Manuscript Title: The effects of in-season, low-volume sprint interval training with and without sport-specific actions on the physical characteristics of elite academy rugby league players.

Abstract

Purpose: To determine the utility of a running and rugby-specific, in-season sprint interval interventions in professional rugby league players. ***Methods:*** Thirty-one professional academy rugby players were assigned to a rugby-specific ($SIT_{r/s}$, n = 16) or running (SIT_r, n = 15) sprint interval training group. Measures of speed, power, change of direction (CoD) ability, prone Yo-Yo IR1 performance and heart rate recovery (HRR) were taken before and after the 2-week intervention as were sub-maximal responses to the prone Yo-Yo IR1. Internal, external and perceptual responses were collected during $SIT_{r/s}$/SIT_r, with wellbeing and neuromuscular function assessed before each session. ***Results:*** Despite contrasting (*possible* to *most likely*) internal, external and perceptual responses to the SIT interventions, *possible* to *most likely* within-group improvements in physical characteristics, HRR and sub-maximal responses to the prone Yo-Yo IR1 were observed after both interventions. Between-group analysis favoured the $SIT_{r/s}$ intervention (trivial to moderate) for changes in 10 m sprint time, CMJ, change of direction and medicine ball throw as well as sub-maximal (280-440 m) high metabolic power, PlayerLoad™ and acceleratory distance during the prone Yo-Yo IR1. Overall changes in wellbeing or neuromuscular function were *unclear*. ***Conclusion:*** Two-weeks of $SIT_{r/s}$ and SIT_r was effective for improving physical characteristics, HRR and sub-maximal responses to the prone Yo-Yo IR1, with no clear change in wellbeing and neuromuscular function. Between-group analysis favoured the $SIT_{r/s}$ group, suggesting that the inclusion of sport-specific actions should be considered for in-season conditioning of rugby league players.

Keywords: rugby training, training load; responders; collision sport, shuttle sprinting

Introduction

The physical demands of rugby league require players to perform high-intensity efforts that include high-speed running, sprinting, changing direction, tackling and wrestling.[1] These characteristics are essential for players to succeed[1] and should be central to rugby league conditioning practices.[2] Developing the physical characteristics of rugby league players is the focus of preseason;[3,4] thereafter emphasis is placed on recovery, technical and tactical development, and match preparations.[5] This change in focus and reduced exposure to maximal-intensity work during training might explain the observed reductions in physical characteristics such as high-intensity intermittent running ability, sprint speed and lower-body power during the latter stages of a ~28-week season.[3] Considering the importance often placed on the final stages of the season (i.e. finals), finding an effective strategy to maintain key performance characteristics could be particularly beneficial.

Low-volume sprint interval training (SIT) might be appealing during the season where players can be exposed to maximal-intensity activity through a reduced workload that also enables coaches to address technical and tactical aspects of the game.[6] It is well-documented that SIT (~20-30 s) offers an effective strategy for inducing rapid physiological remodelling[7,8] and increasing physical 'fitness' in athletic populations.[6,9] Moreover, improvements in intermittent- and endurance-based exercise performance have been observed after only two weeks of SIT,[6,10,11] and are attributed to morphological and metabolic adaptations within the skeletal muscle[10-12] and improved cardiorespiratory capacity.[10,12] However, whilst SIT appears effective for promoting adaptation, current research is largely limited to soccer players.[6,7,11] Studies have also failed to report the responses to this additional load during the intervention period, which is essential for managing the training load and determining the efficacy of SIT. The activity type should also be considered given the phase of implementation, such that SIT protocols containing metabolically demanding actions (i.e. changing direction or accelerating) and/or sport-specific actions (i.e. tackling), are likely to impose a greater systemic physiological load.[2,13] Indeed, Dobbin et al.[13] reported that the inclusion of an up/down action during a test of high-intensity intermittent running ability elicited small to moderate increases in $\dot{V}O_{2peak}$, $\dot{V}CO_{2peak}$, $\dot{V}E_{peak}$ and rating of perceived exertion (RPE) as well as moderate to large increases in PlayerLoad™, time at high metabolic power and acceleration loads. Whether the inclusion of an up/down action has any effect on physiological adaptation and responses to SIT remains unknown and warrants investigation given its association with running performance in rugby.[14] Finally, it is important to consider players' ability to tolerate in-season SIT in order to ensure this training modality incurs no detrimental effects within this period.

