). Presumably, endogenous buffering capacities were exceeded at these distances, and the associated proton (H⁺) accumulation contributed to a decline in force production (36). During repeated maximal efforts, it was originally proposed that the cumulative effect of increased [H⁺] may directly inhibit the rate-limiting enzyme glycogen phosphorylase and consequently decrease the rate of glycogenolysis (36). However, it is now generally accepted that the increased proton production causes both competition on the ionizable binding sites of actin and myosin, together with sarcoplasmic reticulum dysfunction with regards to Ca²⁺ release and uptake (see review by Allen [1]). In either case, we can assume that the increased time requirement during each maximal effort in the 30- and 50-m sprints caused an impairing loss of endogenous [HCO₃⁻] (from ~24.0 to <14.0 mmol·L⁻¹) compared to 15 m (~16.0 mmol·L⁻¹).

The second finding of this study is that recovery mode did not influence sprint performance. Previous studies showing performance decrements when using active recovery have used sprints of longer duration (range 4–30 seconds) (14,34). For many years, sport scientists and coaches have advised athletes to use an active recovery between sprints to optimize metabolic and performance recovery (7,38). However, most of the previous research on active and passive recovery have tended to use much longer sprint durations (6,39), with much longer absolute recovery durations (6,39), and a focus on the recovery of blood lactate rather than on performance (37). van Someren (38) states that “research has consistently shown that CP is resynthesized at a higher rate during low-intensity exercise than at rest; therefore, rest intervals should be active rather than passive.” However, previous studies (9,34) show the opposite for short sprints of ~6 seconds or less. The mechanisms responsible for a decreased performance when using active recovery have been suggested to be related to competition for adenosine triphosphate between the resynthesis of PCr and muscular movement (14,33). However, based on the results of this study, it would appear that either recovery mode can be used.

Practical Applications

The results of this study have shown that the sprint-to-rest ratio required to maintain performance during repeated sprint protocols is dependent on the sprint distance, such that a 1:10 sprint-to-rest ratio allows complete performance recovery between sprints of 15 m, whereas the same sprint-to-rest ratio does not allow full performance recovery between sprints of 30 and 50 m. Consequently, if sport scientists or coaches need their athletes to recover completely between short sprints of 15 m or less, then using a 1:10 sprint-to-rest ratio will achieve this. A sprint-to-rest ratio of substantially greater than 1:10 would be required to maintain sprint performance during repeated sprints of 30 and 50 m. The results of our study also show that recovery mode did not influence sprint performance.

References


