Physical Preparation Recommendations for Elite Rugby Sevens Performance

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PHYSICAL PREPARATION RECOMMEDATIONS FOR ELITE RUGBY SEVENS PERFORMANCE

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Abstract

Rugby Sevens, a new Olympic sport, features high intensity intermittent running and contact over short match durations normally six times across two to three days in a tournament format. Elite Rugby Sevens seasons often include over a dozen competitive tournaments across less than nine months, demanding deliberate and careful training-stress balance and workload management alongside development of the necessary physical qualities required for competition. Focus on running and repeated power skills, strength, and match-specific conditioning capacities is advised. Partial taper approaches in combination with high velocity running exposures before and between tournaments in succession may reduce injury rates and enhance performance. In a sport with substantial travel and repetitive chronic load demands, management of logistics including nutrition and recovery is inclusive of the formula for success in the physical preparation of elite Rugby Sevens athletes.

Introduction

As of the XXXI Games in Rio de Janeiro, Sevens is the Olympic code in the sport of Rugby. As a new Olympic sport it is expected that global participation will surge beyond the 2015 mark of just under three million registered athletes. With skill levels rising across all levels to create remarkable parity of competition, physical preparation comes into focus in a sport with highly unique match and competition demands. The aims of this paper are to provide a detailed outline of best-practice methods utilized by practitioners at the highest level of physical preparation in Rugby Sevens.

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Match Demands

Although played under essentially the same laws as fifteen-a-side Rugby Union, Rugby Sevens play contains fourteen minute matches with seven players per side. The sport is normally played in a tournament format consisting of five to six games over the course of two to three days rather than one eighty minute match on a weekly basis. As of 2016, The World Rugby Sevens Series, consisting of ten tournaments for the men and six tournaments for the women played over the course of eight months often paired across consecutive weeks, is widely considered the highest standard of Rugby Sevens competition in the world. Further standalone pinnacle events such as the Rugby Sevens World Cup, Commonwealth Games, and Olympic Games operate in four-year cycles and take place outside of the World Series season, requiring additional preparation and careful load management across the annual calendar.

As reported by an observational study of the 2013 Men's World Rugby Sevens Series, competitors cover nearly 1500 m per match, of which over 250 m are at high speed (> 5 m/s), with a mean peak velocity of over 8 m/s. The average player takes 3.51±2.51 ball carries, 2.41±2.29 tackles, and 2.26±3.91 total rucks per match in Pool play, with no meaningful differences between Pool match-play and Cup matches [1].

Over 90% of ball-in-play sequences during Rugby Sevens matches last less than 60 seconds, with an average sequence of 27.8 seconds in Pool play and 33.4 seconds in Cup play, while 65% of recovery sequences are under 45 seconds, with an average sequence of 38 seconds in Pool play and 45.2 seconds in Cup play (Ross, Gill, & Cronin, 2014).

Across a wide range of variables, only trivial to small differences have been found between backs and forwards, with forwards engaging in more contact situations and backs performing more high-speed movements, ball handles and passes. Players are commonly required to play a variety of positions during a single match, with the common exceptions of a scrum-half and a hooker. This data indicates that Rugby Sevens athletes should be trained for the same match demands, with adjustments for Individual Player Plans (IPP).

During the unique instance of a Cup final match in international Rugby Sevens competitions in which two ten minute halves are played, 35% increases in distance covered and 55% increases in numbers of tackles made have been observed (Ross et al., 2014, page 42). This finals format may change in future competitions.

Given the importance of between-tournament recovery in a World Rugby Sevens Series campaign, it is of note that Rugby Sevens team starters (those who play all matches from the start) cover approximately 51% greater total distance and approximately 40% more total contacts over the course of a tournament than backs in one 80 minute 15-a-side Rugby Union match. Unique weekly recovery scenarios in Rugby Sevens include (typically) two to three hours between matches in a given day. Therefore, total-tournament loads may be equally or perhaps more useful than single-match reports when monitoring and adjusting training loads.

With such a large variability in activity between matches and lack of clear positional differences, it is suggested that physical preparation of Rugby Sevens athletes should focus on the skillsets required and expected durations and intensities presented by the sport.

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Programming

With up to to 12 international tournaments in a calendar year and the current, sometimes termed "aerated" format of competition in which tournaments are often grouped in pairs, periods in which large training loads are possible exist not only in the preseason as with most team sports, but also throughout the season in between tournament blocks. A separation between three to six week periods of preparation and high training loads, buildups to tournament blocks, and the turnarounds between tournaments are delineated in the sections below.

The structure of any typical training week should allow for effective application of speed/agility, strength and power, injury prevention, aerobic conditioning, and tactical/technical components within the program. The main priority of a physical preparation program is to ensure the players spend as much time as possible to practice their sport, equipped with the physical capacities to play their sport in the style desired by the head coach. Although Rugby Sevens players are exceptional athletes in many areas of physical prowess, it is presumed that few could perform at an elite level in any single physical quality. This suggests a need for a highly specific yet well-rounded program which compliments the area of desired expertise: Rugby Sevens. The physical preparation program should provide the athlete with maximum opportunity to apply and express their abilities on the rugby pitch. Given squad size, travel and varying individual player plans, as well as specific requests of the rugby coach, creativity and an agile, solutions-based approach are necessary for collective success.

Anecdotally, athletes with habitually high running outputs may struggle to perform on three consecutive days, therefore training load management can follow a pattern of two days with

higher loads followed by a day with a lower load. Equally, two-to-three-day competitions must be managed very deliberately to ensure adequate recovery for final matches. As Rugby Sevens is a running sport, proficiency in running skills are essential both for individual match-action successes and for economical energy expenditure, subsequent maximum performance late in matches and in latter matches of competitions [2–6].

