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Upper-body repeated-sprint training in hypoxia in international rugby union players

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Abstract

This study investigated the effects of upper-body repeated-sprint training in hypoxia vs. in normoxia on world-level male rugby union players' repeated-sprint ability (RSA) during an international competition period. Thirty-six players belonging to an international rugby union male national team performed over a 2-week period four sessions of double poling repeated-sprints (consisting of 3 × eight 10-s sprints with 20-s passive recovery) either in normobaric hypoxia (RSH, simulated altitude 3000 m, n = 18) or in normoxia (RSN, 300 m; n = 18). At pre- and post-training intervention, RSA was evaluated using a double-poling repeated-sprint test (6 × 10-s maximal sprint with 20-s passive recovery) performed in normoxia. Significant interaction effects (P < 0.05) between condition and time were found for RSA-related parameters. Compared to Pre-, peak power significantly improved at post- in RSH (423 ± 52 vs. 465 ± 69 W, P = 0.002, η^2=0.12) but not in RSN (395 ± 65 vs. 397 ± 57 W). Averaged mean power was also significantly enhanced from pre- to post-intervention in RSH (351 ± 41 vs. 388 ± 53 W, P < 0.001, η^2=0.15), while it remained unchanged in RSN (327 ± 49 vs. 327 ± 43 W). No significant change in sprint decrement (P = 0.151, η^2 = 0.02) was observed in RSH (−17 ± 2% vs. −16 ± 3%) nor RSN (−17 ± 2% vs. −18 ± 4%). This study showed that only four upper-body RSH sessions were beneficial in enhancing repeated power production in international rugby union players. Although the improvement from RSA to game behaviour remains unclear, this finding appears of practical relevance since only a short preparation window is available prior to international games.

KEYWORDS: *Repeated-sprint training in hypoxia, repeated-sprint ability, team sports, competition, upper limbs, rugby union*

Highlights

- Upper-body repeated-sprint training in in hypoxia is beneficial for improving repeated-sprint ability in international rugby players.
- Only a short windows of preparation is needed.
- RSH can be implemented in international competition preparation.

Introduction

Rugby union is a game that requires high levels of fitness and technical abilities to be successful (Deutsch, Kearney, & Rehrer, 2007; Duthie, Pyne, & Hooper, 2003). The physical requirements of rugby union are dependent on playing position and whether players are playing in attack or defense throughout the game (Duthie et al., 2003), which demand players to complete upper- or lower-body dominant movements or combination of both. Upper-body movements include wrapping the arms around the player when tackling, grappling and wrestling in rucks, mauls and collisions and fending players off in attack. Lower-body movements include leg drives in tackling, jumping in line-outs, pushing in scrums, rucks and mauls and all running activities such as change of directions, accelerations, decelerations and sprinting (Deutsch et al., 2007; Duthie et al., 2003). The intermittent nature of rugby union has shown this sport requires a high number of repeated bouts of maximal-intensity

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efforts involving the aforementioned upper- and/or lower-body activities to be performed throughout the game (Duthie et al., 2003; Quarrie, Hopkins, Anthony, & Gill, 2013).

High-intensity repeated efforts and sprints have been identified as a physical fitness quality potentially connected to performance within intermittent team sports such as rugby union and league, basketball, field hockey, soccer, and Australian rules football (Austin, Gabbett, & Jenkins, 2011; Gabbett & Wheeler, 2015). Repeated-sprint ability (RSA) is a complex component of fitness and may have many factors that influence its level of performance such as neural and/or metabolic mechanisms (Bishop, Girard, & Mendez-Villanueva, 2011; Girard, Mendez-Villanueva, & Bishop, 2011; Glaister, 2005). The ability to repeatedly produce high amounts of force or speeds (i.e. power) comes from the utilization of the fast-twitch fibres more so than their slow-twitch counterparts (Girard et al., 2011). It may be therefore interesting to enhance the fatigue resistance of the fast-twitch fibres through specific RSA-type training. To date, the repeated-sprint training literature has mainly concentrated on the lower-body (i.e. ergocycling, treadmill and over-ground running), whereas a number of studies examining the upper-body responses to RSA have recently shown that there may be some differences between how the upper- and lower-body react to RSA training protocols (Halperin et al., 2018; Koppo, Bouckaert, & Jones, 2002; Sandbakk et al., 2015; Zinner et al., 2016). For instance, Koppo et al. (2002) found that the fast-twitch fibres are recruited earlier and to a greater magnitude in upper-body high-intensity exercise (arm cranking) than in lower-body high-intensity exercise (cycling). This could be due to the higher concentration of fast-twitch fibres in the upper-body compared to the lower-body (Terzis, Stattin, & Holmberg, 2006), resulting in an increased reliance on anaerobic pathways (Zinner et al., 2016).

