Title: Repeated sprints: an independent not dependent variable

Submission type: Invited commentary

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Running title: Role of repeated-sprints

Abstract word count: **126**

Text only word count: **1946**

Figure: **0**

Tables: 1

Abstract

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

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

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

In a commentary on RSA testing, Dawson[3] suggested that a compelling area for future investigation is whether RSA relates well to team-sport performance (in an overall sense) or only player work rates. This is an insightful appraisal of the role of repeated-sprints and poses to us the question of whether repeated-sprinting should be viewed as a dependent or independent variable? Despite a lack of studies examining the relationship between training-induced changes in RSA and match physical performance,[1] if, in accordance with the belief that repeated-sprinting is commonplace in team-sports, then enhancing players' RSA makes sense. In such a scenario, RSA would be perceived as a dependent variable (a measure of fitness/performance) - yet this supposition relies on repeated-sprint bouts being frequent during team-sport match play. However, the frequency of repeated-sprint bouts (often defined as 2 or more sprints interspersed by <60s recovery), and number of sprints in these bouts is low,[4-7] therefore questioning the validity of RSA as a dependent variable.

Training for worst-case scenarios makes sense within any athlete preparation[3] and clearly there is benefit in following the recommendations of Bishop et al.[1] for the development of RSA via HIT and speed/strength training, given the relevance of these individual fitness components to team-sport match performance.[8, 9] However, a recent meta-analysis reported that repeated-sprint training simultaneously induces improvements in the speed, power and high-intensity running performance of trained team-sports players.[10] With this in mind, we propose that repeated-sprints be implemented for the simultaneous training of several fitness components, as opposed to the concurrent implementation of several disparate modes of training (speed, strength, HIT) to improve the ability to produce repeated-sprints. This identifies repeated-sprints as an independent variable (training method).

Validity of RSA as a dependent variable

While it is possible that the ability to perform intense periods of repeated-sprinting can influence the outcome of match-play in team-sports,[11] until recently the activity profile of team-sports with respect to repeated-sprinting has not been well understood. This is important given that accurate assessment of the in-game activities of players facilitates physical match preparation. An overview of the repeated-sprint activity profiles of various team-sports (both male and female) is presented in Table 1, with respect to the frequency of repeated-sprints, the number of sprints per repeated-sprint bout, and the speed thresholds used to determine sprinting. While not systematic in our methodology, it is evident from these data that the occurrence of repeated-sprinting in soccer,[4-7,15] rugby league,[5, 13-14] basketball,[12] field hockey[16] and Australian football league (AFL)[5] is infrequent, thereby questioning the role of repeated-sprints during team-sport match play. It would appear that repeated-sprinting is perhaps more common in elite female team-sports with between 4-5 repeated-sprinting bouts per player occurring per match in soccer and basketball.[6,12,15] However, male team-sport players perform noticeably less repeated-sprints during match play, with elite male soccer, rugby league and

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

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

Repeated-sprints: An independent variable

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

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

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

Research establishing whether it is best to develop fitness components such as speed, power and high-intensity running separately (e.g. using isolated training methods such as sprints, plyometrics, HIT), or whether these can be developed concurrently (without interference effects) is necessary.[2] Such research would allow practitioners to make cognisant decisions regarding the inclusion of repeated-sprinting within an athlete's schedule. Buchheit[2] briefly reviewed this, reporting similar effects of repeated-sprint training and isolated training on straight-line sprint speed and unclear results regarding maximal oxygen uptake. In experimental studies, Ferrari-Bravo et al.[34] compared the effects of repeated-sprint training and HIT on RSA and high-intensity running performance, reporting that repeated-sprint training had a greater beneficial effect (~15%) on high-intensity running performance, while improvements in RSA (2.1%) were only observed following repeated-sprint training. Similarly, Buchheit et al.[35] compared the effects of repeated-sprint training and explosive strength training on team-sport specific fitness. Their results demonstrated similar improvements in linear sprint speed, but a small between-group difference (ES -0.38) with respect to countermovement jump, with greater improvements (~8%) following explosive power training. We recently reported moderate and large effects of repeated-sprint training on 20 m and 30 m sprint speed respectively, which compares favourably to the effects observed following plyometric training.[10] However, in comparison to the small effect of repeated-sprint training on the countermovement jump performance of trained team sport players,[10] Markovic[36] reported a large effect (ES 0.88) following isolated plyometric training. It must, however, be noted that this effect was a pooled estimate of both athletes and non-athletes. While we acknowledge this is by no means an exhaustive comparison, there is evidence to suggest that repeated-sprint training, when compared to isolated training, may not be as effective in developing explosive-leg power, yet does elicit comparable effects for linear speed and high-intensity running.

There has been an emergence of research examining the effectiveness of repeated-sprint training performed concurrently with other training methods as this could be the most effective way to use repeated-sprints.[35] The work of Marques et al.[37] supports such a notion as they reported significantly greater improvements in sprint performance following combined resistance and repeated-sprint training (2.3%) when compared to isolated sprint or resistance training (1.7% or 1.8%, respectively). All forms of training were sufficient to induce significant beneficial effects following the 6-week intervention, however. Similarly, combined repeated-sprint and resistance training (one of each session per week) in rugby union players induced greater improvements (~12%) in explosive leg power than repeated-sprint training alone.[38] Campos-Vasquez et al.[39] also reported improved explosive performance following additional concurrent repeated-sprint and strength training, although the authors did report that including only one repeated-sprint session and two strength sessions per week was insufficient to stimulate improvements in high-intensity running performance in elite under-19 soccer players. As such, it appears that combining repeated-sprint training with strength training is effective for the development of team-sport specific fitness although the optimal training dose and appropriate way to periodize concurrent repeated-sprint training has yet to be established.[2]

Future perspectives

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

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