Therefore the aims and priorities of a physical preparation coach in Rugby Sevens are to produce and maintain athletes who are:

1) Healthy and robust with as few injuries as possible
2) Capable of performing basic physical demands of the sport
3) Able to complete the physical tasks required for the coaches desired style of play

Planning an effective weekly program:

Program efficacy is largely dependent on synergy between the physical preparation coach and the head coach, working together to complement one another's desired programming. A physical preparation program will only be effective if there is cohesion with the rugby program. In a sport with deliberate "training camps" leading up to competitions, days with multiple rugby sessions must be monitored carefully to avoid contraindicative spikes in training load.

Management of players and coaches expectations with respect to the training process can be conducive to positive training culture. While stress is required in order to initiate adaptations to subsequently enhance performance, careful periodization and deliberate communication with rugby coaches around training approach decisions is essential for coherent team preparation. – Sometimes fatigue and therefore capacity building is priority, whereas other times else readiness to perform is desired. Furthermore, it is postulated that communication of such decisions and logic with the players themselves may enhance adherence. Rating of perceived exertion (the simple modified 1-10 RPE scale) can be used as a clear and simple way of planning session intensities and reflect retrospectively on the training process [7].

A successfully implemented physical preparation program features clear and deliberate delineations between the aims of the training phase, training stress balance, and readiness to play when the time comes. Furthermore, individual player plans are addressed while building capacities to be able to perform in the sport at the coaches demands in a robust manner with as few injuries as possible.

Strength and Conditioning

Given that stronger athletes have a lower risk of injury[8–10], a primary avenue of injury prevention and preparation for the physical demands of Rugby Sevens is well-developed strength qualities.

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Lower body strength may also protect against the fatigue-induced reductions in tackling skill which occur during repeated efforts [11]. In a preseason or midseason preparation phase, blocks of strength oriented work may be programmed as detailed below using intensity descriptors.

Given other training demands both on and off the rugby pitch, it is essential to avoid excessive neuromuscular fatigue resulting from strength and power training. Careful structure of training balances achievement of desired stimuli for physical development in complement with the rugby programme. Weeks featuring a deliberately reduced load or "deload" can ensure an element of recovery in the training schedule, made even more effective if applied in combination with reduced running load, leading to opportunity for higher outputs both on-field and in the gym the following week. These recommendations and dynamics may be more relevant in well-trained groups and developmental athletes may not require deloads as much or as often. One-week deload periods every four weeks of programming can allow for flexibility (e.g. a player incurring a contusion in week two, which therefore becomes a deload week rather than week three, with the same total and aggregate training load and strength gains achieved within the four week block).

Exercise selection and segmentation is at full discretion of the physical preparation coach and will not be covered in detail in this paper. It is advised that an effective stimulus, rather than exercise or body parts, be the focus of programming aims for any given training week. Given the growing body of literature on the minimum effective dose required for strength adaptations, spontaneous modifications to the physical preparation program can occur frequently. In these instances it is important that exercise modifications retain the original desired stimulus.

In a preparation phase, four strength-oriented sessions are highly feasible, so programming three sessions within four windows of opportunity to execute the sessions can ensure necessary work is achieved at a high rate of compliance. With the below-detailed biases an athlete who only manages to complete two weightlifting sessions per week still reaches substantial volume for both upper and lower body segments much like tiered systems common in American Football programs.

Desired stimulus must be a consideration behind all exercise selections, whether motor learning and skill acquisition, strength or power development, or strength-endurance in any given session or program block. As with any physical preparation program, Olympic lifting derivatives can be greatly beneficial provided that the teaching and learning cost does not outweigh the stimulus benefit, so return on investment must be considered. Where the motor learning of triple-extension is intended, in many cases an Olympic lift may not be ideal in favour of a jump squat. While the protective element of strength training is also highly conducive to power development, strength should be a focus of preparatory phases where running and rugby loads are relatively low as compared to competition phases when strength development opportunities diminish and power development and transfer of training to rugby skills become higher and more feasible priorities.

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Rugby Sevens requires exceptional levels of fitness, including well-developed aerobic capacity which can provide the basis from which a player can express all of their other physical qualities. As speed, power, strength and anaerobic qualities all diminish in output as a result of repeated efforts without adequate recovery time, a well-developed aerobic base may minimise these required recovery times and can contribute to repeatability of such capacities[12]. A recent examination of Gaelic footballers demonstrated that athletes with a relatively high aerobic capacity display lower injury risk at multiple volumes of training and during spikes in training load[13]. Given the lasting nature of aerobic qualities, aerobic development should form a large basis of off season preparation phase work. A logical progression throughout a season is to progress from extensive aerobic work to intensive anaerobic work, whilst consistently matching and exceeding maximal loading scenarios which players may encounter during gameplay.

Beyond this early-stage basic aerobic work, a majority of conditioning of Rugby Sevens athletes should orient closely around the duration demands of the sport as detailed above. Repeated sprint-efforts and small-sided-games are two effective examples of running-based conditioning which can be tailored to mimic play sequences found in Rugby Sevens matches. Further off-feet conditioning options such as rowing, cycling and swimming exist as alternative options to condition athletes without a foot-strike exacerbation load.

There is a growing notion that athletes with greater levels of strength tolerate intense physical activity with lower decreases in strength and power. Maintenance of muscle mass within the travel and competition demands of elite Rugby Sevens is a challenge commonly encountered by physical preparation coaches. Muscle loss has been observed in as little as 5 days disuse [14], so strategies to mitigate this should be implemented to avoid otherwise unnecessary hypertrophy blocks during preparatory phases. Additionally, inhibitory systems which could be elevated during travel and competition periods should also be a consideration for the physical preparation coach. Unpublished data from the authors suggest that athletes self-report increased muscle soreness on day two of competition if a tournament is preceded by 7 days or more without any exposure to heavy loaded resistance training.

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Speed and Power

Maximal effort running

While field sports spend a dominant proportion of match-time running at submaximal speeds, actions which determine outcomes of matches nearly always include sprints of maximum effort[15–18]. Therefore, training maximal effort and velocity sprinting skills are highly conducive to success in Rugby Sevens. While a faster player would hypothetically cover ground more economically at proportionately lower running speeds and therefore conserve energy, the ultimate aspiration may be an athlete who possesses both outstanding absolute sprinting and repeated sprint abilities[1920].