Recently, it has been shown that combining lower-body repeated-sprint training with hypoxia (RSH) led to greater RSA enhancement than the same training in normoxia (Brocherie, Girard, Faiss, & Millet, 2015, p. 2017; Faiss, Girard, & Millet, 2013; Galvin, Cooke, Sumners, Mileva, & Bowtell, 2013; Girard, Brocherie, & Millet, 2017; Hamlin, Olsen, Marshall, Lizamore, & Elliot, 2017; Millet, Faiss, Brocherie, & Girard, 2013). RSH is a method derived from the 'live low-train high' (LLTH) branch of the altitude/hypoxic panorama (Girard et al., 2017; Millet et al., 2013). In 2013, when Faiss, Leger, et al. (2013) reported better RSA improvements in well-trained cyclists after 8 RSH sessions in comparison to similar training in normoxia (RSN), they postulated that the maximal nature of the RSH paradigm favors the usage of fast-twitch fibres (Faiss, Girard, et al., 2013). The drop in arterial oxygen content accompanied with any hypoxic exposure is then matched by the increased perfusion of blood to the active muscles which matches this drop in oxygen (Casey & Joyner, 2012). RSH methodology being made up of maximal "all-out" efforts of short duration (<30 s) with incomplete recoveries (Brocherie, Girard, Faiss, & Millet, 2017; Girard et al., 2017), would therefore impact favorably the fast-twitch fibres due to the "compensatory vasodilation" and subsequent hypoxia-induced enhanced exercise hyperaemia (Casey & Joyner, 2012). This mechanism is known to be mediated by the nitric oxide synthase pathway and is intensity-dependent; being larger at higher intensity (Casey, Curry, Wilkins, & Joyner, 2011). RSH differs from intermittent hypoxic training (IHT) that utilizes intervals of either the aerobic or anaerobic systems and is completed at a sub-maximal level therefore not always employing preferential vasodilation of the vessels to the fast-twitch fibres (Faiss, Leger, et al., 2013).

As previously mentioned, the upper-body movements (e.g. tackling, rucking and mauling) are frequent repeated skills in rugby union (Duthie et al., 2003; Quarrie et al., 2013). Therefore, it may be of interest to investigate the upper-body's responses to RSH. The upper-body muscles having a greater concentration of fast-twitch fibres than the lower-body muscles (Terzis et al., 2006), it was postulated that RSH using the upper-body musculature could potentially have larger performance gains. To date, Faiss et al. (2015) have been the sole study that has investigated RSH on the upper-body among cross-country skiers. While double poling may not be considered movement pattern specific to many team sports, it is regularly used as a training exercise in rugby union. Therefore, it was of interest to us to see if there were similar results in power-based athletes who utilized repeated upper-body movements such as rugby. This study showed significant benefits for RSH vs. RSN after six sessions over a 2-week period, with a larger ability to reduce the increasing muscle fatigue throughout the double-poling RSA set (i.e. 58% more sprints at post- in the RSH group) while no significant difference in power output was reported between the RSH and RSN groups. The increase in the number of sprints completed but not in power output between RSH and RSN groups may be explained with the participants (cross-country skiers) being predominately involved in endurance sport. With such positive results shown by Faiss et al. (2015), the number of sessions, length of hypoxic exposure and the duration of the training period is still to be optimally determined. Recently, it has been suggested that a short block of RSH in team (Brocherie et al., 2017; Brocherie, Girard, et al., 2015) and racket (Brechbuhl, Schmitt, Millet, & Brocherie, 2018) sports may be of interest to further determine the minimal dose especially in competition when RSH sessions are combined with other normoxic conditioning training. This would be of practical interest in many professional sports where the window for physical preparation between games is extremely short.