Accordingly, this study aimed to 1) examine the effectiveness of an in-season, low-volume rugby-specific and running SIT intervention on the physical characteristics of elite academy rugby league players; 2) determine any between-group differences in internal, external and perceptual loads during the SIT interventions and to document the accumulated training load; and 3) explore the wellbeing and neuromuscular responses to the intervention.

Methods

Design and Participants

Thirty-one elite academy rugby league players (age = 17.1 ± 1.0 y, stature 179.6 ± 5.8 cm, body mass 86.9 ± 5.8 kg) were recruited from two Super League clubs. All players across the two clubs were assigned to a rugby-specific ($SIT_{r/s}$, *n* = 15) or running (SIT_r, *n* = 16) SIT intervention, with the minimization approach used to balance both training groups for playing position and rugby-specific intermittent fitness using the prone Yo-Yo IR1.[14]

A parallel two-group, matched-work experimental design was used to assess the effects of two SIT interventions on the physical characteristics of academy rugby league players. The intervention followed that of Macpherson and Weston[6] and involved players completing six sessions over a 2-week period during the competitive season. The intervention period coincided with a mid-season break in the team's fixtures (i.e. week 12-14 of a 28-week season), though players completed their normal training during this period. The prescribed sessions replaced all conditioning practices with 24-48 hours between sessions. Institutional ethics approval and informed consent were obtained before starting the study.

Procedures

Training intervention

The intervention involved six sessions over a 2-week period with each session including 6 (week 1) or 8 (week 2) 30 s repetitions of maximal shuttle sprinting. Both interventions required the participant to complete as many shuttles as possible in the 30 s with a high degree of verbal encouragement given by the lead researcher. The $SIT_{r/s}$ group were required to adopt a prone position at the start of each 20 m shuttle whilst the SIT_r group remained on their feet throughout. A 3-minute active recovery (walking at 1.1 $m \cdot s^{-1}$) followed each 30 s repetition.

Outcome measures

To assess the effectiveness of the intervention, a standardised testing battery[15] was conducted before and after the two-week intervention period. In all, this involved completing a standardised warm-up before performing two 10- and 20-m sprints; a change of direction test on the left and right sides; two medicine ball throws; two countermovement jumps (CMJ); and a rugby-specific Yo-Yo Intermittent Recovery Test (prone Yo-Yo IR1).[14] Full details of the testing battery can be found in Supplement 1.

All testing took place at each club's own training ground at the same time of day on artificial turf and was preceded by 48 hours of no leisure- or club-based physical activity. To control for the influence of diet, participants recorded all food and fluid intake in the 3-hours before the testing sessions and were asked to refrain from caffeine consumption on the day of testing (ES ± 90% CL between pre- and post-testing: carbohydrate = 0.02 ± 0.05; protein, = -0.02 ± 0.08; fat = -0.03 ± 0.07). The same researcher conducted all testing and training sessions in a standardised order with two club coaches present but who refrained from giving verbal encouragement. All participants were familiar with the testing procedures.

Total training load quantification

Players provided an RPE for all activities 30 min after training using a 10-point scale, which was then multiplied by the duration to provide a measure of training load (sRPE).[16]

Internal, external and perceptual responses

Measures of internal and external loads were collected during the pre- and post- intervention prone Yo-Yo IR1, and SIT interventions, whilst perceptual responses were collected during SIT only. Heart rate was measured continuously during the pre- and post-intervention prone Yo-Yo IR1 (Polar, FS1, Polar Electro Oy, Finland) to ascertain mean heart rate (HR_{mean}) at 160, 280 and 440 m, and to compute heart rate recovery (HRR), defined as the number of beats recovered in the 60 s after cessation of the prone Yo-Yo IR1. During all SIT sessions, HR was measured for the entire session and expressed as a percentage of peak HR ($\%HR_{peak}$).

****INSERT FIGURE 1 HERE****

A 10 Hz microtechnology device fitted with a 100 Hz triaxial accelerometer, gyroscope and magnetometer (Optimeye S5, Catapult Innovations, Melbourne, Australia) was worn with the unit harnessed between the scapulae. Participants wore the same unit throughout the study. The available satellites and horizontal dilution of precision were 16.7 ± 0.8 and 0.7 ± 0.1, respectively. After the pre- and post-intervention prone Yo-Yo IR1, the data were downloaded (Sprint Version 5.1, Catapult Sports, Victoria, Australia) and analysed for PlayerLoad™ (AU), time above > 20 $W \cdot kg^{-1}$ (HMP) and distance accelerating above 3 $m \cdot s^{-1}$ (m) at 160, 280 and 440 m. For the SIT sessions, total distance (m), time above HMP, distance accelerating above 3 $m \cdot s^{-1}$ (m) and mean speed (%peak speed from 20 m sprint test using GPS) were analysed.

