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The Physician and Sportsmedicine

ISSN: 0091-3847 (Print) 2326-3660 (Online) Journal homepage: http://www.tandfonline.com/loi/ipsm20

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Publisher: Taylor & Francis

Journal: *The Physician and Sportsmedicine*

DOI: 10.1080/00913847.2018.1541701

SCIENTIFIC BASES TO IMPROVE THE RECOVERY PROCESS IN MEN RUGBY ATHLETES: A REVIEW

Review

Evidence-based post-exercise recovery strategies in rugby: a narrative review

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Abstract

In the sport of rugby, athletes need a multitude of sport-specific skills along with endurance, power, and speed in order to optimize performance. Further, it is not unusual for athletes to play several competitive matches with insufficient recovery time. Rugby requires repeated bouts of high-intensity actions intermixed with brief periods of low to moderate active recovery or passive rest. Specifically, a match is characterized by repeated explosive activities, such as: jumps, shuffles, and rapid changes of direction. To facilitate adequate recovery, it is necessary to understand the type of fatigue induced and, if possible, its underlying mechanisms. Common approaches to recovery may include nutritional strategies as well as active (active recovery) and passive recovery (water immersions, stretching, and massage) methods. However, limited research exists to support the effectiveness of each strategy as it related to recovery from the sport of rugby. Therefore, the main aim of the current brief review is to present the relevant literature that pertains to recovery strategies in rugby.

Keywords: Recovery, rugby, athletes, nutrition.

Introduction

Both rugby union (15 players per side), commonly known as 'rugby', and rugby league (13 players per side) are international technical team sports whose matches are characterized by a high frequency of physical contact in conjunction with repeated intermittent bouts of high-intensity caffeine activity [1]. Therefore, players need to develop a multitude of sport-specific skills along with endurance, power, and speed to optimize rugby performance [2]. Indeed, physiological characteristics related to games are similar among rugby union, rugby league, and in particular rugby sevens [2] as each type encompasses low-intensity recovery (standing, walking, and jogging) and intermittent activity over two 2*7 minutes (rugby sevens) halves [3]. Thus, the varied and demanding necessities of a match, will lead to different degrees of muscle damage and fatigue dependent upon competition demands. Given that fatigue following competition is multifactorial and mainly related to dehydration, glycogen depletion, muscle damage and mental exhaustion [4]. The higher incidence of injury in the second half of matches is probably the result of player fatigue [5]; Hence, a relationship exists between on-field training loads and injury rates detected in professional contact team sports, stressing the need to minimize injury risk without compromising training adaptation [6]. The differences in the activity profiles and injury rates between short, medium, and long between-match recovery cycles should be considered when developing recovery strategies for professional rugby players. Besides, during congested schedules, recovery strategies are therefore required to alleviate post-match fatigue, regain performance faster and reduce the risk of injury [7]. In that way, Insufficient post-match recovery in elite players may cause an increased risk of injuries, illnesses and non-functional over-reaching [8]. However, there is often inadequate time between practice and matches for complete recovery to occur; thus, athletes could experience diminished performance during subsequent competition [9]. Further, in the competitive season short recovery times between scheduled performances (i.e. 24

hours) have been shown to lead to insufficient glycogen replenishment [10]. For that, recommendations are made to modify half-time practices in an aim to enhance subsequent physical performance in the second part. During this period, an overview of strategies thought to benefit team-sports athletes is presented; specifically, the efficacy of heat maintenance strategies (including passive and active methods), post-activation potentiation, hormonal priming, and modified hydro-nutritional practices are discussed [11].

During periods of frequent competition practitioners implement various recovery practices to enhance the recovery process, reduce injury occurrence, and maintain peaks of performance [12]. Several methods have been proposed to measure the magnitude of fatigue in athletes [13]. Specifically, recovery methods utilized by strength and conditioning practitioners include: nutritional strategies, ergogenic aids, active recovery, stretching, hydrotherapy, compression garments, massage, psychological means, and rest and sleep [14]. However, current literature concerning the efficacy of such practices is debatable [15].

Recovery methods remain an underrepresented topic in the literature. In fact, some reviews have considered recovery methods in other team sports [15]. However, none of them investigated specific recovery methods in rugby. Therefore, the aim of the current brief review is to present the relevant literature that pertains to recovery strategies in rugby. A second purpose is to present application for rugby coaches and athletes in regard to the effectiveness of the reviewed strategies.