To develop sprinting ability, outright maximal-effort sprints must firstly occur at a high velocity with sufficient horizontal power expression to withstand tackle efforts by opponents in the course of a carry or else to successfully tackle an attacking opponent arriving at the point of contact with great momentum. Therefore it is essential to program the training of maximal effort sprints in isolation as separate stimuli from fatigue-based capacities. Horizontal force application is a determining factor of sprinting at both accelerative and maximal-velocity distances, and such qualities can be monitored simply and trained specifically [21–24]. Chronic accrued volume of sprinting within a training program can improve tolerance to running loads which can benefit the athletes overall physical preparation [13]. Furthermore the separation of the various sprinting skills in the form of linear, multidirectional unplanned and planned agility as well as accelerative and maximum velocity actions can be beneficial for optimization of both learning pedagogies and physiological adaptations. With such dynamics of decision making, reactions and ball carrying, successful integration of sprinting skills with rugby training can enhance scope and volume opportunities for the physical preparation coach as well as ensure maximum possible transfer of training effects.

International Rugby Sevens players have been observed to run an average of 1452 +/- 243 meters per match, with an average of 252 +/- 103 meters accumulated at or above 5 $m \cdot s^{-1}$[25], and international level women at an average of 1556 +/- 189.3 meters per match. With an average of 141.1 +/- 52.8 5 meters accumulated at or above 5 $m \cdot s^{-1}$ at average maximal velocities of 7.90 +/- 0.83 $m \cdot s^{-1}$ (male forwards) and 8.40 +/- 0.72 $m \cdot s^{-1}$ (male backs), and 6.77 +/- 0.55 $m \cdot s^{-1}$ (female forwards and backs) respectively, high speed running is viewed as an prevalent action in the sport[26,27]. Given the moderate to high correlations observed between 10-meter sprint time, 40-meter sprint time, and 10-meter momentum, and defenders beaten (-0.41, -0.50, and 0.30) and line breaks (-0.47, -0.51, and 0.32) and men completing an average of 7.5 +/- 1.6 sprints above 5.5 $m \cdot s^{-1}$ (Forwards and Backs) over an average of 18.75 +/- 6.65 meters[26], and women will completing an average of 5.3 +/- 1.6 sprints above 5.5 $m \cdot s^{-1}$ (Forwards and Backs) over an average of 17.15 +/- 8.8 meters[28], sprinting can be viewed as a requisite skill for Rugby Sevens performance. Average velocity, number of sprints, and distance covered while sprinting are all variables which have been shown to differentiate between amateur and national level Rugby Sevens players [27]. While sub-maximal efforts make up the vast majority of running achieved in a Rugby Sevens match, there is still a distinct need for players to be able to express both rapid acceleration and repeated maximal velocity efforts as evidenced by the impact of sprint actions on match outcomes [29].

Finally, in evaluating 196 Rugby Sevens matches, Higham et al (2014) stated the following in relation to the style of play most associated with winning (pg. 363):

"The associations of performance indicators with points scoring and probability of winning suggest higher-scoring and more-successful teams tend to control possession of the ball and play a patient, disciplined and evasive style of game. A less disciplined and more direct approach, characterized by conceding more penalties and free kicks and performing more rucks and mauls,

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gives the opposition greater opportunity to gain ball possession and is associated with lower scores."

Thus, it is not only acceleration and maximal velocity that are important to Rugby Sevens, but also the ability to evade defenders through the effective use of agility. While not explicitly evaluated within a cohort of Rugby Sevens players, multiple studies have shown that reactive agility (i.e., changing direction in response to a stimulus) performance can differentiate between elite and sub-elite level rugby players (Gabbett & Benton, 2009; Gabbett, Kelly, & Sheppard, 2008). This provides further evidence that all elements of speed (i.e., acceleration, maximal velocity sprinting, and reactive agility) contribute to success in the various codes of rugby.

From a training perspective, chronic accrued volume of sprinting within a training program can improve tolerance to running loads which can benefit the athletes overall physical preparation [13] [13], while the authors postulate that frequent exposure to velocities equal or greater to those achieved during a match can greatly reduce risk of running-related injuries such as hamstring tears. However, coaches are required to identify if practice conditions are adequate to develop and maintain these qualities or if additional training time dedicated to the development of speed and agility is required. For example, while practice may provide a maximal velocity stimulus, the stimulus may be inconsistent and/or inadequate in intensity and volume to encourage significant increases in speed, especially over the course of a competitive phase [30]. Further, sprinting within the context of practice is not likely to support definitive changes in running efficiency, as sprinting within rugby is a means to and end rather than the end itself. Thus, if coaches seek to improve speed, then time needs to be dedicated to linear speed (i.e., acceleration and maximal velocity) and/or multidirectional speed (i.e., planned and unplanned agility) development within the weekly structure. Specifically, to improve speed over 0-20 meters, coaches are encouraged to have athletes perform 6-12 full speed efforts over 15-20 meters over the course of 1-2 training sessions lasting no longer than 45-minutes. Moreover, to improve speed over 20-meters, coaches are encouraged to have athletes perform 3-6 full speed efforts over 20-50 meters over the course of 1-2 training sessions lasting no longer than 45-minutes. Note that drill work and sub-maximal sprint efforts would be included within the 45-minutes to bolster the development of coordinative capacity for both acceleration (0-20 meters) and maximal velocity sprinting (>20 meters). Methodologically, both free sprinting and resisted sprinting have been shown to significantly improve speed from 0-20 meters and >20 meters to a far greater extent than resistance training and plyometric training alone [31]. Thus, when prioritising time for the weight room and time on the pitch, if speed development is the goal, the development of strength and power cannot be seen as a substitution for full speed sprint efforts.

