Relationship between brief and prolonged repeated sprint ability

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Summary
Repeated sprint ability (RSA) is often assessed over a brief time period with limited recovery between sprints; however, it is not known how performance in such tests is related to the ability to perform repeated sprints over a more prolonged duration. Eighteen boys aged 15.3 ± 0.5 years completed both a brief and prolonged RSA test on a non-motorised treadmill. The brief RSA test consisted of seven 5 s sprints with 20 s of recovery between sprints and the prolonged RSA test lasted for 42 min and included a 5 s sprint every 2 min. There was a moderate but significant relationship between the mean speed in both tests ($r = 0.51$, $p < 0.05$). The maximal speed achieved in a single sprint provided strong relationships with both brief RSA speed ($r \geq 0.72$, $p < 0.001$) and prolonged RSA speed ($r \geq 0.77$, $p < 0.001$). Total work done during the brief protocol was significantly correlated to both total work ($r = 0.81$, $p < 0.001$) and total sprint distance ($r = 0.79$, $p < 0.001$) during the prolonged test. There were no significant relationships between percentage decrement scores across the two protocols ($r \leq 0.33$, $p > 0.05$). Maximal speed in a single sprint and total work done during repeated sprints represent general qualities related to RSA that are independent of the test protocol. The mean speed and decrements in performance represent specific RSA qualities, which are dependent on the frequency of sprints and duration of the test protocol.

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Introduction

Although sprint efforts represent a relatively small proportion of the activity completed in a multiple-sprint sport such as football, rugby or hockey, the contribution of these sprint efforts is thought to be critical to the outcome of a match.\textsuperscript{1} Several studies have found that soccer players of a higher standard perform more high-intensity running than players of a lower standard during a soccer match.\textsuperscript{2,3} Therefore, assessing the ability of players to repeatedly sprint is considered a worthwhile performance measure for those involved in multiple-sprint sports.\textsuperscript{4}

Repeated sprint ability (RSA) has been defined as the ability to perform repeated short-duration...
sprints over a brief period of time (<3 min). The link between performance in a brief RSA test and match performance, where a player will have to repeatedly sprint over the duration of a match, is not well established. Recently, Rampinini et al. reported significant relationships between the mean sprint time achieved during an RSA test and the amount of distance covered at very high-intensity running \( (r = -0.60, p < 0.01) \) and sprinting \( (r = -0.65, p < 0.01) \) during a soccer match. Whilst the correlations reported were significant they were only moderate in strength, suggesting that an RSA test may not be well related to match performance.

Establishing relationships between fitness measures and match performance is problematic given the random pattern of activity and varying influence of tactics during any given match. To overcome this, prolonged protocols have been developed with structured and repetitive activity patterns. To date little is known about the relationship between performance in a set of brief and prolonged repeated sprints. Bishop et al. compared performance in a set of brief cycle sprints and a simulated field hockey game, testing the theory that if RSA exists as a general quality then any RSA test protocol will distinguish between individuals with varying levels of RSA. Results of their study suggest that there are some general and some specific qualities of RSA that are dependent on the test protocol. However, the use of cycle ergometry may weaken the relationships reported due to the lack of validity when using this mode of exercise to assess the RSA of multiple-sprint sport players.

A non-motorised treadmill provides a method to measure responses to sprint exercise in the laboratory using a mode of exercise specific to multiple-sprint sports. Protocols have previously been developed to examine responses to both brief and prolonged repeated sprints. Bishop et al. compared performance in a set of brief cycle sprints and a simulated field hockey game, testing the theory that if RSA exists as a general quality then any RSA test protocol will distinguish between individuals with varying levels of RSA. Results of their study suggest that there are some general and some specific qualities of RSA that are dependent on the test protocol. However, the use of cycle ergometry may weaken the relationships reported due to the lack of validity when using this mode of exercise to assess the RSA of multiple-sprint sport players.

Methods

Eighteen boys from a local secondary school volunteered to take part in the study and all the boys were members of the school football or rugby team. The mean age of the players was 15.3 ± 0.5 years, stature 1.73 ± 0.05 m and body mass 63.4 ± 5.5 kg. The Institutional Ethics Committee approved the project and written informed assent and consent was obtained from the boys and their parents/guardians, respectively.

Participants completed a comprehensive familiarisation and two test sessions. During the two test sessions participants completed both the brief and prolonged RSA test, with testing occurring in a randomised order and with at least 24 h separating test sessions. A standardised warm-up was completed before each test with a 5 min run on the NMT at a speed of 8 km h\(^{-1}\) which included 2 brief sprints (<4 s), 5 min was then allowed to perform individual stretching exercises.