Before the intervention, participants were habituated to the CR100® scale and educated about the purpose of differential RPE (dRPE). With this knowledge, players were asked to differentiate between central (i.e. breathlessness [dRPE-B]) and local (i.e. legs [dRPE-L]) ratings of exertion 15 to 30 minutes after each $SIT_{r/s}$ and SIT_s session and on their own. To eliminate order effect, players provided ratings in a randomised order across the sessions.

Psychometric questionnaire and neuromuscular function

Players provided ratings of perceived fatigue, soreness, sleep quality, mood and stress using a 1-5 Likert scale before each session. All players were familiar with the questionnaire and were asked to complete this away from teammates and coaches. Neuromuscular function was assessed during a CMJ using the same procedures described in Supplement 1.

Statistical analysis

Within-group changes were analysed using a post-only crossover spreadsheet,[17] and between-group changes analysed using a pre-post parallel-groups spreadsheet[17] with the uncertainty of estimates expressed as 90% confidence intervals (90% CL). In analysing the changes in testing battery scores, and the change in CMJ and wellbeing between groups over time, we used the baseline (pre-intervention/session 1) variable as a covariate to control for baseline imbalances between groups. The SD of individual responses (within-subject variation) was determined using the pre-post parallel-groups.[17] To provide an interpretation of the magnitude of change, effect sizes (ES) were calculated as the difference between trials divided by the pooled SD derived from both interventions and the following thresholds applied: 0.0-0.2, *trivial*; 0.2-0.6, *small*; 0.6-1.2, *moderate*; 1.2-2.0, *large*; >2.0, *very large*.[18] Changes were determined mechanistically with inferences qualified using the following scale: 25% to 75%, *possibly*; 75% to 95%, *likely*; 95% to 99.5%, *very likely*; and >99.5%, *most likely*.[19] In instances when the confidence limits overlapped both substantially positive and negative thresholds, the change was interpreted as unclear.

Results

Within- and between-group analysis on physical characteristics and HRR are presented in Table 1. Between-group differences were trivial for CMJ, change of direction time and medicine ball throw distance; small for 10 m sprint time; and unclear for 20 m sprint time, prone Yo-Yo IR1 distance and HRR. No clear differences were observed for the SD of the individual responses between SIT_r and $SIT_{r/s}$ for 10 m (0.03 ± 0.05 s), 20 m (0.04 ± 0.05 s), CMJ (0.01 ± 0.01 s), change of direction (0.08 ± 0.23 s), medicine ball throw (-0.1 ± 0.2 m) prone Yo-Yo IR1 (47 ± 92 m) and HRR (3 ± 5 b·min^{-1}).

****INSERT TABLE 1 HERE****

Sub-maximal internal and external responses during the prone Yo-Yo IR1 along with within-group and between-group analysis are presented in Table 2. Results revealed trivial to small positive within-group changes in HR_{mean} and a trivial between-group difference at 160 m. Small to very large within-group changes were observed in time spent at HMP, PlayerLoad™, and distance accelerating above 3 m·s^{-1}, with unclear to moderate between-group differences. No clear differences were observed for the SD of the individual responses between SIT_r and $SIT_{r/s}$ for HR at 160 m (3 ± 3 b·min^{-1}), 280 m (-2 ± 4 b·min^{-1}) and 440 m (2 ± 3 b·min^{-1}), HMP at 160 m (0.6 ± 1.4 s) and 280 m (-0.7 ± 0.7 s), PlayerLoad™ at 280 m (-0.8 ± 0.9 AU) and 440 m (-0.7 ± 1.0 AU) and distance accelerating at 160 m (-0.7 ± 1.0 m), 280 (0.4 ± 1.2 AU) and 440 (-0.5 ± 1.1 AU). The SD of individual responses to $SIT_{r/s}$ was *most likely* greater for HMP at 440 m (1.4 ± 0.6 s) and *very likely* lower for PlayerLoad™ at 160 m (-1.3 ± 0.7 AU).