Finally, research has shown that the primary mechanical determinant of acceleration is the ability to maximize horizontal force production [22,32,33], while maximal velocity sprinting has been associated with the capacity to generate higher vertical forces during the first half of ground contact[3435]. Research by Buchheit et al. (2014) demonstrated that acceleration and maximal velocity sprinting, while highly correlated with one another, are underpinned by different

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mechanical factors. Specific to agility, evidence suggests that a players' dominant cutting leg (i.e., preferred kicking leg) and non-dominant cutting leg are highly correlated with relative lower body strength (-0.52 and -0.56) and average maximal velocity sprint speed (-0.63 and -0.52)[22]. Furthermore, relative strength and power have been shown to correlate with 10-meter sprint times[36] and is also associated with sprint momentum, which has been shown to differentiate between elite and sub-elite rugby players[37]. Thus, a comprehensive training program should seek to develop high levels of relative strength and power, while programming for multidirectional and linear speed based on the loads being achieved in the context of practice and the individual player's need to improve coordinative capacities and/or performance outcomes.

Repeat power ability

In addition to high and moderate speed running demands, Rugby Sevens involves repeated high intensity actions including accelerations, decelerations, changes of direction and importantly the contact elements of game play. These actions can occur at multiple times within a 30 second period and can occur up to 45 times in a game; of substantial importance is that these actions come at a high physiological cost[26,28,38,39]. A significant decrease in the number of these repeated high intensity actions have been shown to occur in the second half of games[26], reflective of the accumulation of fatigue and the inability to sustain high intensity actions throughout a match[3]. Enhancing repeated power ability (RPA) in seven's players may provide a performance advantage with regards to repeated high intensity efforts (RHIE). This suggestion comes in light of poor indications within the literature of the relationships between both aerobic capacity and repeated sprint ability with RHIE [40]. A need for emphasized specificity exists when training capacities for repeatability of high intensity sporting actions.

To avoid excessive running loads in the physical preparation for rugby sevens, high volume power training (HVPT) may be used to build capacity for repeated bouts of high intensity work. HVPT consists of volumes of work much greater than those used in the traditional training of maximal power (≤ 5 sets of 1-6 repetitions [41–43]). Exercises in such protocols are typically ballistic in nature, such as squat jumps and Olympic lifting derivatives and moderate loads of between 30-50% 1RM are commonly used. The total repetitions used per session have been found to range from as low as 50 up to 600 repetitions with repetitions per set generally ranging from 10 to 16 [44–46]. The use of cluster sets, where brief inter-set recovery is provided, can also be prescribed to assist in the maintenance of maximal power [47,48]. These methods have been shown to improve measures of RPA and other sporting tasks involving repeated high intensity performance such as repeated jump performance, repeated change of direction and repeated sprint ability Importantly, HVPT has also been shown to enhance maximal power output and therefore offer a training modality whereby maximal power and RPA can be enhanced simultaneously [49–51]. There is some evidence that upper-body muscular endurance is a significant correlative factor for RHIE performance, in particular repeated tackling [52]. However, contrary to this finding

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Gabbett & Wheeler (2015) found estimated aerobic power to be a poor indicator of RHIE performance and this is important when considering training specificity for the development of RPA and the inclusion of HVPT in preparatory programmes.

Based on the current body of literature and the applied cases, one of three below-detailed potential HVPT progressions can be used to develop RPA and physically prepare Seven's players for the repeated high intensity efforts experienced in a game (Table 1.). From the below table, it is suggested that progressions B and C are used more during pre-season or else when longer preparatory phases between tournaments occur, while Progression A is considered appropriate for use within 3-5 days of competition in order to maintain RPA with lower levels of fatigue. Elite team sport athletes may need higher volumes of work than sub-elites, having been observed achieving the re-attainment of maximal power between sets, less fatigue within sets and no further accumulation of fatigue between sets (Figure 4. unpublished data).

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Athlete Load Monitoring and Injury Prevention

Given the unique duration and frequency of international Rugby Sevens competitions, management of player fatigue is crucial both for maintaining team performance and limiting injuries at four time scales: the season, the stage, the tournament, the competition day.

To date, the relationship between training load, injury, and performance has not been investigated in Rugby Sevens. However, all practitioners involved in Rugby Sevens (e.g. coaches, physiotherapists, and strength and conditioning staff) are interested in identifying the optimum amount of training to elicit specific performance levels. This training "dose-response" relationship is analogous to pharmacological studies where chemists wish to understand the positive and negative effects of a particular drug. Sport scientists understand that physically hard training is required in order to prepare athletes for the demands of competition, but are also aware that excessive loading can result in increased injury risk.

Early research reported a positive relationship between training load and injury, suggesting that the harder athletes train the more injuries they are likely to sustain [53–55]. Furthermore, greater amounts of high-speed running have been associated with greater lower-body, soft-tissue injury risk [56,57], while reductions in training load resulted in fewer injuries and greater improvements in aerobic fitness[55]. However, in more recent times, a significant body of evidence has emerged to demonstrate that high chronic training loads may protect athletes against injury [58,54,59–63]. Collectively, these results suggest that training load might best be described as the "vehicle" which drives athletes towards *or away from* injury[64].

Several studies have demonstrated the protective effect of high training loads [58,13,59,60]; athletes from a wide range of sports experience a lower risk of injury when their chronic training loads are high. Importantly, the best predictor of injury was the size of the current week's training load

(termed *acute training load*) in relation to the chronic training load. This has been termed the "*acute:chronic workload ratio*" (also previously referred to as "training-stress balance") [54]. When the acute:chronic workload ratio was within the range of 0.8 to 1.3 (i.e. the acute training load was approximately equal to the chronic training load), the risk of injury was relatively low. However, when the acute:chronic workload ratio ≥1.5 (i.e. the acute training load was much greater than chronic training load), the risk of injury increased exponentially [65]. The protective effect of training appears to arise from two sources: (1) exposure to "load" allows the body to tolerate "load", and (2) training develops the physical qualities (e.g. strength, prolonged high-intensity running ability, and aerobic fitness) that are associated with a reduced injury risk [13,53,57].

