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27 **Abstract**

28 The ability to repeatedly perform sprints has traditionally been viewed as a key performance
29 measure in team-sports and the relationship between ‘repeated-sprint ability’ (RSA) and
30 performance has been explored extensively. However, when reviewing the repeated-sprint
31 profile of team-sports match-play it appears that the occurrence of repeated-sprint bouts is
32 sparse, indicating that RSA is not as important to performance as commonly believed.
33 Repeated-sprints are, however, a potent and time-efficient training strategy, effective in
34 developing acceleration, speed, explosive leg-power, aerobic power and high-intensity running
35 performance - all of which are crucial to team-sport performance. As such, we propose that
36 repeated-sprint exercise in team-sports should be viewed as an independent variable (e.g., a
37 means of developing fitness) as opposed to a dependent variable (e.g., a means of assessing
38 fitness/performance).

39

40 **Key words:** repeated-sprint training, team-sports, speed, power, high-intensity running

41 Repeated-sprint ability (RSA) is viewed as a key fitness component in team-sports due to the
42 perception that short maximal sprints, interspersed with brief recovery periods are frequent
43 during match play.¹ Consequently, there has been substantial interest in the most effective
44 means of developing this particular component of fitness. Following a comprehensive review
45 on training RSA, Bishop et al.¹ recommended the inclusion of single sprint, strength and high-
46 intensity interval training (HIT) to improve the ability to produce sprints and recover in-
47 between sprints. The effectiveness of repeated-sprints for the improvement of RSA also has
48 intuitive appeal; however, because of strong similarities between tests of repeated-sprinting
49 and training routines, the effectiveness of repeated-sprint training may have been
50 overestimated.²

51 In a commentary on RSA testing, Dawson³ suggested that a compelling area for future
52 investigation is whether RSA relates well to team-sport performance (in an overall sense) or
53 only player work rates. This is an insightful appraisal of the role of repeated-sprints and poses
54 to us the question of whether repeated-sprinting should be viewed as a dependent or
55 independent variable? Despite a lack of studies examining the relationship between training-
56 induced changes in RSA and match physical performance,¹ if, in accordance with the belief
57 that repeated-sprinting is commonplace in team-sports, then enhancing players' RSA makes
58 sense. In such a scenario, RSA would be perceived as a dependent variable (a measure of
59 fitness/performance) - yet this supposition relies on repeated-sprint bouts being frequent during
60 team-sport match play. However, the frequency of repeated-sprint bouts (often defined as 2 or
61 more sprints interspersed by <60s recovery), and number of sprints in these bouts is low,⁴⁻⁷
62 therefore questioning the validity of RSA as a dependent variable.

63 Training for worst-case scenarios makes sense within any athlete preparation³ and clearly there
64 is benefit in following the recommendations of Bishop et al.¹ for the development of RSA via
65 HIT and speed/strength training, given the relevance of these individual fitness components to
66 team-sport match performance.^{8,9} However, a recent meta-analysis reported that repeated-
67 sprint training simultaneously induces improvements in the speed, power and high-intensity
68 running performance of trained team-sports players.¹⁰ With this in mind, we propose that
69 repeated-sprints be implemented for the simultaneous training of several fitness components,
70 as opposed to the concurrent implementation of several disparate modes of training (speed,
71 strength, HIT) to improve the ability to produce repeated-sprints. This identifies repeated-
72 sprints as an independent variable (training method).

73 **Validity of RSA as a dependent variable**

74 While it is possible that the ability to perform intense periods of repeated-sprinting can
75 influence the outcome of match-play in team-sports,¹¹ until recently the activity profile of team-
76 sports with respect to repeated-sprinting has not been well understood. This is important given
77 that accurate assessment of the in-game activities of players facilitates physical match
78 preparation. An overview of the repeated-sprint activity profiles of various team-sports (both
79 male and female) is presented in Table 1, with respect to the frequency of repeated-sprints, the
80 number of sprints per repeated-sprint bout, and the speed thresholds used to determine
81 sprinting. While not systematic in our methodology, it is evident from these data that the
82 occurrence of repeated-sprinting in soccer,^{4-7,15} rugby league,^{5, 13-14} basketball,¹² field hockey¹⁶
83 and Australian football league (AFL)⁵ is infrequent, thereby questioning the role of repeated-
84 sprints during team-sport match play. It would appear that repeated-sprinting is perhaps more
85 common in elite female team-sports with between 4-5 repeated-sprinting bouts per player
86 occurring per match in soccer and basketball.^{6,12,15} However, male team-sport players perform
87 noticeably less repeated-sprints during match play, with elite male soccer, rugby league and