****INSERT TABLE 2 HERE****

Training load across the intervention period is presented in Figure 1, with unclear between-group differences observed across all sessions for skills (ES ± 90% CL = 0.06 ± 0.51), SIT (0.04 ± 0.30) and resistance training (0.05 ± 0.31). Moderate differences in the response to $SIT_{r/s}$ and SIT_r were observed for distance (108.6 ± 12.7 *cf.* 118.3 ± 10.2 m), time at HMP (17.2 ± 2.3 *cf.* 14.6 ± 2.5 s) and distance accelerating above 3 m·s^{-1} (9.0 ± 3.0 *cf.* 7.0 ± 2.0 m). A very large difference in mean speed was observed between $SIT_{r/s}$ and SIT_r (60.3 ± 3.5 *cf.* 67.6 ± 4.0 %peak speed). Small differences were observed between $SIT_{r/s}$ and SIT_r in HR_{mean} (154 ± 9 *cf.* 151 ± 12 b·min^{-1}), dRPE-L (74 ± 14 *cf.* 74 ± 13 AU) and dRPE-B (65 ± 18 *cf.* 62 ± 13 AU) (Figure 2).

****INSERT FIGURE 2 HERE****

Small to moderate reductions in perceived wellbeing were observed during the intervention period (ES -0.23 to -1.02); albeit with no clear mean difference between session 1 and 6 (Figure 3). Neuromuscular function demonstrated a trivial to small reduction across the intervention period (ES = -0.52 to 0.28) with no clear mean difference between session 1 and 6 (Figure 3).

****INSERT FIGURE 3 HERE****

Discussion

The aim of the current study was to investigate the effects of two sprint interval interventions on the physical characteristics, wellbeing and neuromuscular function of academy rugby league players when conducted in-season. The internal, external and perceptual response to training indicated that both interventions were very high-intensity training modalities; $SIT_{r/s}$ elicited a greater metabolic load, whilst the SIT_r group covered greater distance at a higher mean speed. Both interventions were effective for eliciting positive changes in the physical characteristics, HRR and the submaximal responses to the prone Yo-Yo IR1 with few clear differences in the SD of the individual responses. Between-group analysis favoured the $SIT_{r/s}$ for some characteristics despite similar absolute training loads across the intervention. Overall mean change in wellbeing and neuromuscular function were unclear.

The within-group mean improvements in sprint, CMJ, change of direction and medicine ball throw performance contrast previous observations demonstrating no clear effect of 3 to 7 weeks of SIT on power-, force- and speed-based actions.[7,20] Our results do agree with studies that have used repeated sprint training with mean improvements in all outcome measures,[21,22] though the observed mean change for 10 m, 20 m, CMJ, change of direction and medicine ball throw in this study were less than the required change noted by Dobbin et al.[15]. Nonetheless, the small to moderate within-group changes might be explained by muscular adaptation, including an increase in substrate (i.e. phosphocreatine), enzymatic activity[7,8] and alteration of contractile properties,[23] as well as potential neural adaptations (i.e. fibre recruitment, firing rate, motor unit synchronisation, recruitment of the gluteal muscle group).[21,22] Results indicate that exposure to maximal speed and emphasis on accelerated running, particularly during $SIT_{r/s}$, constitutes an important element for improving power-, force, and speed-based actions,[22] and likely explains the trivial to small between-group differences in favour of $SIT_{r/s}$ for 10 m sprint, CMJ, change of direction and medicine ball throw performance. Practitioners might consider including sport-specific actions in conjunction with SIT to maximise adaptation in power-, force- and speed-orientated characteristics in rugby league players.

Both interventions appeared equally as effective for eliciting improvements in prone Yo-Yo IR1 performance with the mean change in $SIT_{r/s}$ (120 m) and SIT_r (112 m) being similar to the required change of 120 m noted by Dobbin et al.[15] Such finding are important given its relationship with the internal and external responses to simulated match-play.[14] These results reaffirm the small to large improvements in Yo-Yo IR1 performance after SIT and/or repeated sprint training in team-sport athletes.[6,9,21] Although not directly measured, the improvement in total distance covered are potentially explained by several central and peripheral adaptations that promote oxygen delivery and uptake as well as mitochondrial enzyme activity, protein content (i.e. monocarboxylate transport 1 and Na^+/K^+ pump subunit β_1), muscle lactate and H^+ regulation capacity and phosphocreatine and muscle glycogen stores, amongst others; all of which likely delayed the onset of fatigue during the prone Yo-Yo IR1.[8,12] Two weeks of high intensity training might also have increased exercise-induced pain tolerance that contributed to participants willingly extending their running time at maximal intensity during the second Yo-Yo IR1.[24] For example, O'Leary et al.[27] demonstrated that 6 weeks of high-intensity exercise increased pain tolerance through greater central tolerance of nociception, and was positively associated with time to exhaustion during a cycling test. Further work is required to elucidate the mechanisms that contribute to improve high intensity intermittent running performance after short-term sprint interval training interventions in team sport athletes.