Although "spikes" in training load may contribute to injuries, undertraining and "troughs" in training load may elicit similar negative consequences. For example, a "U"-shaped relationship between the number of maximal velocity exposures and injury risk has been shown in team sport athletes; both over-*and under-training* increased injury likelihood [13]. The risk sometimes associated with exposure to maximal velocity running is mitigated through exposure to high chronic training loads [13,66,67].

These results have three important practical implications; (1) high chronic training loads may protect against injury, (2) athletes are better able to tolerate the high-intensity components of training and competition if they have been exposed to higher chronic training loads, and (3) the acute:chronic workload ratio is a greater predictor of injury than either acute or chronic load in isolation. As such, to adequately prepare Rugby Sevens players for match-play, physical preparation coaches should aim to safely develop high chronic training loads, using the acute:chronic workload ratio to guide increases and decreases in load.

Unpublished data from the authors of this paper suggest that the physical preparation coach could benefit from a combination of both objective and subjective data encompassing physiological wellness, neuromuscular status, fluctuations in body mass and athlete ratings of their recovery and readiness to train. Further unpublished data shows that indices of exercise heart rate recover at a different rate to peak velocity on a vertical jump and at different rates depending on the length and direction of travel demonstrating the need for multifaceted monitoring systems to encompass these different biological systems. Furthermore, Saw, Main & Gastin (2015) demonstrate the value in subjective data; therefore it is recommended that this is also a central component of monitoring an athlete's readiness to train. Due to the nature of long haul travel, the physical preparation coach may also benefit from utilising measures of mobility such as a sit and reach or knee to wall tests on a daily basis. With all monitoring practices, in order to give them context it is important to compare an athlete to their individual normative data. It is recommended that these tests be scheduled into the weekly training out-of-competition periods to establish baseline data and meaningful changes.

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Tournament Preparation

Within the current format of competition, a balance must be struck between the high loads required to develop physical capacity [54] and instigation of peak performances on the day of competition [69–71]. The challenge of consecutive competition days separated by a six-day week featuring international travel across multiple times zones is relatively unique in sport and must be deliberately addressed in order to maximize results of a physical preparation program. It can be expected that athletes will suffer from disrupted sleep (length and quality), other jet lag symptoms, hormonal disruptions, alterations in markers of muscle damage and a short term decrease in performance [72]. Physical preparation coaches should consider their travel schedules and attempt to begin the travel process with adjustments in sleep prior to departure along with ensuring travel hygiene and nutritional quality is maintained. A taper, variously defined as "a specialized exercise training technique which has been designed to reverse training-induced fatigue without a loss of the training adaptations" [73] or "a period of reduced training volume to enhance performance" [74], is *one* such method which can be utilized in the buildup to tournaments. Based on the data presented by Mujika and Bosquet, the following practical implications for optimum tapering strategies can be drawn:

1. Maintenance of training intensity to avoid detraining
2. Reductions in training volume as high as 30-60%
3. Use of a period lasting to 4-28 days

Decreasing training load by ~30% during taper weeks via a reduction in the duration and frequency of training while maintaining intensity can increase performance in high-intensity activities among field sport athletes [75]. Figure 7 details load variations before and between two successive IRB World Series tournaments among an elite, Olympic-qualified team during the 2015/2016 season.

Data were collected from 9 players (age: 27.2±5.2 years; body mass: 90.0±11.5; height: 182.8±8.5 cm) who participated in all ten (seven rugby, three power) training sessions during the observed period. The first week, termed "week of preparation" WP preceded that just prior to and between the two tournaments (W T1 and W T2, respectively). The ABC details sample programming across three such weeks, while Table 1 and 2 shows training loads observed during the three weeks, as calculated by the sum of the Session Rating of Perceived Exertion (sRPE, session duration multiplied by RPE) for all training sessions performed per week [7]. The data demonstrate effective reduction of the training load between the last week of preparation (WP) and the week before the first tournament (W T1) alongside a total duration of training (min) and sRPE decrease of 34±0% and 36±9%, respectively (table 1). The total distance and consequently the distance covered at low and high intensities were also significantly reduced in W T1 (table 2). Because of reduced movement on the field during the training sessions in W T1, the observations

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of fewer sprints during this week were predictable. However, with the ratio between the number of sprints and the rugby duration of the week, players actually performed more sprints per minute in W T1 than WP. High intensity distance (HID) in W T1 were slightly reduced (-2.6±8.9 %), perhaps due lower duration of match-simulation sequences undertaken during tactical rugby sessions. In order to retain a high number of explosive moments, physical preparation coaches can add short, high-intensity running drills to the end of warm ups during sessions occurring in these tournament preparation weeks. In summary, the week before the first tournament (W T1) in a pair can be distinguished by a significant reduction of volume (duration, sRPE and distance) with intensity maintained via repeated high-intensity running drills.

A second consecutive weekly instance of international travel shapes the training load between paired tournaments (W T2). Recent research [76] concluded that a single Sevens tournament reduces the neuromuscular function such that players are not fully recovered to baselines by the start of the second competition stage. During this period, emphasis should be placed on enhancing recovery strategies. Total training loads are reduced in W T2 as compared to both WP and W T1 in part due to a reduction in number of sessions completed, with only one additional sequence of maximal power (table 1 and 2). A progressive reduction within the week for the total and high intensity distance covered is common (figure 2).

Common among team sports are a “captains run” or ritual session in the day before (or last hours before) the start of a competition. These sessions are often termed as “preloading” consisting of small-sided games and repeated sprints, though it has been observed [77] that no significant benefits were observed on a soccer-specific endurance test performed 4 hours after such a session. Therefore, further work on this topic is warranted in order to determine the effect and role of different types of sessions immediately prior to competitions in order to optimize match-play preparation. Alternative to the above-described taper is a “high-low-high” approach, which may also be successful. Unpublished data from the authors indicates reduced intra-tournament muscle soreness resulting from such an approach, compared to a traditional taper. While an overall reduction in load during the lead-up to competition in some form is almost certainly beneficial, mitigation of the acute impact of live matches on the body via small exposures of specific stimuli (i.e. high velocity sprints) in the day or days prior to competition is advisable. Physical preparation coaches must also use trial and error to determine the most appropriate approach to prepare their athletes for tournaments.