Both RSA tests were performed on a Woodway Tramp non-motorised treadmill (Woodway GmbH, Germany). The experimental set-up of the non-motorised treadmill has previously been described by Sutton et al. A custom software application developed using LabVIEW (National Instruments, Newbury, UK) programming software was used to sample signal voltages from the treadmill at 100 Hz. Data were then averaged and reported over 1 s intervals. Horizontal force (N) and treadmill belt velocity (m s\(^{-1}\)) were directly measured, whilst the product of these variables and sprint duration (s) was used to calculate the horizontal work done (kJ).

The protocol for the brief RSA test was identical to that previously described by Oliver et al. Participants were required to complete 7 maximal 5 s sprints with 20 s of active recovery between sprints. Each test commenced from a rolling start of 8 km h\(^{-1}\); participants were also required to maintain this speed during the active recovery periods. The reliability of the test protocol has previously been assessed in a population of 15-year-old boys, with coefficients of variation of <3% reported for speed variables.

Prolonged RSA was measured using a previously described soccer-specific intermittent exercise test (SSIET). During the SSIET, participants completed three 14 min bouts of exercise separated by 3 min rest periods. Each 14 min bout is further subdivided into 2 min exercise periods, which were repeated throughout the test. The exercise pattern during each 2 min period was 45 s walking (4 km h\(^{-1}\)), 15 s cruising (12 km h\(^{-1}\)), 15 s stationary, 40 s jogging (8 km h\(^{-1}\)) and a 5 s maximal sprint. A visual display monitor and a stopclock placed in front of the treadmill allowed participants to monitor their speed and identify when a change in speed was required. The experimenter also provided continuous feedback and instructions as to when to change speed, which included a verbal countdown.

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Repeated sprint ability 3
to each sprint. Heart rate (HR) was monitored throughout the SSIE (Polar Electro, Finland). The reliability of the SSIE has been previously established in a group of 15 year old soccer players with coefficients of variation for speed data of \(<4\%)^9\).

Performance in each test was assessed from speed data and the work done during sprint efforts. Maximal and mean speeds were recorded over 1 and 5 s for each sprint, respectively. Maximal speed (MxSp) was measured as the highest speed achieved over a 1 s period during each test. The mean maximal speed (MnMxSp) was measured as the mean value of the maximal speed achieved across all sprints during each test. The mean speed (MnSp) was defined as mean speed recorded across all sprints during each test. Both absolute and relative (to body mass) total work done were calculated for each test together with the mean work done during each sprint. To quantify reductions in performance, MxSp and MnSp were recorded during each sprint and the drop-off in performance across each test calculated using the percentage decrement method.$^{10,11}$

A paired Student’s t-test was used to assess whether a significant difference existed between performance results obtained during the brief and prolonged RSA tests. The strength of relationship between test variables was analysed using Pearson’s correlation coefficient. To test the concept of generality between test scores, a correlation of \(r \geq 0.71\) was used to accept generality, indicating a minimum 50% common variance.$^4$ A repeated measures ANOVA was used to determine if there was a significant change in HR across the three bouts of the prolonged RSA test. For all tests, significance was set at a level of \(p < 0.05\). All analyses were performed using SPSS for Windows version 10 (SPSS Inc., Chicago, USA).

Results

Performance results in the brief and prolonged RSA are presented in Table 1. Whilst there was a significant difference in the MxSp achieved in the two tests (Table 1) there was no difference when comparing the maximum speed achieved in sprint 1 of each test, with speeds of \(6.34 \pm 0.33 \text{ m s}^{-1}\) in sprint 1 of the brief RSA test and \(6.30 \pm 0.30 \text{ m s}^{-1}\) in sprint 1 of the prolonged RSA test. In the brief RSA test all participants achieved their maximum speed in the first \((n=16)\) or first and second \((n=2)\) sprints. In the prolonged RSA there was a more varied response in the attainment of MxSp across the duration of the test; MxSp was attained in the first seven sprints by 7 boys, in the second set of seven sprints by 3 boys and in the third and final set of 7 sprints by the remaining 10 boys.