Improvements in sub-maximal HR_{mean} and HRR in both $SIT_{r/s}$ and SIT_r are associated with improvements in cardiorespiratory fitness[25] including increases in stroke volume, cardiac output, blood volume[12] and reductions in sympathetic activity.[25] The mean change in HRR was similar to Buchheit et al.[25] after 10 weeks of high-intensity training in adolescent soccer players (60.0 ± 12.2 *cf.* 75.6 ± 13.6 $b \cdot min^{-1}$). Such findings indicate that both interventions induced an increase in parasympathetic reactivation and sympathetic withdrawal at exercise cessation.[25] Sub-maximal responses during the prone Yo-Yo IR1 also suggest that $SIT_{r/s}$ appears to have enhanced the neuromuscular adaptation that might explain the trivial to moderate between-group differences in the time spent at HMP and small between-group differences in distance accelerating above 3 $m \cdot s^{-1}$. From an applied perspective, this finding might encourage practitioners and coaches in rugby league to incorporate such actions within conditioning practices in an attempt to develop rugby players' ability to get up from the floor quickly, which in turn might reduce the external loads (i.e. acceleratory distance) placed on players during intermittent running

Whilst our results support the notion that $SIT_{r/s}$ and SIT_r are effective training modalities for promoting the physical characteristics of rugby league players, a key purpose of this study was to explore the efficacy of this during the competitive season. Our results for wellbeing and neuromuscular function revealed likely to most likely reductions during session two, which reflects the introduction of novel high-intensity activity during a period where maximal intensity training is typically limited.[5] However, it is important to note that the mean change in wellbeing and neuromuscular function were unclear between sessions 1 to 6, indicating that 2-weeks sprint interval training can be incorporated in-season without residual neuromuscular and perceptual fatigue.

This study builds on the existing literature and addresses a number of the limitations previously noted. For example, a detailed insight into the accumulated training load across the two weeks enables practitioners to understand the required exercise dose to elicit the improvements observed. The intervention was also included within each team's current training schedule with only field-based conditioning replaced by $SIT_{r/s}$ or SIT_r; thus increasing the ecological validity of this study. Furthermore, our study included measures of neuromuscular function and wellbeing throughout the training period that have not been considered previously. There are, however, several limitations that warrant acknowledgement. We were unable to include a control group in this study that completed only their normal training, meaning the effectiveness of $SIT_{r/s}$ and SIT_r beyond their usual conditioning remains unknown. We were also unable to determine whether the change in physical characteristics positively influenced a player's match performance. However, given the relationship between tests of physical characteristics and match-play performance,[14] we anticipate both interventions would offer several benefits to enhance match performance. We also acknowledge that, when taking into account the reliability of the outcome measures, the sample size required for adequate precision in change of mean is likely greater than that used in this study and may at risk of type I or type II errors. However, the sample size is in accordance with previous research and raises questions regarding the reliability of the performance tests used despite reflecting the 'typical' noise practitioners are likely to observed in rugby league academy players. Whilst the inclusion of repeated trials conducted pre- and post-intervention might be one method to reduce this noise, this is likely to be impractical in the applied setting, particularly when conducting research in-season. Finally, the intervention coincided with a mid-season period of no fixtures for the two clubs, so whether

$SIT_{r/s}$ and SIT_r are suitable when combined with weekly matches is unclear.

Practical Applications

Between-group analysis supports the inclusion of sport-specific actions in the attempt to increase the systemic loads of SIT training and promote greater adaptation for physical characteristics and sub-maximal responses to intermittent running. Such findings should encourage practitioners to consider including sport-specific, metabolically demanding actions such as the up/down action used in this study within current training practices in rugby league. Furthermore, we highlight how repeated shuttle sprinting can provide a stimulus that reduced the acceleratory responses to rugby-specific prolonged high-intensity intermittent running and therefore emphasis placed on accelerating, decelerating and changing direction should be incorporated into future training practices. Finally, our results also revealed that incorporating SIT training within the competitive season is feasible without compromising athlete wellbeing or neuromuscular function, and should be consider by practitioners, particularly during the latter stages where some physical characteristics might deteriorate.[3]

Conclusions

In conclusion, $SIT_{r/s}$, and to a lesser extent SIT_r, are effective in-season micro-dosing strategies for improving a range of physical characteristics important in rugby league.Furthermore, the inclusion of SIT during the season and when combined with players' normal training routine did not elicit detrimental reductions in wellbeing and neuromuscular function. Therefore, $SIT_{r/s}$ and SIT_r are effective training modalities that can be used to promote the physical characteristics of elite academy rugby league players in-season with similar variability in the response likely to be observed.