Preparation for travel with respect to maintaining training adaptations is emphasized in WP, recovery from travel with reduction in training volume alongside maintenance (or slight increase) of intensity features in W T1, while focus turns largely to neuromuscular recovery of the athletes in W T2. “Captains runs”, or sessions programmed in the immediate 4 to 24 hours prior to commencement of competition, may impact positively (or potentially negatively) on performance, however are case-specific, with the potential benefits unclear at this time.

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Match-day Nutrition and Recovery

Careful and deliberate athlete management across two or three days must be achieved if a full roster of athletes is to be fit and available for a sixth and final tournament match where honors are at stake. A significant fatigue-induced decrease in physical performance and increase in physiological load occurs in the second half of games compared to the first half (Suarez-Sanchez, 2015) potentially explaining the higher incidence of injury both late in individual games and over the course of tournaments [79]. On the IRB World Series, intervals from one game to the next are typically between two and three hours. Coaches and medical staff must implement efficient strategies throughout and between the competition days in order to minimize injuries and maximize game to game performance.

Post-match priorities include parasympathetic system activation, rehydration and nutrient replenishment, and soft tissue care via a variety of methods. A typical example of recovery and game preparation protocols between two Rugby Sevens games, although highly dependent on resources, feasibility and athlete individualization, is described below:

- **Step 0 - Postgame Debriefing**: A very short game debriefing (2-min) is given by the head coach directly on the pitch.
- **Step 1 - Rehydration and Refueling**: Replenishment of muscle glycogen and repairing of muscle tissue damage incurred from the physical demands of Rugby Sevens (repeated high-intensity running, sprinting, accelerations/decelerations, collisions) can be initiated by consuming 1-1.5g carbohydrate.kg^{-1} in addition to 20-25g of protein within 30 min of the game. The consumption of 150% of sweat losses in fluid during the recovery phase can effectively rehydrate an athlete, especially in hot conditions [80]. In all cases, within these broad guidelines, it is recommended that personal preferences be recognized and palatability and osmolality of food and beverages consumed be prioritized to avoid gastric distress.
- **Step 2 – Cold and Contrast Water Immersion**: Despite conflicted literature, Contrast Water Immersion has been shown to be an effective strategy to enhance recovery after high intensity exercise by controlling hyperthermia, reducing muscle inflammation and damage and decreasing muscle soreness [81]. Parasympathetic reactivation has been demonstrated with this method in simulated Sevens games[82]. While Cold Water Immersion is a highly individual preference and may offer primarily a placebo effect, where available and desired by the athlete [83] a protocol of whole-body immersion lasting at least 10 minutes (max.: 20 min) at a temperature of 12 to 15°C immediately after the game may be effective [84].
- **Step 3- Soft Tissue Care:** Given that many athletes present post-match with minor injuries, soft tissue care protocols are an important part of preparation for subsequent games in a tournament. Massage is resource-dependent, while simple inversion of legs vertically up a wall or on a chair can be a cheap and effective way of redirecting fluid from the lower extremities [85]. Foam rollers and self-massage balls are commonly used as well and are recommended for potential range of motion and blood flow benefits once the above time-sensitive priorities have been addressed [86]. Recent literature has detailed potentially beneficial effects of compression

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garments for recovery of muscle function, muscle soreness and blood markers of muscle damage [87,88], so the use of these materials could be utilized by athletes between games.

- **Step 4 – Pre-Game Snack:** While feeding remains a highly individual preference and response, in an effort to continue (re)fueling it is recommended to consume a carbohydrate-rich meal no later than 1 hour before each game. Carbohydrate-rich foods and drink may help to ensure that fuel targets are met before subsequent exercise bouts (1-1.2 g/kg/hour) [89], while food density and fiber and fat portions must be considered with gastric comfort as a priority. Caffeine ingestion (1-3 $mg.kg^{-1}$, equivalent to about 2-3 espressos for a Rugby Sevens player one hour prior games) can be utilized as an ergogenic aid [90], although caution must be taken over a 2-3-day tournament concerning the deleterious effects of repeated dosing of caffeine, with quality sleep between competition days prioritized [91].
- **Step 5 – Brief Nap (optional):** Time permitting, brief (15-20 min) naps between games may improve both cognitive and motor performance [92]. Caffeine consumption immediately prior to the nap may lessen the phenomenon of sleep inertia after waking [93].
- **Step 6 – Repeat Soft Tissue Care**
- **Step 7 – Pre Game Briefing**
- **Step 8 – Warm-up**

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Summary

Elite Rugby Sevens performance requires skilled high velocity running, repeated power application, and exceptional levels of conditioning expressed over fifteen minutes from the first whistle of a match to the last, normally six times across two or three days, often in consecutive weeks. Careful and deliberate management of load and athlete health across periods of high load and acute competition preparation can mitigate injuries and maximize performance. Safe achievement of high chronic training loads can create robust athletes able to withstand the high acute loads achieved during competition periods. Physical preparation coaches in elite Rugby Sevens are advised to pivot the above best-practice examples to feasible applications within their own programs, prioritizing basic modalities while recognizing the highly individual nature of responses to physical performance methodologies.