Therefore, the aim of the present study was to investigate the effects of upper-body RSH vs. RSN on RSA in world-level male rugby union players' during an international competition period. We hypothesized that completing only 4 sessions of upper-body RSH would potentially induce greater enhancement in RSA performance than RSN during an international competition period in senior International rugby union players.

Methods

Participants

Thirty-six world-level players (24.1 ± 2.7 years, 186.4 ± 6.3 cm and 103.9 ± 12.2 kg) belonging to a senior international rugby union male national team (at the time of the study, the team was the current Six Nations champions) participated in the study as part of their normal national squad training schedule in preparation for the Six Nations rugby union tournament. The experiment was conducted according to the Declaration of Helsinki and the study was approved by the local Ethical Committee (Commission Cantonale Valaisanne d'Ethique Médicale, CCVEM).

Experimental design

The study consisted of two testing sessions before (Pre-) and after (Post-) a 2-week "in-season" training period including 4 RSH vs. RSN sessions. Players were matched regarding their normal units (backs and forwards) and randomized in either normobaric hypoxia (RSH, 3000 m, F_IO_2, 13.8%; n = 18) or normoxia (RSN, 300 m; F_IO_2, 20.9%; n = 18) (Table I). The 2-week period consisted of 2 small sided games sessions, 8 specific rugby sessions, 2 captains run sessions, 4 weight training sessions and 4 recovery sessions. The specific repeated-sprint training intervention was inserted in the aforementioned program of the team. No additional tapering period was added (Table II).

Table I. World-level Rugby Union players' characteristics in repeated-sprint training in hypoxia (RSH) and repeated-sprint training in normoxia (RSN) group.

	RSN (n = 18)	RSH (n = 18)
Age (y)	22.7 ± 1.5	25.6 ± 2.8
Body mass (kg)	103.3 ± 12.6	104.5 ± 11.7
Height (cm)	185.1 ± 6.6	187.8 ± 5.6

Specific repeated-sprint training

As part of their normal national squad training, in a double blinded fashion players performed four additional double-poling ergometer (SkiErg: Concept 2, Morrisville, VT, USA) sessions over a 2-week period. Players' trained in either hypoxic or normoxic conditions for two sessions per week that were completed in a normobaric hypoxic chamber (POWERbreathe, Southam, England, UK). This consisted of three sets of eight 10-s sprints with 20-s intervals of passive recovery with 2 min between each set, with players being encouraged to complete all repetitions maximally while trying to produce the highest power output possible (Figure 1). Overview

Table II. Training, RSH and testing schedule.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Pre-test							
am	Recovery	Light practice	RSA Test	Practice	Walk-thru		Day-off
pm				weights		Game	
Week 1							
am	Weights	Practice	Day-off	Practice	Walk-thru		Day-off
pm	Recovery	RSH-1		RSH-2		Game	
Week 2							
	Weights	Practice	Day-off	Practice	Walk-thru		Day-off
	Recovery	RSH-3		RSH-4		Game	
Post-test							
	Recovery	Light Practice	RSA-Test	Practice	Walk-thru		Day-off
				Weights		Game	

Testing was conducted between 10:00am and 12:00pm, in the National indoor gym that was set at a consistent 22 °C. Bold values are RSA and RSH sessions.