References

1. Gabbett TJ, Gahan CW. Repeated high-intensity effort activity in relation to tries scored and conceded during rugby league match-play. *Int J Sports Physiol Perform* 2016;11(4):530-534.
2. Mullen T, Highton J, Twist C. The internal and external responses to a forward-specific rugby league simulation protocol performed with and without physical contact. *Int J Sports Physiol Perform* 2015;10(6):746-753.
3. Dobbin N, Highton J, Moss SL, *et al.* Factors affecting the anthropometric and physical characteristics of elite academy rugby league players: a multi-club study. *Int J Sports Physiol Perform* doi: 10.1123/ijspp.2018-0631.

4. Dobbin N, Gardner A, Daniels M, *et al.* The influence of preseason training phase and training load on body composition and its relationship with physical qualities in professional junior rugby league players. *J Sports Sci* 2018; 36(24):2778-2786.
5. Gabbett TJ. Influence of training and match intensity on injuries in rugby league. *J Sports Sci* 2004;22(5):409-417.
6. Macpherson TW, Weston M. The effect of low-volume sprint interval training on the development and subsequent maintenance of aerobic fitness in soccer players. *Int J Sports Physiol Perform* 2015;10(3):332-338.
7. Iaia FM, Fiorenza M, Perri E, *et al.* The effect of two speed endurance training regimes on performance of soccer players. *PLoS One* 2015;10(9):e0138096.
8. Fransson D, Nielsen TS, Olsson K, *et al.* Skeletal muscle and performance adaptation to high-intensity training in elite male soccer players: speed endurance runs versus small-sided games training. *Eur J Appl Physiol* 2018;1118(1):111-121.
9. Ferrari Bravo D, Impellizzeri FM, Rampinini E, *et al*. Sprint vs. interval training in football. *Int J Sports Med* 2008;29(8):668-674.
10. Burgomaster KA, Hughes SC, Heigenhauser GJ, *et al.* Six session of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans. *J Appl Physiol* 2005;98(6);1985-1990.
11. Thomassen M, Christensen PM, Gunnarsson TP, *et al.* Effect of 2-wk intensified training and inactivity on muscle Na+-K+ pump expression, phospholemman (FXYD1) phosphorylation and performance in soccer players. *J Appl Physiol* 2010;108(4):898-905.
12. MacInnes MJ, Gibala MJ. (Physiological adaptations to interval training and the role of exercise intensity. *J Physiol* 2017;595(9):2915-2930.
13. Dobbin N, Moss SL, Highton J, *et al.* An examination of a modified Yo-Yo test to measure intermittent running performance in rugby. *Eur J Sport Sci* 2018;18(8):1068-1076.
14. Dobbin N, Highton J, Moss SL, *et al.* Concurrent validity of a rugby-specific Yo-Yo intermittent recovery test (level 1) for assessing match-related running performance. *J Strength Cond Res* 2018; doi: 10.1519/JSC.0000000000002621.
15. Dobbin N, Hunwicks R, Highton J *et al.* A reliable testing battery for assessing physical qualities of elite academy rugby league players. *J Strength Cond Res* 2018;32(11):3232-3238.
16. Foster C, Florhaug JA, Franklin J *et al.* A new approach to monitoring exercise training. *J Strength Cond Res* 2001;15(1):109-115.