Tables and Figures

Table 1. Duration, frequency and training load before and between two Rugby Sevens tournaments

	Pool Mean ± SD	Cup Mean ± SD	ES ± 90% CL
Locomotor Demands	*N=78*	*N=58*	
Total Distance (m)	1446±299	1423±285	-0.012±0.25
High-Speed Running (m)	254±123	246±117	-0.094±0.96
Maximal Velocity (m/s)	8.11±0.70	8.22±0.80	0.067±0.27
Match Activities	*N=199*	*N=207*	
Ball Carries	3.51±2.51	3.82±2.57	0.047±0.15
Total Rucks Attended	2.26±3.91	3.15±3.54	0.07±0.12
Tackles	2.41±2.29	2.72±2.48	0.12±0.14
Notes: N=number of data files. High-Speed Running = >5m/s; ES= effect size, CL= confidence limits			

From Ross et al 2014

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Figure 1. A sample Rugby Sevens weekly training schedule

Monday (medium)	Tuesday (hard)	Wednesday (low)	Thursday (very hard)	Friday (low-medium)	Saturday (low)	Sunday (rest)
Monitoring	Monitoring	Remote Monitoring	Monitoring	Monitoring	Remote Monitoring	Remote Monitoring
Physical Prep (mobility/activations)	Physical Prep (mobility/activations)	Soft Tissue Active Recovery Pool Sessions Low Level Aerobic Work	Physical Prep (mobility/activations)	Physical Prep (mobility/activations)	Active recovery Top Ups or additional training components	
Speed (acceleration bias)	Rugby – Hard		Speed (max velocity biased)	Rugby – low/medium		
Gym (Lower Bias)		Rest	Gym (Whole Body Bias)			
Rugby - Medium	Gym (Upper Bias + Posterior Chain)		Rugby - Hard	Gym (circuits/extras)		

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Figure 2. A sample monthly periodization scheme

Week	Intensity	Sets x Reps
Week1	Medium	4x5
Week2	Hard	4x4
Week3	De-load	2-3x 3-4
Week4	Very Hard	5x2

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Figure 3. Sample weekly exercise selection

Session 1		Session 2		Session 3	
Lower Body Bias		**Upper Body Bias**		**Whole body Bias**	
A1 Back Squat	4x5	A1 Bench Press	4x5	A1 BB Step Ups	4x5e/s
		A2 Wtd Pull Ups	4x5		
B1 SL Hip Thruster	4x8e/s	B1 RDL	4x5	B1 BB Push Press	4x5
B2 OH Push Ancillary	3x10-12			B2 Ancillary Chest	3x10-12
C1 Lateral Slideboard	4x8e/s	C1 DB Seated Shoulder Press	4x5	C1 Ancillary LB (goblet)	3x10
C2 DB walking Lunges	3x8e/s	C2 Ancillary Row	3x10-12	C2 Ancillary Row	3x10-12

LB=Lower Body, UB=Upper Body, BB=Barbell, DB=Dumbbell

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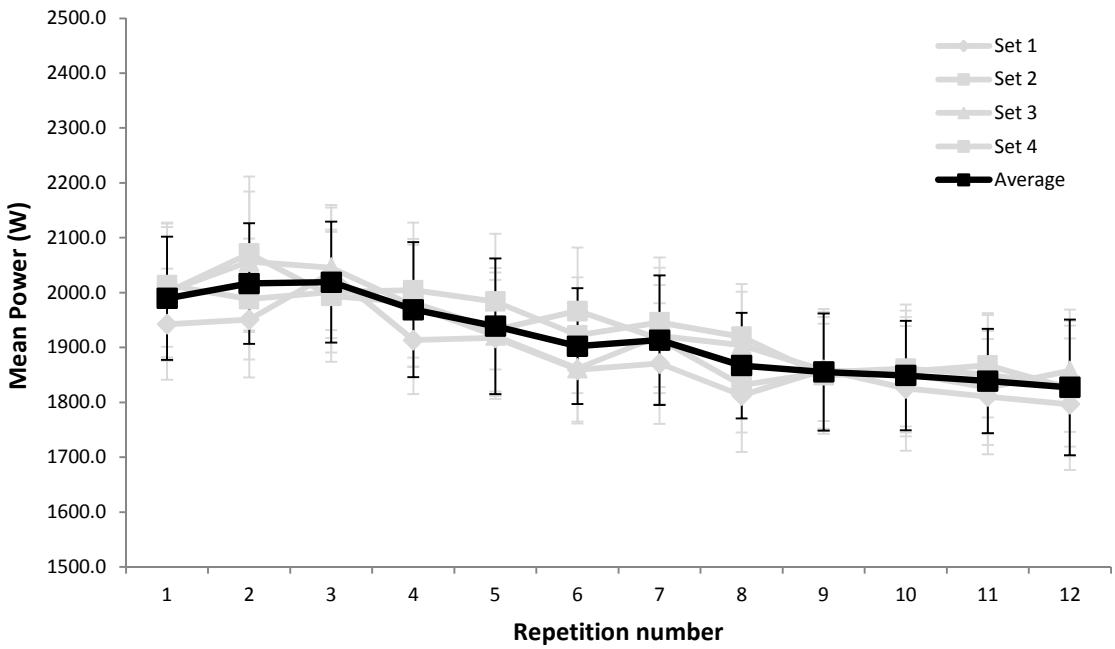
Figure 4. Power decrement across an exercise set



Repetition x repetition mean power output for 4 sets of 12 CMJs with a 30% 1RM load (*n* = 12)

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Figure 5. Sample repeated-power-training progressions

Progression	Number of series (no.)	Number of sets (no.)	Number of repetitions (no.)	Within-Set Rest/Clusters (s rest/no. repetitions)	Inter-set Rest (s)
A	1	4	15	5 s rest/5 rep Cluster	120
B	2	4	12	n/a	60
C	3	4	10	n/a	30

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Figure 6. Weekly programming of the international Rugby Sevens team before and between two tournaments.