88 AFL players generally completing less than 3 repeated-sprint bouts per game,^{4-5, 7, 13-14} and in
89 some instances repeated-sprints do not occur during matches.⁴ It should be noted, however,
90 that repeated-sprinting is often subjectively determined,⁵ which impacts the recorded frequency
91 of repeated-sprint activities. Furthermore, the use of arbitrary speed thresholds for the
92 classification of sprinting fails to individualize sprint activity to players' specific movement
93 speeds or physiological capacity.¹⁷

94 Recently there has been an emergence of research investigating the occurrence of repeated-
95 high intensity efforts in rugby league.¹⁸ This encompasses activities such as tackling, jumping
96 and high-intensity running which is not termed 'sprinting', and this approach provides perhaps
97 a better representation of the physiological demands of team-sports. For example, repeated-
98 high intensity efforts occur in close proximity to tries.¹⁹ Similarly, the concept of repeated-
99 acceleration ability - the ability to perform repeated accelerations - has been proposed as
100 repeated-acceleration sequences occur more frequently than repeated-sprint sequences,²⁰ with
101 8-fold greater maximal accelerations than sprints performed during match play.²¹ These
102 activities are likely to have similarly fatiguing effects to sprinting despite not meeting the
103 maximal velocities required to be termed sprinting.²¹ This highlights the issues of looking at
104 repeated-sprinting activity in isolation; whereas repeated-accelerations seem more closely
105 associated with the match demands of team sports, and thus might be appealing to coaches and
106 practitioners. Further research in these areas is required, however.

107 **Repeated-sprints: An independent variable**

108 Repeated-sprint training can be used to improve RSA.² Yet, the beneficial effects of repeated-
109 sprint training extend beyond that of only improving RSA. Specifically, repeated-sprint
110 training is effective for developing a variety of fitness components including: acceleration (the
111 rate of change in velocity that allows a player to reach maximum speed in minimum amount
112 of time), speed (the maximal velocity at which a player can sprint)²² explosive-leg power (the
113 ability of the legs to rapidly generate and apply a large amount of force)²³ and high-intensity
114 running performance (distance covered on the Yo-Yo intermittent recovery test level 1).^{10,24} In
115 a recent meta-analysis, repeated-sprint training elicited moderate beneficial effects on
116 explosive leg-power (effect size (ES) 0.63), moderate to large beneficial effects on 20 m and
117 30 m sprint performance (ES -0.65 and -1.01, respectively) and moderate beneficial effects on
118 high-intensity running performance (ES -0.61).¹⁰ This illustrates the effectiveness of repeated-
119 sprinting as a means of improving the all-round fitness of trained team-sports players. These
120 findings are important given the relationship between high-intensity running performance and
121 match running performance demonstrated in rugby league ($r = 0.48$)²⁵ and soccer ($r = 0.73$).²⁶
122 The relationship between explosive performance and key moments in soccer has also been
123 demonstrated, with Faude et al.⁸ reporting that 83% of goals are preceded by powerful actions
124 such as shorts sprints or jumping.

125 Time-efficiency of fitness training has appeal in the programming of team-sport training as it
126 permits coaches to maximise the available time for adequate skill and tactical development.²⁷
127 Repeated-sprinting training can be viewed as a time-efficient training method that induces
128 rapid fitness improvements.²⁸ For example, as little as six repeated-sprint training sessions over
129 a two-week period elicited substantial beneficial effects on 5-20 m sprint speed (4-10%) and
130 high-intensity running performance (24-31%) in semi-professional soccer players.²⁸ Within
131 this study, the players completed only 105-140 s of maximal work per session.²⁸ Therefore, the
132 time-efficient nature of repeated-sprint training should add to the appeal of this training method
133 in team-sports.

134 Repeated-sprint training elicits a series of metabolic adaptations, such as increases in muscular
135 enzymatic activity, phosphocreatine and glycogen stores, and improved lactate buffering
136 capacity.^{29,30} Neuromuscular adaptations such as increased muscle fibre recruitment, firing
137 frequency, motor unit synchronisation, changes in muscle fibre type, greater development of
138 the sarcoplasmic reticulum, and increases in the cross-sectional area of the muscle also occur
139 in response to repeated-sprint training.^{30,31} It is possible that the physiological response to
140 repeated-sprint training is dependent upon programming variables such as the work: rest ratio,
141 sprint distance/duration, type of sprints and overall sprint volume.³² Given the varied demands
142 of match-play in different populations (e.g., age, gender, playing position etc.) it could be
143 necessary to adapt repeated-sprint training depending on the sport and player characteristics.
144 Further, repeated-sprint training should be implemented in a sensible manner, with
145 practitioners ensuring adequate pre-conditioning of athletes (strength and/or HIT), to reduce
146 the risk of injury occurring.^{32,33}