METHODS

Information sources

A computer-based literature search was completed for the years 1960 - 2017 using the following information sources: Medline (PubMed), Web of Science, the Cochrane

Collaboration Database, Cochrane Library, Evidence Database (PEDro), Evidence Based Medicine (EBM) Search review, National Guidelines, EMBASE, Scopus and Google Scholar system. We used the keywords: rugby*, recovery, nutrition, fatigue, ergogenic aids and hydration,* along with Boolean operators such as *"and"* or *"or"*. Furthermore, this narrative review was conducted in accordance with the Preferred Reporting Items for Review Statement [16].

Study Inclusion Criteria

One researcher obtained the titles and abstracts of all publications and determined the relevance of the publication for inclusion. The criteria for allocations in the Articles were satisfied. A manuscript's full-text was obtained to ascertain if the publication satisfied the inclusion criteria. In addition, the reference sections of the selected articles were searched to identify other relevant articles. Finally, for the current review only studies focusing on the effect of ergo-nutritional (ergogenic aids and supplements), physiological (active recovery, rest, and sleep), physical (water therapy, stretching, and massage), and psychological methods for recovery in rugby were included.

Study Exclusion Criteria

Other team sports were no considered and duplicated articles were deleted. On the other hand, abstracts, non-peer reviewed papers and book chapters were excluded.

Furthermore, to effectively quantify the effectiveness of scientific evidence, each recovery strategy sub-category was given a letter grade of 'A', 'B', 'C', or 'D' based upon the criteria set forth by the Australian Institute of Sport [17]. The letter grades of 'A', 'B', 'C' or 'D' were then converted to categories of: *no, low, medium, or high evidence* respectively. This rating is noted after each sub-category.

RESULTS

The initial search of the literature detected 250 articles about rugby; nevertheless, 224 were excluded after being determined unrelated to recovery in rugby or failure to fulfill the inclusion criteria, or both (Figure 1). A total of 26 studies were included. Ten studies examined ergo-nutritional aids (Table 1) and 10 studies concerned additional recovery techniques (Table 2).

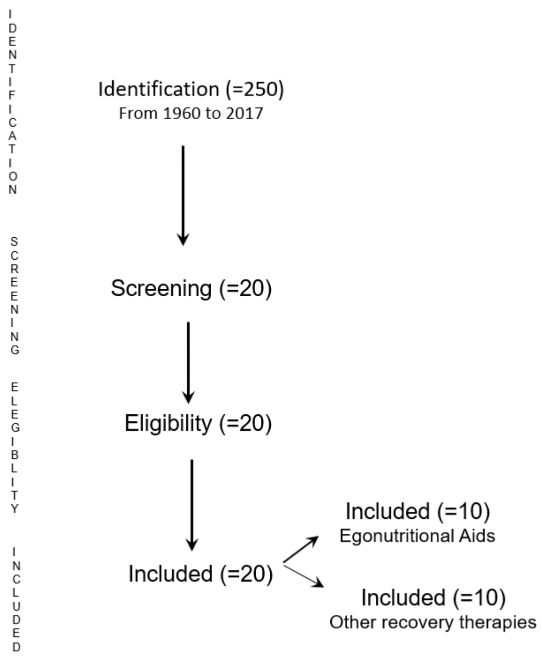

Figure 1. Flow diagram of study selection

DISCUSSION

In an attempt to increase performance and augment the recovery process, rugby players commonly apply numerous methods. Recovery methods are often implemented pre-, per- or post-competition; thus, within this review they have been classified as such.

Ergo-nutritional Aids

Antioxidants

Oxidative stress has well-documented long-term adverse effects on chronic disease states and athletic performance [18]. Oxidative stress occurs once the human body does not possess adequate capacity to protect against free radicals [15]. Such physiological states commonly occur in athletes involved in maximal- or high-intensity exercise (e.g. rugby) [19, 20], and it has to take into account the oxidative stress testifying of a bad recovery in these type of players [21]. Athletes involved in such exercise may consume vitamins C and E in an attempt to decrease the presence of free radicals. In a survey of the nutritional habits of top-level rugby players, those who scored higher in nutritional knowledge were more likely to consume increased fruits, vegetables, and carbohydrate-rich foods [22]. Given that increased oxidative stress and muscle tissue damage have been observed in rugby athletes, it may be advisable to recommend dietary supplementation of antioxidant enzymes (e.g. Cu, Zn, Fe, Se), antioxidant vitamins (e.g. C ,E) and amino acids [23] , given that, we have to consider a follow-up of oxidative stress and antioxidants according their results [21].