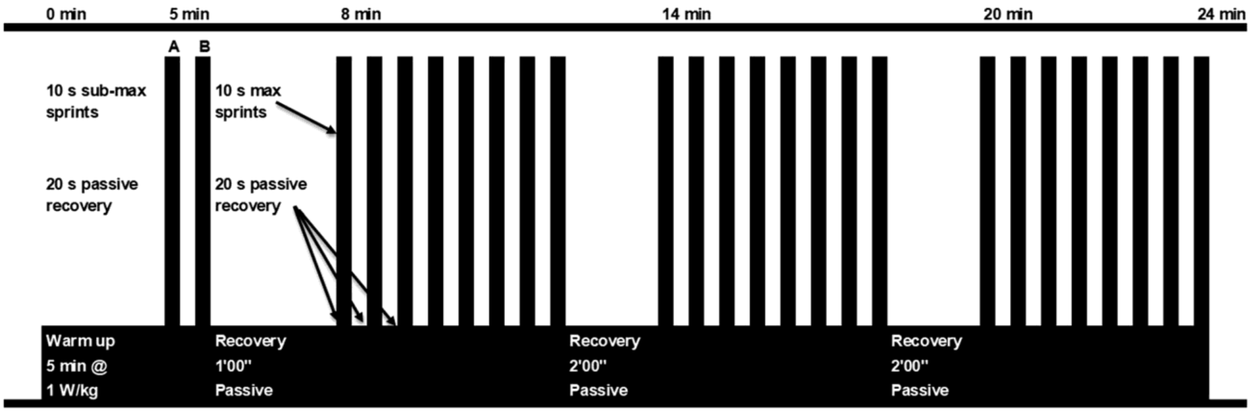

Figure 1. Description of one repeated-sprint training session.

of the training sessions consisted of a 5-min warm-up at 1 W kg^{-1}, followed by a subsequent 1-min block with a 10-s submaximal sprint and 50-s passive recovery and a second 1-min block repeating block 1 but with greater emphasis on maximal sprint. After 1 min of rest, the training exercise was initiated. Players were given a count down and encouraged energetically to complete every sprint maximally. Total hypoxic exposure per session was 24 min for RSH while cool-down was completed in normoxic conditions for both RSH and RSN groups. To ensure the participants isolated the arm and shoulder musculature while minimizing the potential bias of the trunk and legs' contribution, players were instructed to stand with straight legs, to look up at the screen and not to flex at the torso. The SkiErg double-poling ergocycle was calibrated according to the manufacturer guideline prior to each session.

Repeated-sprint ability test

The RSA performance tests were both conducted at the same time of the day (between 10:00am and 12:00pm), and day of the week (Wednesday), while players were explained the test several days prior to testing and again the day before the test was completed. RSA was evaluated in normoxia using a double-poling ergometer (same as mentioned in training protocol) set at a fixed drag resistance (highest level – 10) and consisted of 6 repeated double-poling 10-s maximal sprints with 20 s of passive recovery.

The test started with a 5-min warm-up at 1 W kg^{-1}, followed by a subsequent 1-min block with an isolated 10-s maximal sprint and 50-s passive recovery followed by a second isolated maximal sprint. After 3 min of rest, the test was initiated. Players were given a count down and encouraged energetically to complete each of the 6 sprints maximally. To avoid any protective pacing, average power during the first two sprints was controlled to reach at least 90% of the best performance (peak power output, PPO) of the two isolated sprints, which was the case in all subjects. PPO was recorded for each of the six repetitions and averaged mean power output (MPO) was reported for the entire 6 × 10-s effort). PPO was used to calculate the sprint decrement score (S_{dec}, %) as follows: [1 – (total power/ideal power)] × 100; where total power is the cumulated PPO across repetitions, while ideal power refers to the highest PPO during one single 10-s sprint multiplied by the number of repetitions (Glaister, Howatson, Pattison, & McInnes, 2008). The double poling technique was utilized in an upper-body fashion as mentioned in the training protocol.

Statistical analysis

Data are presented as mean (±SD) or relative changes (%) unless otherwise stated. Normal distribution of the data was tested using the Shapiro–Wilk test. Two-way repeated-measures analysis of variance (ANOVA) with 1 between factor (condition; RSH vs. RSN) and 1 within factor (time; Pre- vs. Post-) were used to compare RSA-related performance variables. Multiple comparisons were made using Holm-Sidak post hoc test. For each ANOVA, partial eta-squared (η^2) was calculated as measure of effect size (Levine & Hullett, 2002). Values of 0.01, 0.06, and 0.14 were considered as small, medium, and large, respectively. All analyses were made using Sigmaplot 11.0 software (Systat Software, Inc., San Jose, CA, USA). Null hypothesis was rejected at $P < 0.05$.