Total distance sprinted was \(181.20 \pm 10.36 \text{ m}\) in the brief RSA test and \(576.90 \pm 29.53 \text{ m}\) in the prolonged RSA test. The mean HR during the prolonged RSA test was \(172 \pm 10 \text{ b min}^{-1}\) and did not change significantly across the three bouts of the test. Significant, although not strong, relationships between the two RSA tests were found for both MnSp \((r=0.51, p<0.05)\) and MnMxSp \((r=0.47, p<0.05)\) (Fig. 1A). Correlations stronger than that required to denote generality \((r \geq 0.71)\) were found between the MxSp achieved in both tests \((r=0.72, p<0.001)\) and MxSp achieved in the prolonged RSA test and the MnMxSp and MnSp achieved during the brief RSA test (see Fig. 1B). The MxSp achieved during the prolonged test also provided strong relationships with other speed measurements during that test \((MnMxSp r=0.78, MnSp r=0.77, both p<0.001)\). Significant relationships were also found between the total work done in the brief RSA test and total work done \((r=0.81, p<0.001)\) and total distance sprinted \((r=0.79, P<0.001)\) during the prolonged RSA test. However, the strength of the relationship between brief RSA work done and prolonged RSA distance covered was reduced to \(r=0.21 (p>0.05)\) when work was expressed relative to body weight. The lack of a relationship between percentage decrement scores calculated in both tests is shown in Fig. 1C; there was a correlation of only \(r=0.05 (p>0.05)\) for the MxSpDec and \(r=0.33 (p>0.05)\) for the MnSpDec.

Table 1    Sprint performance during the brief and prolonged RSA tests

<table>
<thead>
<tr>
<th>RSA test</th>
<th>Brief</th>
<th>Prolonged</th>
</tr>
</thead>
<tbody>
<tr>
<td>MxSp (m s(^{-1}))</td>
<td>6.34 ± 0.33</td>
<td>6.66 ± 0.35*</td>
</tr>
<tr>
<td>MnMxSp (m s(^{-1}))</td>
<td>5.82 ± 0.30</td>
<td>6.33 ± 0.38*</td>
</tr>
<tr>
<td>MnSp (m s(^{-1}))</td>
<td>5.18 ± 0.30</td>
<td>5.49 ± 0.28*</td>
</tr>
<tr>
<td>Total work (kJ)</td>
<td>15.8 ± 1.3</td>
<td>50.2 ± 4.3*</td>
</tr>
<tr>
<td>Mean work per sprint (kJ sprint(^{-1}))</td>
<td>2.3 ± 0.2</td>
<td>2.4 ± 0.2*</td>
</tr>
<tr>
<td>MxSpDec (%)</td>
<td>8.3 ± 3.5</td>
<td>4.9 ± 3.7*</td>
</tr>
<tr>
<td>MnSpDec (%)</td>
<td>8.8 ± 2.7</td>
<td>6.3 ± 1.7*</td>
</tr>
</tbody>
</table>

MxSp, max speed; MnMxSp, mean maximum speed; MnSp, mean speed; MxSpDec, maximum speed decrement; MnSpDec, mean speed decrement.

*Significantly different to the brief repeated sprint test, \(p \leq 0.01\).

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Discussion

The purpose of the present study was to compare repeated sprint performance during a brief and prolonged test. A major finding of the present study was that maximal speed achieved during a single sprint is a general quality of RSA performance, with strong relationships with both brief and prolonged RSA performance. Conversely, other measures of repeated sprint speed only provided modest correlations when comparing brief and prolonged repeated sprints, suggesting a specific component to such measures dependent on the test protocol employed.

The reduction in performance during the brief RSA test suggests participants were producing maximal efforts throughout, whilst the HR response of participants in the prolonged test is very similar to that previously reported and supports the soccer-specific demands of the test. Participants achieved a significantly greater MxSp during the prolonged RSA test, although the values achieved during sprint 1 of each test did not differ significantly. Whilst inadequate PCr resynthesis probably prevented improvements in MxSp in the latter sprints of the brief RSA test, this was not the case during the prolonged protocol. Possible factors explaining the faster MxSp during the prolonged RSA test could include increased muscle temperature, increased firing and synchronisation of motor neurons, motivational factors or random variation. Given the variability in the achievement of MxSp in the prolonged test, there is a likely contribution from random variation. With longer recovery bouts and more sprints in the prolonged test, identifying MxSp from a single best sprint effort will lead to a positive influence of random variation on the test score.