Level of Evidence: Medium

Timing: before training/competition

Creatine

Creatine (Cr) is a widely consumed nutritional supplement that has been reported to promote recovery during the performance of intermittent exercise in basketball athletes [24]. Analysis of Cr supplementation in rugby players is limited and, no published research has addressed the recovery process. Nonetheless, the information presented provides a basic understanding of the underlying mechanisms of Cr; thus, guiding the implementation of Cr supplementation for recovery practices. Chilibeck et al. observed that Cr supplementation during a rugby union football season is effective for increasing muscular endurance, but has no effect on body composition or aerobic endurance [25]. Further, another study reported that 50 or 100 mg/kg of Cr may help to alleviate decrements in skill performance in situations of sleep deprivation, such as trans meridian travel [26]. Although Cr is a widely used ergogenic aid, it is recommended to keep in mind that the mechanisms of action after competition are not completely understood [27].

Level of Evidence: Low

Timing: before training/competition

Carbohydrates and proteins

It is well acknowledged that in the athlete's diet the majority of energy should come from carbohydrate (CHO) as they are used as a predominant source of fuel during intense and prolonged exercise [28]. As part of rehydration beverages, CHO has been shown to improve palatability of the beverage as well as the replenishment of muscle glycogen stores [12]. Within rugby, CHO and protein are the primary contents of an athlete's diet, and adequate hydration is imperative to optimize performance [29, 30]. Moreover, it has been established that consumption of macronutrients, particularly CHO, and possibly a small amount of proteins and the branched chain amino acid leucine (0.3g/kg of CHO, 0.2g/kg of protein and 0.01g/kg of leucine), within 30 minutes of endurance exercise can resynthesize muscle glycogen stores. Thus, it is recommended CHO should be ingested with hydrolyzed whey proteins at a 3-4/1 ratio, with 1g/kg, the current CHO recommendations for optimal recovery [30]. However, contradictory results have been presented, indicating that in experienced rugby players, the small degree of muscle damage and reduction in function induced by the exercise protocol were not attenuated by the ingestion of carbohydrate and protein. Anyway, it was identified that when compared to specific recommendations for players, CHO intakes were below recommendations in a group of youth rugby players

To our knowledge, the only paper describing the efficacy of amino acids, evaluated a 3.6g total mixture per dose containing L-leucine (0.54 g), L-isoleucine (0.43 g), L-valine (0.36 g), L-arginine (0.65 g), and L-glutamine (0.61 g), ingested 7.2 a day for 90 days Following three months of supplementation, a majority sample of the players reported improvement in vigor and earlier recovery from fatigue [31]. In this sense, recent studies affirm that individual differences may limit the diagnostic accuracy of group-based reference ranges [32].

In rugby one interesting study, described the effect of ingesting CHO alone (1.2 g · kg body mass (-1) · h(-1)) or carbohydrate with protein (0.4 g · kg body mass(-1) · h(-1)) before, during, and after rugby union-specific protocol on functional and metabolic markers of recovery. Markers of muscle damage and muscle soreness were measured.. There were no differences between trials for any measure. These results indicate that in experienced rugby players, the small degree of muscle damage and reduction in function induced by the exercise protocol were not attenuated by the ingestion of carbohydrate and protein [33].

Other studies, suggest multinutrinets supplements may assist in the maintenance of high intensity running during rugby union games, possibly via the buffering qualities of SUPP ingredients in order to recover faster [34].

Level of Evidence: Low

Timing CHO: before, during and after training/competition

Timing Protein: before and after training/competition

Minerals

Iron

Iron (Fe) is an essential mineral for functions that facilitate athletic performance, such as oxygen transport capacity [35]. After a period of adaptation supported by adequate work/recovery series, athletes undergo a biological redistribution of hematological and biochemical parameters concerning Fe metabolism. Prior literature has not examined the impact of Fe supplementation upon recovery from rugby. Nonetheless, daily Fe supplementation could aid the restoration process following periods of extensive training [36]. In elite rugby athletes, hematological and Fe metabolism parameters have been shown to fluctuate in relation to training and competition workloads [37]. Further research has demonstrated that mild anemia (sports anemia) may develop in well-trained rugby players who are exposed to high training loads, primarily as a result of increased plasma volume with a relative thinning of red blood cells. This pseudo-anemic condition is associated with a reduction in Fe stores, which can lead to true iron-deficiency anemia. A yearly blood test and, if necessary, Fe supplementation could prevent this condition [38].