17. Hopkins WG. Spreadsheets for analysis of controlled trials, crossovers and time series. *Sportscience* 2017;21:1-4 (sportsci.org/2017/wghxls.htm).
18. Hopkins, WG. A scale of magnitudes for effect statistics. *Sportscience* 2002: Available at: http://www.sportsci.org/resource/stats/ effectmag.html.
19. Batterham AM, Hopkins WG. Making meaningful inferences about magnitudes. *Int J Sports Physiol Perform* 2006;1(1):50-57.
20. Buchheit M, Mendez-Villanueva A, Quod M, *et al.* Improving acceleration and repeated sprint ability in well-trained adolescent handball players: speed versus sprint interval training. *Int J Sports Physiol Perform* 2010;5(2):152-164.
21. Taylor JM, Macpherson TW, McLaren SJ, *et al.* Two weeks of repeated-sprint training in soccer: to turn or not to turn? *Int J Sports Physiol Perform* 2016;11(8):998-1004.
22. Iaia FM, Fiorenza M, Larghi L, *et al.* Short- or long-rest interval during repeated-sprint training in soccer. *PLoS One* 2017;12(2):e0171462.
23. Ross A, Leveritt M. Long-term metabolic and skeletal muscle adaptation to short-sprint training: implications for sprint training and tapering. *Sports Medicine* 2001;31(15):1063-1082.
24. O'Leary TJ, Collett J, Howells K, *et al*. High but not moderate-intensity endurance training increases pain tolerance: a randomised trial. *Sport Med* 2017; 117: 2201-2210.
25. Buchheit M, Millet GP, Parisy A, *et al.* Supramaximal training and postexercise parasympathetic reactivation in adolescents. *Med Sci Sports Exerc* 2008;40(2):362-371.

Table 1. Outcome measures at baseline with the mean change and qualitative inference for the within- and between-group comparisons.

	$SIT_{r/s}$ (*n* = 15)			**SIT_r (*n* = 16)**			**Group Comparison**	
	Baseline	Change in score (mean ± SD; ±90%CL)	Qualitative inference	Baseline	Change in score (mean ± SD; ±90%CL)	Qualitative inference	Between-group difference (mean; 90%CL)	Qualitative inference
10 m sprint (s)	1.76 ± 0.08	-0.07 ± 0.05; ±0.03	Moderate +ve***	1.78 ± 0.08	-0.05 ± 0.04; ±0.02	Small +ve***	0.02; ±0.03	Small* favouring $SIT_{r/s}$
20 m sprint (s)	3.02 ± 0.11	-0.07 ± 0.06; ±0.03	Moderate +ve***	3.05 ± 0.10	-0.06 ± 0.05; ±0.02	Small +ve***	0.01; ±0.03	Unclear
CMJ flight time (s)	0.58 ± 0.04	0.02 ± 0.01; ±0.01	Small +ve**	0.58 ± 0.03	0.01 ± 0.01; ±0.01	Small +ve****	-0.01; ±0.01	Trivial*
Change of direction (s)	19.79 ± 0.71	-0.37 ± 0.25; ±0.11	Small +ve***	19.53 ± 0.60	-0.35 ± 0.24; ±0.11	Small +ve***	0.02; ±0.15	Trivial**
Medicine ball throw (m)	7.5 ± 0.8	0.2 ± 0.2; ±0.1	Small +ve**	7.6 ± 0.7	0.2 ± 0.2; ±0.1	Small +ve**	0.0; ±0.13	Trivial**
Prone Yo-Yo IR1 (m)	821 ± 215	120 ± 103; ±46	Small +ve***	863 ± 266	112 ± 92; ±41	Small +ve***	-8; ±60	Unclear
HRR ($b \cdot min^{-1}$)	20	8 ± 5; ±2	Large +ve****	21 ± 5	8 ± 5; ±2	Large +ve****	0.02; ±3.04	Unclear

Abbreviations: $SIT_{r/s}$, rugby-specific sprint interval training; SIT_r, running only sprint interval training; CMJ, countermovement jump; HRR, heart rate recovery.

Notes: Data presented as mean ± standard deviation. Within-group comparison: +ve, beneficial (positive) effect; -ve, harmful (negative) effect. Between-group comparison: +ve, beneficial (positive) effect of $SIT_{r/s}$ when compared to SIT_r; -ve, harmful (negative) effect of $SIT_{r/s}$ when compared to SIT_r. * *possibly* (25-75%), ** *likely* (75-95%), *** *very likely* (95-99.5), **** *most likely* (> 99.5%).

Table 2. Sub-maximal internal and external response during the prone Yo-Yo IR1 at baseline with mean change and qualitative inference for the within- and between-group comparisons.