Results

Training exposure

Players using RSH were exposed to 24 min of normobaric hypoxia (3000 m, F_IO_2 13.8%) per training session, thereby totalizing 96 min over the entire intervention. Conversely, RSN spent 24 min in normoxia per training session for a total of 96 min (300 m, F_IO_2 20.9%).

Repeated-sprint ability

Figure 2(A,B) presents the time-course changes in the power output during the RSA test (6 × 10-s sprints – 20-s passive recovery) before and after the intervention period. While no significant differences ($P = 0.145$) between groups were observed in any RSA-related variables at Pre-, significant condition × time interactions were found in PPO ($P < 0.05$, $\eta^2 = 0.02$) and averaged MPO ($P < 0.01$, $\eta^2 = 0.03$) performed during the RSA test. Post hoc tests revealed the beneficial effect of adding hypoxia to the repeated-sprint training (RSH) in PPO ($P = 0.002$, $\eta^2 = 0.12$) and averaged MPO ($P < 0.001$, $\eta^2 = 0.15$), compared to similar training in normoxia (RSN).

Relative to Pre-, significant increases in PPO were observed at Post- in RSH (423 ± 52 vs. 465 ± 69 W, $P = 0.002$, $\eta^2 = 0.11$), but not in RSN (395 ± 65 vs. 397 ± 57 W, $P = 0.855$, $\eta^2 = 0.00$) (Figure 2(A,B)). PPO significantly increased in all sprint repetitions in RSH (+13 ± 16%, all $P < 0.001$–0.01, η^2 ranging 0.08–0.28) but not in RSN (+3 ± 11%, all $P > 0.156$, η^2 ranging 0.00–0.03) (Figure 2). The improvement in PPO was significantly higher in RSH vs. RSN (all $P < 0.01$, η^2 ranging 0.11–0.20) in all sprint repetitions except the last one ($P = 0.928$). Likewise, averaged MPO significantly improved from Pre to Post intervention in RSH (351 ± 41 vs. 389 ± 53 W, $P < 0.001$, $\eta^2 = 0.14$), while it remained unchanged in RSN (328 ± 49 vs. 326 ± 41 W, $P = 0.836$, $\eta^2 = 0.00$) (Figure 2). No significant change in S_{dec} ($P = 0.151$, $\eta^2 = 0.02$) was observed in RSH (−17 ± 2% vs. −16 ± 3%) nor RSN (−17 ± 2% vs. −18 ± 4%). There was an interaction ($F = 4.485$, $P < 0.05$) on the isolated sprint with RSH improving from Pre- to Post- (408 ± 72 vs. 457 ± 69 W, $P = 0.002$) but not RSN (386 ± 76 vs. 392 ± 67 W).

Discussion

In the present study, we investigated the addition of four upper-body repeated-sprint sessions either performed in hypoxia (RSH) or normoxia (RSN) to the normal squad training schedule during the 2-week preparation period of the 6-nations