Level of Evidence: Low

Timing: before and after training/competition

*** Table 1 around here***

Cool-down recovery techniques

Cool-Down and Post-Exercise Stretching

The cool-down is a generally used protocol to be performed after practice or competition [39]. Further, physiological data (i.e. immunoglobulin A concentrations) suggest professional rugby players remain in a state of recovery up to 36 hours post-game [40]. The cool-down, with a goal to increase muscle length, reduce lactate concentrations, resynthesize high-energy phosphates, replenish oxygen in the blood, replenish bodily fluid and myoglobin, and support elevated circulation and ventilation [39]. Practically, active recovery methods are more efficient options for athletes, as they maximize time usage by improving sport-specific movement qualities in addition to achieving the aforementioned cool-down goals [41]. The addition of low intensity exercise to the rest period does not adversely affect physiological recovery, and it significantly improves psychological recovery by enhancing relaxation [42]. However, the literature in this area remains inconclusive [43, 44]. Moreover, Jougla et al., researched the effects of active vs. passive recovery on performance of a rugby-specific intermittent test in rugby union players. On two separate sessions, 7 male rugby players performed the Narbonne test, which is a rugby-specific repeated-sprint test that consists of 6 x 4 consecutive actions (1, scrummaging; 2, agility sprinting; 3, tackling; 4, straight sprinting) [45]. The 30-s recovery protocol was randomized and consisted of of passive or active recovery (running at 50% of maximal aerobic speed). Results indicated that passive recovery enabled enhanced performance during the Narbonne test. However, it is impractical to suggest that players should stand still during and following repeated-sprint bouts within competition [45]. In summary, limited evidence exists supporting the potential effect of active recovery in rugby players. Future research is needed in order to identify optimal guidelines for cool-down strategies within rugby.

Level of Evidence: Low

Timing: After training/competition

Stretching

Currently, much of the static stretching literature has considered pre-exercise implementation, demonstrating potential decrements in sports performance [46]. Published research in regard to static stretching as a method of post-match recovery in rugby is limited. While static stretching is commonly used under the guise of improving post-match recovery, evidence reports no effects of static stretching on recovery rates *(i.e. soreness and muscle fatigue)* for athletes of other team sports [47]. In summary, while there is limited evidence to support post-match static stretching, there is also no evidence to suggest static stretching is detrimental to recovery [48].

Level of Evidence: Low

Timing: After training/competition

Hydrotherapy

Hydrotherapy involves using water for exercise recovery. Optimal levels of immersion, duration of practices, and temperature of the water have not been clearly defined.

Current literature suggests that hydrotherapy can enhance the recovery process 24–72 h after exercise [49]. A recent meta-analysis concluded that cold-water immersion enhances recovery from fatigue; however, the implementation of contrasting hot and cold immersion was not shown to be efficacious for reducing time to recovery [50]. These articles have analyzed the effect of cold-water immersion pertaining to rugby performance, many purporting positive effects upon recovery [40, 51-57]. In 2016, Garcia et al., reported that cold-water immersion improves 30s continuous jump performance and total quality recovery with a randomized crossover design to determine the effect of contrast water immersion and control group on the acute physical performance and 12-h recovery of the players [52] .Cold-water immersion practices are an easy to implement tool for practitioners during congested periods of competition with limited time (~12 h) between activities [52].

Further literature includes guidelines for successfully implementing cold-water immersion practices within rugby. It has been suggested that a minimum of 2 x 5-minute cold-water immersion exposures immediately post-game can attenuate the delayed onset of muscle soreness [53]. Moreover, Webb et al. analyzed 21 professional rugby league players who performed 3 different post-match recovery modalities: cold-water immersion, contrast water therapy, and active recovery. Contrast water therapy was significantly more effective at aiding the recovery of muscle soreness by 42h post-game [43]. Further, similar findings were reported following successive games of rugby union, and post-training and active recovery with ten athletes from the Italian National team [51].

Other literature has reported no effect of cold-water immersion upon recovery within rugby players [55, 56]. Specifically, Takeda et al., reported cold-water immersion to have no effect upon recovery of muscle power and muscle damage blood biomarkers (no significant interactions were found between time and group in any of blood markers such as AST, LDH, CPK) in highly trained rugby players following an 80-minute match simulation [55]. Moreover, contrast bath practices have been purposed to have somewhat trivial benefits during a cyclic week of rugby union [56]. In this article the authors described there was no significant difference in mean scores for Heart rate and blood lactate scores between groups in either of the simulated games [56]. In conclusion, it is recommended that cold water immersion be implemented as part of the post-match recovery process for rugby players.