	$SIT_{r/s}$ (***n* = 15**)			SIT_r (***n* = 16**)			**Group Comparison**	
	Baseline	Change in score (mean ± SD; ±90%CL)	Qualitative inference	Baseline	Change in score (mean ± SD; ±90%CL)	Qualitative inference	Between-group difference (mean; ±90%CL)	Qualitative inference
HR_{mean} ($b \cdot min^{-1}$)								
160 m	168 ± 7	-3.4 ± 3.0; 1.3	Small +ve***	166 ± 13	-2.7 ± 3.8; 1.7	Trivial*	0.7; ±2.1	Trivial**
280 m	183 ± 6	-2.6 ± 3.7; 1.7	Small +ve**	181 ± 9	-2.6 ± 4.3; 1.9	Small +ve*	0.1; ±2.5	Unclear
440 m	189 ± 5	-2.8 ± 3.4; 1.6	Small +ve**	186 ± 8	-2.7 ± 3.0; 1.4	Small +ve**	0.1; ±2.0	Unclear
Time > HMP (s)								
160 m	17.2 ± 1.9	-1.9 ± 1.5; 0.7	Moderate +ve****	17.4 ± 1.8	-1.7 ± 1.4; 0.6	Moderate +ve****	0.2; ±0.9	Unclear
280 m	17.8 ± 1.3	-1.3 ± 0.6; 0.3	Moderate +ve****	17.6 ± 1.9	-1.1 ± 0.9; 0.6	Small +ve***	0.2; ±0.5	Trivial*
440 m	22.8 ± 1.1	-2.2 ± 1.5; 0.8	Large +ve****	21.4 ± 1.4	-1.2 ± 0.9; 0.3	Moderate +ve****	1.0; ±0.9	Moderate** favouring $SIT_{r/s}$
PlayerLoad™ (AU)								
160 m	20.3 ± 2.5	-0.6 ± 0.8; 0.4	Trivial*	20.6 ± 2.6	-0.5 ± 1.5; 0.7	Small +ve*	0.0; ±0.7	Unclear
280 m	15.4 ± 2.6	-0.8 ± 0.9; 0.4	Small +ve**	15.8 ± 2.0	-0.6 ± 1.1; 0.5	Small +ve*	0.2; ±0.6	Trivial**
440 m	20.5 ± 2.9	-1.5 ± 1.0; 0.4	Small +ve***	21.3 ± 2.2	-0.9± 1.2; 0.5	Small +ve**	0.6; ±0.7	Small* favouring $SIT_{r/s}$
Accel. > 3 $m \cdot s^{-1}$ (m)								
160 m	7.6 ± 1.1	-2.4 ± 1.0; 0.4	Very large +ve****	7.5 ± 1.4	-1.8 ± 1.1; 0.5	Large +ve****	0.6; ±0.6	Small** favouring $SIT_{r/s}$
280 m	7.0 ± 1.4	-2.4 ± 1.3; 0.8	Large +ve****	6.9 ± 1.5	-1.9 ± 1.3; 0.7	Moderate +ve****	0.6; ±0.8	Small* favouring $SIT_{r/s}$
440 m	8.1 ± 1.5	-1.9 ± 1.1; 0.5	Large +ve****	7.9 ± 1.4	-1.4 ± 1.2; 0.5	Moderate +ve****	0.5; ±0.7	Small* favouring $SIT_{r/s}$

Abbreviations: $SIT_{r/s}$, rugby-specific sprint interval training; SIT_r, sprint interval training; HR_{mean}, mean heart rate; HMP, high metabolic power; Accel., acceleration

Notes: Data presented as mean ± standard deviation. Within-group comparison: +ve, beneficial (positive) effect; -ve, harmful (negative) effect. Between-group comparison: +ve, beneficial (positive) effect of $SIT_{r/s}$ when compared to SIT_r; -ve, harmful (negative) effect of $SIT_{r/s}$ when compared to SIT_r. * *possibly* (25-75%), ** *likely* (75-95%), *** *very likely* (95-99.5), **** *most likely* (> 99.5%).

Figure 1. Schematic showing training load for all resistance, rugby and sprint interval sessions across the two-week intervention.

Figure 2. Between-group differences in internal, external and perceptual responses to the $SIT_{r/s}$ and SIT_{r} interventions. The whiskers-box plots represent the 25^{th}-75^{th} percentile of results inside the box; the median is indicated by the horizontal line across the box and the mean by a solid black circle. The whiskers on each box represent the 5^{th}-95^{th} percentile of results. * *possibly* (25-75%), ** *likely* (75-95%), *** *very likely* (95-99.5), **** *most likely* (> 99.5%).

Figure 3. Mean ± SD daily perceived wellbeing (circles) and countermovement flight time (bars) for the $SIT_{r/s}$ (light grey) and SIT_{r} (dark grey). * *possibly,* ** *likely* (75-95%), *** *very likely* (95-99.5%) within-group change. # possible between-group difference.