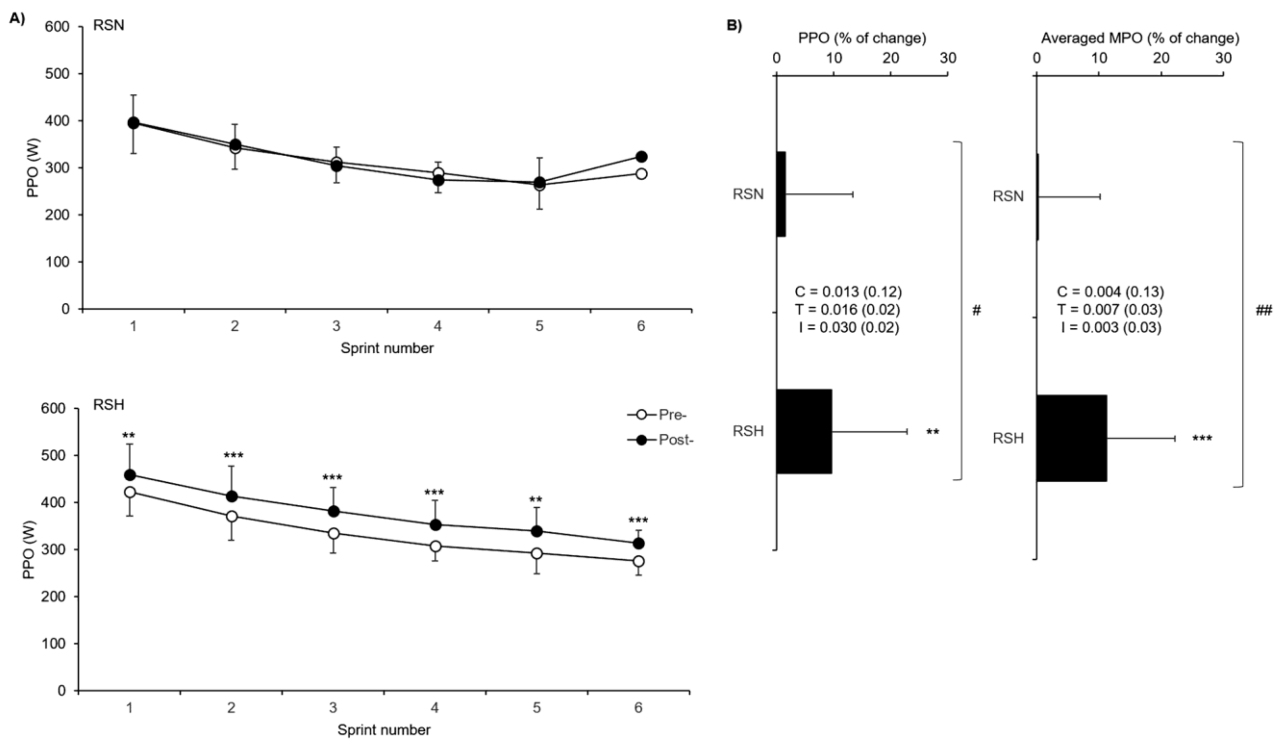

Figure 2. Time-course changes in power output (panel A) and percentage changes in the peak (PPO) and mean power output (MPO) (panel B) during the double-poling repeated-sprint test Pre- and Post- repeated-sprint training in hypoxia (RSH) or in normoxia (RSN). Values are mean ± SD. C, condition effects; I, interaction effects; T, time effects. Significant differences from Pre-test, ** $P < 0.01$ and *** $P < 0.001$; Significant difference from RSN, # $P < 0.05$ ## $P < 0.01$.

international men's rugby union competition. The main findings were that completing repeated double-poling RSH showed a greater improvement in both PPO and MPO in upper-body RSA than RSN in world-level rugby union players. These results provide novel insights into utilizing physical development strategies in competition for high-level team-sport athletes, especially in sports that utilize upper-body frequently such as ice-hockey, field hockey, Australian rules football, lacrosse, American football, combat sports and both rugby union and league.