Level of Evidence: Medium

Timing: After training/competition

Table 2 around here

Compression garments

Recently, compression garments have become an increasingly popular recovery practice [58]. Compression garments apply mechanical pressure to the body, compressing and supporting underlying tissue to enhance recovery from exercise induced muscle damage [59, 60].

At this time, some research groups have analyzed the effect of compression garments for recovery within rugby players [61-63]. Hamlin et al. investigated the impact of wearing compression garments during recovery upon subsequent repeated sprint and 3-km run performance in 22 well-trained male rugby union players. Players were either given a full-leg length compressive garment (76% Meryl Elastane, 24% Lycra) or a similar-looking, no-compressive placebo garment (92% Polyamide, 8% Lycra) to wear continuously for 24 hours post-match simulation. Delayed onset of muscle soreness was substantially lower in the compression group 48 hours after testing. Wearing compressive garments during recovery periods is likely beneficial, and very unlikely to harm the recovery process for well-trained rugby union players [62]. Further, a recent study by Upton et al. reported wearing compression garments after a rugby-specific, muscle-damaging protocol reduced perception of muscle soreness and creatine kinase levels [63].

In contrast, another study considered the impact of compression garments upon consecutive performances [61]. Fourteen male rugby players performed two simulated team sport exercise protocols under two randomized testing conditions (with or without compression garments). Performance tests were separated by 24 h of recovery within each condition and 2 weeks between conditions. The authors concluded that the use of compression garments did not improve nor hamper simulated team-sport activity performed on consecutive days. In summary, based upon a recent meta-analysis [60] and previously discussed literature, it is noted that further research is warranted in order to make recommendations related to compression garments and recovery in rugby.

Level of Evidence: Low

Timing: During and after training/competition

Massage

Massage is frequently utilized as a recovery procedure for athletes; however, evidence supporting its efficacy is scarce, and data do not exist in regard to rugby athletes. In fact, a recent meta-analysis concluded that the effects of massage on recovery from fatigue are small and have not been clearly identified; therefore, it remains questionable if the limited effects justify the widespread use of massage as a recovery intervention in competitive athletes [64]. Nonetheless, the small magnitude of benefit that massage may have on recovery can be important if the appropriate conditions are present (i.e. short-term recovery after intensive mixed training).

Level of Evidence: Low

Timing: After training/competition

Electromyostimulation

A proliferation of research and clinical application of electromyostimulation has occurred in sports medicine in the last decade [65]. In team sports the literature suggests that a one-time treatment with electrostimulation may be beneficial to perceptual recovery, subsequently enhancing next-day performance [66]. Pertaining to rugby, two papers published by Finger et al. 2013 demonstrated that electrostimulation elicited psychometric and physiological benefits reflective of an improved recovery-stress state when combined with a lower-body compression garment. On the other hand, the impact of neuromuscular electrical stimulation on recovery after intensive, muscle damaging, maximal speed training in professional team sports players [67]. Due to the limited literature available it is the authors' opinion that no present confirmation exists to recommend electromyostimulation as an effective recovery procedure for rugby players [66].

Level of Evidence: Low Evidence

Timing: After training/competition

Psychological Techniques

It is vital that individual athletes have the ability to identify when and how they need to recover to maximize performance [68]. One component of individualizing the recovery process has been the use psychological techniques [69]. These psychosocial skills include goal setting, imagery, relaxation techniques, motivation, and self-talk. Additional research is needed in order to establish the relevance of such techniques with professional athletes [70]. It has been demonstrated that an increase of self-control could reduce negative effects of anxiety and improve player performance in high-pressure environments [71]. Notably, in rugby two tools are currently utilized: 1) RESTQ-Sport, which is a practical psychometric tool for monitoring responses to training in rugby team-sport athletes [72], and 2) The Brief Assessment of Mood, which can be used as an indicator of recovery status alongside other measures [73].

Finally, when implementing recovery interventions, it is important to consider what impact the timing of intervention implementation has upon individual athlete psychological factors. Lindsay et al. revealed immediate post-game recovery interventions following a game of professional rugby union are likely a significant aspect of psychophysiological recovery [35].