In agreement with the work of Bishop et al., total work done during the brief RSA test was found to be significantly related to total work done (r = 0.81) and total distance sprinted (r = 0.79) during the prolonged RSA test. Therefore, the ability to perform work during an RSA test is suggested to exist as a general quality and is not dependent on the duration of the protocol used. Bishop et al. suggested that the generality of work done during an RSA test was related to the ability to break down PCr stores, which would be a requirement independent of sprint distance or duration of an RSA test. The generality of total work may be more closely associated with body size and active muscle mass. When total work done during the intense RSA test was expressed relative to body mass, there was a

Figure 1 (A) Relationship between MnMxSp (■) achieved in both tests and MnSp (○) achieved in both tests. (B) Relationship between the MxSp achieved during the prolonged RSA test and the MnMxSp (■) and MnSp (○) achieved during the brief RSA test. (C) Relationship between the percentage decrement calculated in the brief and prolonged RSA test; (■) MxSpDec; (○) MnSpDec. *p < 0.05, **p < 0.001. MxSp, max speed; MnMxSp, mean maximum speed; MnSp, mean speed; MxSpDec, maximum speed decrement; MnSpDec, mean speed decrement.
considerable reduction in the strength of the relationship with prolonged RSA total sprint distance ($r = 0.21$).

Relationships between MnMxSp and MnSP across the two protocols were significant ($r \leq 0.51$, $p < 0.05$), but below that required to accept generality, suggesting that there is a specific component of RSA related to the duration of the test and the frequency of sprint efforts. Balsom et al.\textsuperscript{15} investigated the affect of recovery duration on repeated sprint performance during fifteen 40 m field sprints. The authors reported that acceleration over the first 15 m was reduced when recovery was limited to 30 s but not with 60 and 120 s recovery, conversely speed over the last 10 m was reduced in all recovery conditions. It was concluded by Balsom et al.\textsuperscript{15} that force generating capacity was restored more readily than endurance capacity. Similar findings were made in the present study with greater decrements in MnSp during the prolonged test; when compared to MxSp, performance decrements were greater still with limited recovery during the brief RSA test. From the present study, the ability of participants to recover and perform in subsequent sprints appears to be a specific quality dependent on the amount of recovery available and number of sprints to be completed.

The MxSp achieved during the prolonged RSA test was highly correlated with mean sprint performances in the brief ($r \geq 0.72$) and prolonged ($r \geq 0.77$) RSA tests. In a homogenous group of athletes accustomed to multiple-sprint sports, the factors that determine MxSp represent a general quality related to RSA, allowing participants with a faster MxSp to perform better throughout an RSA test regardless of the protocol. It has recently been shown by Rampinini et al.\textsuperscript{6} that the best effort during a repeated agility test was not related to the amount of high-intensity exercise performed by players during a soccer match. However, it is known that there is little association between agility and linear sprint performance.\textsuperscript{16} Therefore, it may be the case that maximal speed during an agility sprint is not related to match performance but the maximal speed achieved in a linear sprint is related to both brief and prolonged repeated sprinting.

No significant relationship was found to exist between the decrement scores calculated during both RSA tests. Similarly, Bishop et al.\textsuperscript{4} reported no relationships between the majority of variables when examining decrements in brief repeated cycle sprints and prolonged repeated field sprints, concluding that decrements in sprint performance are not a general RSA quality. Whilst this may be the case, it is also possible that random variation associated with decrement scores influenced the relationships between tests. Numerous investigations have reported decrement scores to be the most unreliable variable when measuring RSA, with coefficients of variation ranging from 18 to 50\% during repeated field and non-motorised treadmill sprints.\textsuperscript{10–12} The percentage decrement may provide a means to quantify reductions in performance and to state that fatigue has occurred during an RSA test, however, the variability inherent to these measures may prevent significant relationships with other RSA variables.

**Conclusion**

Total work done and MxSp during a single sprint are suggested to be general qualities of RSA independent of the RSA protocol used, which supports the original hypothesis. The relationship between MxSp and RSA reflects the theory that in a group of homogenous multiple-sprint sport athletes, the ability to produce a high sprint speed during a single effort will also positively influence RSA. However, weaker relationships between protocols when analysing MnMxSp and MnSp suggest a specific quality of RSA related to the duration of the test and frequency of sprint efforts. Consideration of the general and specific qualities of brief and prolonged RSA will have implications for the testing and training of multiple-sprint sport athletes and interpretation of results.

**Practical implications**

- The ability to produce maximal speed in a single sprint effort is an important component of repeated sprint ability; improving maximal speed would be expected to have some positive benefit on repeated sprint ability.
- The ability to reproduce speed during a brief repeated sprint ability test is not well related to the ability to reproduce sprint efforts over a more prolonged duration.
- Different methods of training and testing should be employed to improve and monitor the ability to reproduce sprint efforts over both a brief and prolonged period of time.
Acknowledgement

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Appendix A. Supplementary data


References