This demonstrates support for the growing literature on the utilization of RSH as an effective hypoxic training method for enhancing repeated-sprint parameters at sea-level (Brocherie et al., 2017). Recently, it has shown benefits in rugby players (Galvin et al., 2013; Hamlin et al., 2017) soccer players (Brocherie, Girard, et al., 2015), cyclists (Faiss, Leger, et al., 2013), lacrosse players (Kasai et al., 2015), tennis players (Brechbuhl et al., 2018) and cross-country skiers (Faiss et al., 2015), while it may be noted that many factors (e.g. sport/level, type of athlete and protocol) may contribute to the outcome results (Brocherie et al., 2017). In rugby, Galvin et al. (2013) showed a 33% improvement on the Yo-Yo intermittent recovery test level 1 (endurance capacity) with academy level rugby union and league players after 12 sessions of RSH compared to a 14% improvement for RSN completed over 4 weeks, whereas Hamlin et al. (2017) found positive changes in repeated-sprint parameters but not in endurance with well-trained rugby union players after 6 sessions. This may be due to several factors such as the amount of sessions (12 vs. 6), the level of players (academy vs. well-trained) and also the training protocol may not be sufficient load (1 set of 10 × 6, 30 s recovery vs. 4 sets of 5 × 5, 25 s recovery) (Brocherie et al., 2017). Our study supported the results reported by Hamlin et al. (2017) with improvements in RSA parameters when using RSH vs. RSN, which used similar multiple-set protocol (3–4 sets) compared to the single set completed in the study from Galvin et al. (2013). One set of repeated sprints may not be sufficient load to improve RSA parameters or elicit appropriate adaptations to anaerobic glycolysis. From the pioneer RSH study (Faiss, Leger, et al., 2013), it seems that a multiple-set protocol (3–4) may be recommended to enhance RSA parameters (Brocherie et al., 2017). Further, another important reason that may explain the lack of additional benefits of RSH over RSN is the non-specificity of training relatively to the test implemented (e.g. differences in exercise mode, motion direction, sprint duration or exercise-to-rest ratio) as pointed by Fornasier-Santos, Millet, and Woorons (2018). Considering that Baker (2001) has also shown that professional rugby league players were significantly stronger and more powerful in the upper-body than lower level (semi-professional and collegiate) players, the world-level players from an international team (6-nations champion at the time of study) involved here may differ to that of the non-professional players in previous studies (Galvin et al., 2013; Hamlin et al., 2017).

While putative benefits have been shown in the majority of RSH studies, to date, there are some that have reported no differences between RSH vs. RSN (Goods, Dawson, Landers, Gore, & Peeling, 2015; Montero & Lundby, 2017). Athletes' backgrounds, type of test (double-poling, ergocycle, treadmill or over-ground running), number of sessions, hypoxic dose and training protocols (sets × repetitions) could be reasons for inconsistencies in the RSH literature. A major strength of the present study is to show that world-level professional players benefited of this innovative hypoxic training method. Since published studies investigating world-class athletes are lacking (Mujika, 2015), one would emphasize that the present results are directly transferable for practical application in real setting at such level. More importantly, with significant changes observed in already well-developed athletes, this is indicative of the effectiveness of the RSH paradigm for putative performance benefits in all playing level standards.

However, the suggested mechanisms for the performance changes are still under debate. It has been hypothesized that, because acute exposures to hypoxia increase compensatory vasodilation to the vascular beds of the skeletal muscle (Casey & Joyner, 2012), RSH may induce improvements of oxygen utilization by the fast-twitch fibres during 'all-out' maximal repeated sprints performed in hypoxia (Faiss, Girard, et al., 2013). The fast-twitch fibres are the principal driver of maximal power in "all out' efforts such as sprinting activities, in particular in upper-body RSA-related exercise (Kamandulis et al., 2017; Sandbakk et al., 2015), while their ability to reproduce high levels of power are limited to the supply of high energy phosphates which is dictated by the intensity of the sprint effort (Hirvonen, Rehunen, Rusko, & Harkonen, 1987). Further, it cannot be ruled out that RSH may also have a positive impact on anaerobic and glycolytic pathway as shown previously (Girard et al., 2017; Puype, Van Proeyen, Raymackers, Deldicque, & Hespel, 2013). However, in the present study, S_{dec} remains fairly constant, despite increase in both PPO and averaged MPO. While caution is therefore requested in interpreting fatigue using such index, identifying the previously reported mechanisms associated to RSH may be difficult here.