Level of Evidence: Low

Timing: After training/competition

Rest and sleep

The amount of sleep an athlete gets appears to have a large impact on sports performance [15]. Research with rugby players has previously concluded that sleep deprivation negatively affected post-match recovery [74], specifically impairing physical performance outputs (i.e. counter movement jump) and cognitive function. In particular, these findings show players have significantly reduced sleep following a home game [75] or when sceneries westward long-haul travels between continents exacerbating subjective jet-lag and sleep responses [76]. Practitioners should promote adequate post-match sleep patterns or adjust training demands to accommodate the altered physical and cognitive state after sleep deprivation [77], in order to optimize training and match performance it is recommended to individualize the application of sleep-based interventions [78]. Still, recent research in this field support the use of subjective measures to screen sleep duration in rugby players when objective means are unavailable [79].

Level of Evidence: High

Timing: Before and after training/competition

Photobiomodulation Therapy

Photobiomodulation therapy is an emerging medical and veterinary technique in which exposure to low-level laser light or light emitting diodes stimulate cellular function, which leads to beneficial clinical effects. Growing evidence supports the use of photobiomodulation therapy for performance and recovery enhancement [80]. One study analyzed the effects of photobiomodulation therapy on performance and recovery of high-level rugby players during an anaerobic field test [80]. The therapy significantly improved sprint time, fatigue index, and decreased percentage of change in blood lactate levels and perceived fatigue. Pre-exercise photobiomodulation therapy with the combination of super-pulsed laser (low-level laser), red LEDs, and infrared LEDs can enhance performance and accelerate recovery of high-level rugby players [80].

Level of Evidence: Low

Timing: After training/competition

Light emitting diode therapy

Light-emitting diode therapy is an increasingly popular methodology. Light emitting diode has improved short-term post-exercise recovery in volleyball athletes [81], in order to determine the effects of light emitting diode therapy on blood lactate concentration clearance, peak power output and fatigue index after intense exercise. Further research using different parameters is required to determine how light emitting diode therapy may contribute to post-exercise recovery [82]. However, even though promising, the existing data is limited thus there is low evidence to support the usage of light emitting diode therapy for recovery in rugby players.

Level of Evidence: Low

Timing: After training/competition

Level of Evidence: Low

Timing: After training/competition

Compared different techniques

It is common practice for multiple recovery methods to be used in compared. Gill et al., monitored fatigue in elite male rugby players before, immediately after, 36 hours after, and 84 hours after competitive rugby matches. Players were randomly assigned to complete one of four post-match strategies: contrast water therapy, compression garment, low intensity active exercise and passive recovery. An enhanced rate and magnitude of recovery was observed in the contrast water therapy and low intensity active exercise group [83].

Level of Evidence: Low

Timing: After training/competition

Practical Application

To optimize rugby performance, adequate recovery is required after practice and matches. Nevertheless, literature pertaining to rugby is limited. Traditional nutritional strategies of consuming carbohydrate and proteins combined with the consumption of literature supported supplementation (i.e. creatine and iron) increases recovery during the competitive season. Further methods of recovery including antioxidants, cold-water immersions and adequate sleep are also of benefit to recovery. In summary, a primary limitation of this narrative review is the lack of evidence for recovery strategies specifically pertaining to rugby.

Further, future research should look at the interaction of various recovery methods when utilized in combination. Currently, physicians, sports scientists, athletes, and coaches should primarily utilize the traditional methods which received a rating of 'HIGH' in this manuscript. Furthermore, it is important for nutritionists to be involved in recovery decisions and implementation as a score of "HIGH" was given for protein and CHO consumption. Thus, information in this review provides useful information for strength and conditioning coaches and practitioners.

Funding

This manuscript was not funded.

Declaration of interest

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties. Peer reviewers on this manuscript have no relevant financial relationships to disclose.

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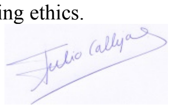

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Table 1. Ergogenic recovery methods in rugby with benefits