147 Research establishing whether it is best to develop fitness components such as speed, power
148 and high-intensity running separately (e.g. using isolated training methods such as sprints,
149 plyometrics, HIT), or whether these can be developed concurrently (without interference
150 effects) is necessary.² Such research would allow practitioners to make cognisant decisions
151 regarding the inclusion of repeated-sprinting within an athlete's schedule. Buchheit² briefly
152 reviewed this, reporting similar effects of repeated-sprint training and isolated training on
153 straight-line sprint speed and unclear results regarding maximal oxygen uptake. In
154 experimental studies, Ferrari-Bravo et al.³⁴ compared the effects of repeated-sprint training and
155 HIT on RSA and high-intensity running performance, reporting that repeated-sprint training
156 had a greater beneficial effect (~15%) on high-intensity running performance, while
157 improvements in RSA (2.1%) were only observed following repeated-sprint training.
158 Similarly, Buchheit et al.³⁵ compared the effects of repeated-sprint training and explosive
159 strength training on team-sport specific fitness. Their results demonstrated similar
160 improvements in linear sprint speed, but a small between-group difference (ES -0.38) with
161 respect to countermovement jump, with greater improvements (~8%) following explosive
162 power training. We recently reported moderate and large effects of repeated-sprint training on
163 20 m and 30 m sprint speed respectively, which compares favourably to the effects observed
164 following plyometric training.¹⁰ However, in comparison to the small effect of repeated-sprint
165 training on the countermovement jump performance of trained team sport players,¹⁰ Markovic³⁶
166 reported a large effect (ES 0.88) following isolated plyometric training. It must, however, be
167 noted that this effect was a pooled estimate of both athletes and non-athletes. While we
168 acknowledge this is by no means an exhaustive comparison, there is evidence to suggest that
169 repeated-sprint training, when compared to isolated training, may not be as effective in
170 developing explosive-leg power, yet does elicit comparable effects for linear speed and high-
171 intensity running.

172 There has been an emergence of research examining the effectiveness of repeated-sprint
173 training performed concurrently with other training methods as this could be the most effective
174 way to use repeated-sprints.³⁵ The work of Marques et al.³⁷ supports such a notion as they
175 reported significantly greater improvements in sprint performance following combined
176 resistance and repeated-sprint training (2.3%) when compared to isolated sprint or resistance
177 training (1.7% or 1.8%, respectively). All forms of training were sufficient to induce significant
178 beneficial effects following the 6-week intervention, however. Similarly, combined repeated-
179 sprint and resistance training (one of each session per week) in rugby union players induced
180 greater improvements (~12%) in explosive leg power than repeated-sprint training alone.³⁸
181 Campos-Vasquez et al.³⁹ also reported improved explosive performance following additional
182 concurrent repeated-sprint and strength training, although the authors did report that including

183 only one repeated-sprint session and two strength sessions per week was insufficient to
184 stimulate improvements in high-intensity running performance in elite under-19 soccer players.
185 As such, it appears that combining repeated-sprint training with strength training is effective
186 for the development of team-sport specific fitness although the optimal training dose and
187 appropriate way to periodize concurrent repeated-sprint training has yet to be established.²

188 **Future perspectives**

189 The ability to perform repeated-sprints has often been suggested to be critical to team-sport
190 performance, which suggests it to be a dependent variable. Recent research of the match sprint
191 profiles of team-sport players conversely demonstrates that repeated-sprints do not occur
192 frequently within competition. Therefore, considering the benefits of repeated-sprinting as a
193 method of training, we feel that it is more appropriate to regard repeated-sprints as an
194 independent variable rather than a dependent variable as this form of training is effective for
195 the development of fitness components relevant for team-sports, namely speed, explosive leg-
196 power and high-intensity running performance. Future research needs to focus on establishing
197 how repeated-sprint training adaptations can be manipulated with variables such as the number
198 of repetitions and sets, sprint duration/distances, recovery duration between sets and
199 repetitions, and directional changes. Also, further exploration of programming variables such
200 as program duration and training frequency along with the combined effects of repeated-sprint
201 training would be of particular relevance to scientists and practitioners alike.

202

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