In the present study, it has been demonstrated that there was an increase in world-level rugby union players' PPO and MPO seen after as little as four RSH sessions, whereas no difference was observed in power increase between RSH and RSN following eight sessions in competitive cross-country skiers (Faiss et al., 2015). It may be postulated that the level of athletes (world vs. competitive), training type (intermittent/power vs. endurance), and the actual physical size of the athletes (103.9 ± 12.2 vs. 74.7 ± 7.8 kg) could directly affect the different results seen between the studies. This warrants further examination while also investigating strength levels of the athletes as mentioned previously which has been shown to impact power outputs (Baker, 2001). This could be an area that is currently being overlooked to postulate the RSH mechanisms, especially between different levels and types of athletes. This could also be possibly different between upper- and lower-body due to the physiological and anatomical differences (upper-body has lower muscle mass and higher fast-twitch fibres, different metabolic and cardiovascular responses (Calbet et al., 2005; Koppo et al., 2002).

Double-poling involves several muscles groups such as the core muscles (i.e. rectus abdominus), the upper thighs (quadriceps) as well as the latissimus dorsi and pectoralis major which are responsible for shoulder extension and the triceps brachii which is a powerful elbow extensor (Holmberg, Lindinger, Stoggl, Eitzlmair, & Muller, 2005). These latter muscles are predominately made up of fast-twitch fibres (Mygind, 1995). Rugby union has been shown to utilize the upper-body in collisions, tackling, rucking and mauling (Duthie et al., 2003; Quarrie et al., 2013). Tackling in rugby union has been demonstrated to differentiate winning and losing teams in the 6-nations rugby union tournament, where winning teams tend to complete a higher percentage of tackles than losing teams (Ortega, Villarejo, & Palao, 2009). This could indicate a higher sustainability of power or lower fatigability to the upper-body musculature to complete more tackles for winning over losing teams (Ortega et al., 2009). In rugby league, fatigue development has been shown to reduce the effectiveness of tackling (Gabbett, 2008). Therefore, it could be advantageous to increase anaerobic power (minimum of 4 sessions as per our findings) and fatigue resistance (minimum of 6 sessions as per Faiss et al. 2015) for the upper-body through RSH in rugby union players. Apart from the performance enhancement and benefits of RSH seen in our study, investigations into how improving fatigue resistance in upper-body activities could also be an area to look at in the future. Research has shown that fatigue may be a risk factor for game and training injuries in the upper-body region in rugby union (Williams, Trewartha, Kemp, & Stokes, 2013).

As possible limit, one may question the translation to the field of the present results. Double-poling exercise is commonly used for conditioning in rugby union, despite being not specific to rugby and differing to the upper-body activities of the players during games. However, since, to our knowledge, there is no reliable and valid test using only upper-body and replicating any rugby action, the choice of an upper-body ergometer for measuring the pre-to-post changes seems relevant.

Conclusion

In summary, the present study shows for the first time greater improvement in the upper-body repeated-sprint ability of world-level team-sport athletes during a competition period when training repeated double-poling sprints in RSH vs. RSN. This adds to the growing evidence of RSH as a putative hypoxic method in improving repeated-sprint ability and its associated parameters while also importantly showing that RSH can be used positively with world-level athletes during short-term competition periods. While conclusion for the effects of RSH on upper-body and lower-body performance enhancements may need to be evaluated independently so more accurate comparisons and protocols can be devised, it is worth mentioning that to date the majority of RSH studies have been lower-body dependent so more studies are required to add to the upper-body RSH literature. Further investigation is also required to improve the understanding on how best to program RSH, what is the most efficient number of sessions, sets and/or repetitions as well as the type of exercise mode (ergocycle, double-poling, treadmill, ground-based sprints or combination).

Practical applications

The usefulness of repeated-sprint training in hypoxia to improve physical performance in world-level rugby union players has wider implications to other elite to high-level team-sport athletes that utilize the upper-body. Prescribing physical fitness training parameters in competition can be difficult as the focus on game performance is paramount. Therefore, when sports have increases in the level of competition (club to international) and small transition periods (1–2 weeks), strength and conditioning coaches and performance experts will always be looking for best practice for peaking performance. Reducing adaptation times in these small preparation windows without increasing loads unnecessarily to become further risk factors for competition safely is the aim of any good performance optimization program. This study has shown that RSH can be implemented in an international competition preparation with only four training sessions in hypoxia with significant larger change in RSA power outputs than the same training in normoxia.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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