AUTHOR	Study Number	Year	n	Variables	Dose	Timing	Results
Finaud et al.	24	2006	High-level rugby players	Oxidative stress, antioxidant status, haematological, and cell damage markers	No intervention	Test the effect of training and competition load	Oxidative stress and antioxidant measurement are significant in the biological follow-up of athletes. Those periods also induced an increase in uric acid and inflammatory markers such as monocytes and vitamin E
Minett et al.	38	2010	12 male rugby union players	Peak power output, anaerobic by-products，Hormonal profiles, markers of muscle damage, and perceived muscular soreness were analyzed	Multinutrient supplement during 5 d (RE-ACTIVATE:01 (Musashi, Notting Hill, Australia)	Before, immediately post and 24 h following rugby union competition	A comprehensive multinutrient supplement may assist in the maintenance of very high intensity running during rugby union games, possibly via the buffering qualities However, correlations between increased work completed at very high intensities and muscular degradation in supplement conditions, may mask any anticatabolic properties of the supplement.
Roberts et al.	37	2011	9 experienced male rugby union forwards	Markers of muscle damage (CK, Myoglobin) and muscle soreness	a. Placebo b. CHO (1.2 g/ kg/h) c. CHO+P (0.4 g/ kg/h)	Before, during, and after a rugby union-specific protocol (Leg strength and repeated 6-s cycle sprint mean power)	No changes in muscle damage and reduction in function by the ingestion of CHO + P. There were no differences between trials for any measure
Pinto et al.	84	2016	High-level rugby players	Average Time of sprints Best time of Sprints Fatigue index Blood lactate	Photobiomodulation therapy with 12 diodes (4 laser diodes of 905 nm, 4 light emitting diodes [LEDs] of 875 nm, and 4 LEDs of 640 nm, 30 J by (Multi Radiance	Baseline, and at 3, 10, 30, and 60 minutes after Bansgbo Sprint Test.	Photobiomodulation therapy with the super-pulsed laser (low-level laser), red LEDs, and infrared LEDs ↑recovery. Photobiomodulation

					Medical).		therapy significantly decreased percentage of change in blood lactate levels and perceived fatigue

Table 2. Physical Recovery methods in rugby with benefits

AUTHOR	Study Number	Year	n	Variables	Dose	Timing	Results
Gill et al.	87	2006	23 elite male rugby players	CK activity	4 post-match strategies: contrast water therapy compression garment low intensity active exercise passive recovery	Before, immediately after, 36 hours after, and 84 hours after competitive rugby matches	Low impact exercise, wearing compression garments, or carrying out contrast water therapy ↑ recovery. Contrast water therapy, compression garment, low intensity active exercise enhanced rate and magnitude of recovery
Hamlin et al.	66	2007	20 junior rugby players	blood lactate, heart rate (HR) and repeated sprint performance	**Contrast temperature water therapy (CTET):** three 1-min hip-height immersions in cold water (8-10 ◦C) alternated with three 1-min hot water (38 ◦C) or **Active recovery:** 6 ‘ slow jogging (6.8kmh−1) around a grassed field, controlled via verbal feedback of lap times.	After performing a repeated sprint test. 2 bouts of repeated sprinting in a randomized cross-over trial	↓ Blood lactate and HR after CTET
Higgins et al.	60	2011	26 from a premier 7rugby club	300-m test and a phosphate decrement test	The participants were randomly assigned to 1 of 3 groups: **Ice baths:** Cold water 5 ‘, above the waistline 10-12° C **Contrast baths** Alternating cold water (10 -12° C) and warm water (8-40° C) for 60 seconds in each cycle, through 7	Pre and postfield tests	Contrast bath Alternating cold water (10 -12° C) and warm water (8-40° C) for 60 seconds in each cycle, through 7 cycles, benefiting recovery in rugby.

					cycles. **Control group** Passive recovery strategy.		
Pointon et al.	61	2012	10 male rugby players	maximal voluntary contraction; MVC) and evoked neuromuscular function (voluntary activation; VA), electromyogram (root mean square (RMS)), ratings of perceived muscle soreness (MS), capillary and venous blood markers for metabolites and muscle damage	Either tackling (T) or no tackling (CONT), followed by a 20-min CWI intervention (TCWI) or passive recovery (TPASS and CONT) in a randomized order. The ISE consisted of a 15-m sprint every minute separated by self-paced bouts of hard running, jogging, and walking for the remainder of the minute. Every sixth rotation, participants performed 5 × 10-m runs, receiving a shoulder-led tackle to the lower body on each effort. Time and distance covered during ISE were recorded, with voluntary (maximal voluntary contraction; MVC) and evoked neuromuscular function (voluntary activation VA), electromyogram (root mean square (RMS)), ratings of perceived muscle soreness (MS), capillary and venous blood markers for metabolites and muscle damage, respectively Measured before	After three sessions consisting of a 2 × 30-min intermittent-sprint exercise (ISE) protocol	CWI results in a faster recovery of MVC, VA, and RMS and improves muscle contractile properties and perceptions of soreness after collision-based exercise

					and after exercise, immediately after recovery, and 2 and 24 h after recovery.		
West et al.	45	2013	36 professional rugby union players	Countermovement jump, followed by a postactivation potentiation stimulus and countermovement jump retesting after 8 minutes of passive or active recovery	The active recovery involved subjects performing ballistic bench throws (1 x 3 repetitions at 30% 1-RM bench press) 4 minutes after the lower body Postactivation Potentiation stimulus	4 minutes after the lower body PAP stimulus	Passive and active recovery periods ↑ peak power output
Webb et al.	47	2013	21 professional rugby league players	Jump height performance and subjective ratings of muscle soreness and muscle damage	a. Cold water immersion (CWI). b. Contrast water therapy (CWT) c. Active recovery (ACT)	at 1, 18, and 42 hours after professional rugby league competition games	CWI and CWT recovered jump height performance (CWI 2.3 ± 3.7%; CWT 3.5 ± 4.1%), reduced muscle soreness (CWI -0.95 ± 0.37; CWT -0.55 ± 0.37), decreased creatine kinase (CWI -11.0 ± 15.1%; CWT 18.2 ± 20.1%) by 42 hours postgame compared with ACT. CWT was more effective compared with CWI on the recovery of muscle soreness and creatine kinase by 42 hours postgame. CWT recovery is recommended postmatch for team rugby sports.
Higgins et al.	57	2013	24 experienced male rugby union players	Countermovement jump, 10- and 40-m sprints, sessional rating of perceived exertion (RPE), flexibility, thigh circumference, and self-reported delayed onset muscle soreness	a. cold water immersion (CWI) b. contrast bath therapy (CBT) c. control group (n = 8) (CG)	Tests, were conducted previous match and 1, 24, and 48 hours after the simulated game of rugby union.	CBT group reported greater measures of DOMS than CG at 1 hour post intervention and than participants in the CWI group did at 48 hours postintervention (p = 0.02, CWI: d = 1.17;

				(DOMS)			contrast bath: d = 1.97). Findings provide modest evidence that contrast baths are a less effective strategy for recovery from rugby union than are CWI or passive recovery. Specifically, 2 × 5-minute CWI is superior to both contrasts baths and passive recovery in alleviating DOMS after exercise-induced muscle damage. CWI or passive recovery was more effective in attenuating fatigue
Takeda et al.	59	2014	20 well-trained collegiate male rugby players	Muscle functional ability and blood markers of muscle damage	a. Cold Water inmersion (CWI) b. Passive rest condition	After game-simulated (80 min.), including tackles and body contacts	CWI has no significant restorative effect in terms of muscle damage
Lindsay et al.	44	2015	37 professional rugby players	Urine and saliva	Cold water immersion (CWI) or pool session (PS), donned compression garments, consumed protein and carbohydrate food and fluid, and slept for 8 hours post-game	Urine and saliva samples were collected pre-game (within 120 min), post-game (within 60 min) and 36 hours post-game (±2 hours) for five home games	Rugby players are still in a state of recovery 36 hours post-game.
Taylor et al.	71	2015	28 professional rugby and football academy players	Blood (lactate and creatine kinase) and saliva (testosterone and cortisol)	Neuromuscular electrical stimulation device or remained in normal attire (CON) for 8h	2 and 24-h post-sprint tests	Player jump height was reduced from baseline at all time points under both conditions at 24-h neuromuscular electrical

							stimulation was significantly more recovered. (mean±SD; neuromuscular electrical stimulation - 3.2±3.2 vs. CON - 7.2±3.7%; P<0.001). Creatine kinase concentrations increased at all time points under both conditions, but at 24-h was lower under neuromuscular electrical stimulation (P<0.001). At 24-h, perceived soreness was significantly lower under neuromuscular electrical stimulation, when compared to CON (P=0.02). Neuromuscular electrical stimulation improves recovery from intensive

							training in professional team sports players.
Upton et al.	67	2017	Nineteen participants club-level rugby players.	Perceived muscle soreness, creatine kinase, maximal voluntary isometric contraction and countermovement jump height	Compression garment group (n = 10) or a SHAM ("recovery" drink) treatment (n = 9)	Variables were measured at baseline, post, 24, and 48 hours after exercise	Perceived muscle soreness was significantly lower in the compression group compared with the SHAM group at both 24 and 48 hours after exercise ($p \leq 0.05$). The compression group was also subject to lower CK values than SHAM, a significant time by group effect ($p \leq 0.05$). There was no significant group effect for MVIC or CMJ ($p > 0.05$). Wearing compression garments after a rugby-specific, muscle-damaging protocol seems to reduce PMS and circulating concentrations of CK, suggesting improved recovery from muscle-damaging exercise.