WP

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Resistance Strength & power	**Resistance** Strength & power		**Resistance** Strength & power		**Travel**	
Rugby tact	**Rugby tech & tact**		**Rugby tact & Lactic** (aer. game)			**Rugby tech and tact**
HIT cycle					**Active recovery** Swimming pool	
Recovery	*Recovery*		*Recovery*			*Recovery*

W T1

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Resistance Strength & power	**Rugby tech**	**Rugby tact**	**Rugby tact**	**Match 1**	**Match 1**	*Recovery*
	Recovery		*Recovery*			
Rugby tact & lact		**Resistance** Explosivity/Power		**Match 2**	**Match 2**	
Recovery		*Recovery*		**Match 3**	**Match 3**	

W T2

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Travel		**Rugby**	**Rugby**	**Rugby**	**Match 1**	**Match 1**
		Recovery	*Recovery*	*Recovery*		
Active recovery Swimming pool	**Active recovery** Cycle and elliptic		**Resistance** Explosivity/Power		**Match 2**	**Match 2**
					Match 3	**Match 3**

WP: one week before the first tournament, W T1: one week before the first tournament, W T2: one week before the second tournament. Tech: technique, Tact: tactical, aer: aerobic

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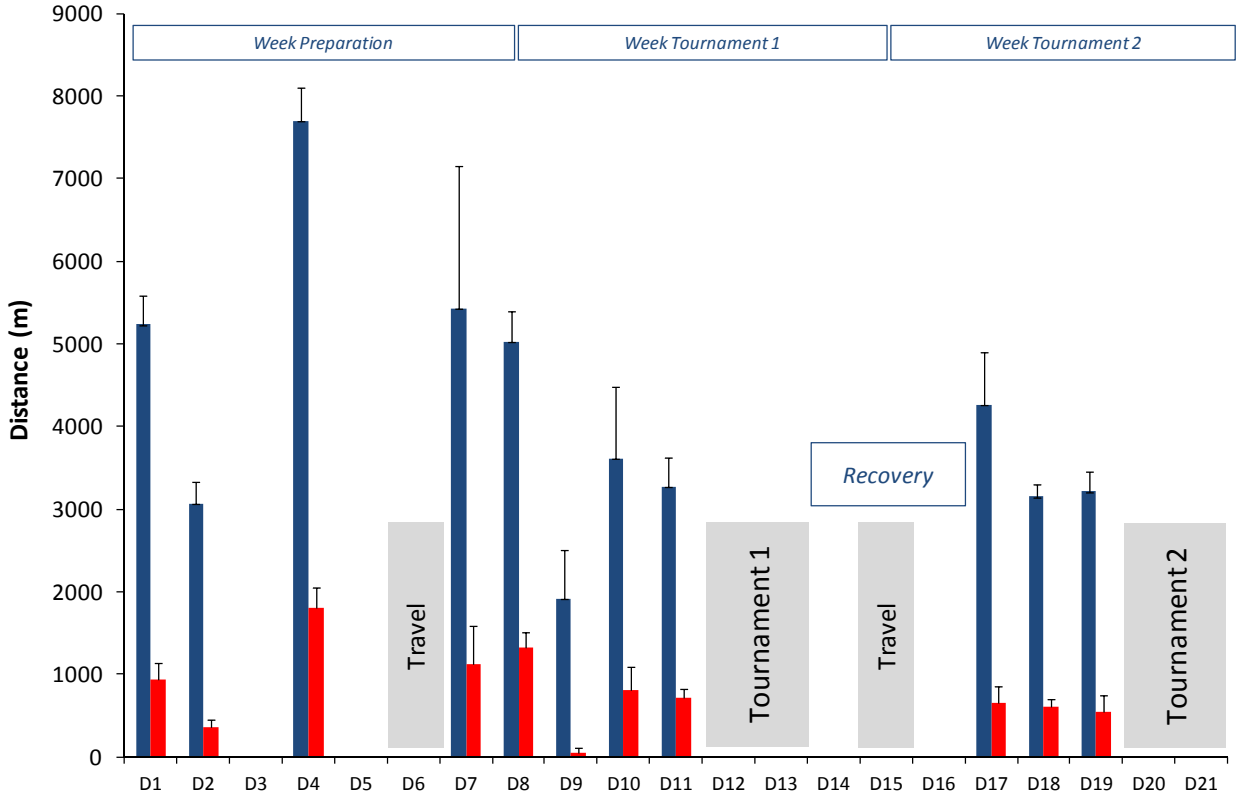
Figure 7. Variation of daily distance covered before and between two Rugby Sevens tournaments.



Blue bars: distance total, red bars: high intensity distance.

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Table 2. Duration, frequency and training load before and between two Rugby Sevens tournaments

	WP	W T1	W T2	% S48/S49	% S49/S50	% S48/S50
Total training (min)	530	350	260	-34%	-26%	-51%
Rugby (min)	350	250	160	-29%	-36%	-54%
HIT (min)	60			-100%		-100%
Strength/power (min)	120	100	40	-17%	-60%	-67%
Active recovery (min)			60		100%	100%
Frequency training (n)	8	6	5	-25%	-16.7%	-27.5%
sRPE (u.a.)	2935±496	1865±287	1269±284	-36±9%	-33±7%	-57±6%

RPE: rate of perceived exertion. sRPE (u.a.)= RPE×duration (min)

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Table 3. Mean values (±SD) of the physical training activity the weeks before and between two Rugby Sevens tournaments

	WP	W T1	W T2	% S48/S49	% S49/S50	% S48/S50
Total distance (m)	23885 ± 952	13620 ± 1462	10634 ± 865	-43,0 ± 5,2	-21,5 ± 7,1	-55,5 ± 3,0
Sprints (n)	200 ± 35	171 ± 28	111 ± 28	-13,8 ± 8,2	-35,3 ± 13,3	-44,8 ± 7,9
Sprints (n/min)	0,57 ± 0,10	0,68 ± 0,11	0,70 ± 0,18	20,8 ± 11,4	1,1 ± 20,8	20,7 ± 17,4
LID (m)	18655 ± 457	10718 ± 1027	8809 ± 650	-42,6 ± 5,2	-17,2 ± 9,6	-52,8 ± 3,6
% LID	78,2 ± 2,1	78,8 ± 2,0	82,9 ± 3,0	0,8 ± 2,5	5,2 ± 3,2	6,1 ± 2,4
HID (m)	5230 ± 698	2901 ± 505	1825 ± 418	-44,4 ± 7,5	-37,2 ± 7,3	-65,4 ± 4,6
% HID	21,8 ± 2,1	21,2 ± 2,0	17,1 ± 3,0	-2,6 ± 8,9	-19,5 ± 11,5	-22,1 ± 9,5

WP: one week before the first tournament, W T1: one week before the first tournament, W T2: one week before the second tournament. LID: low intensity distance, HID: high intensity distance.

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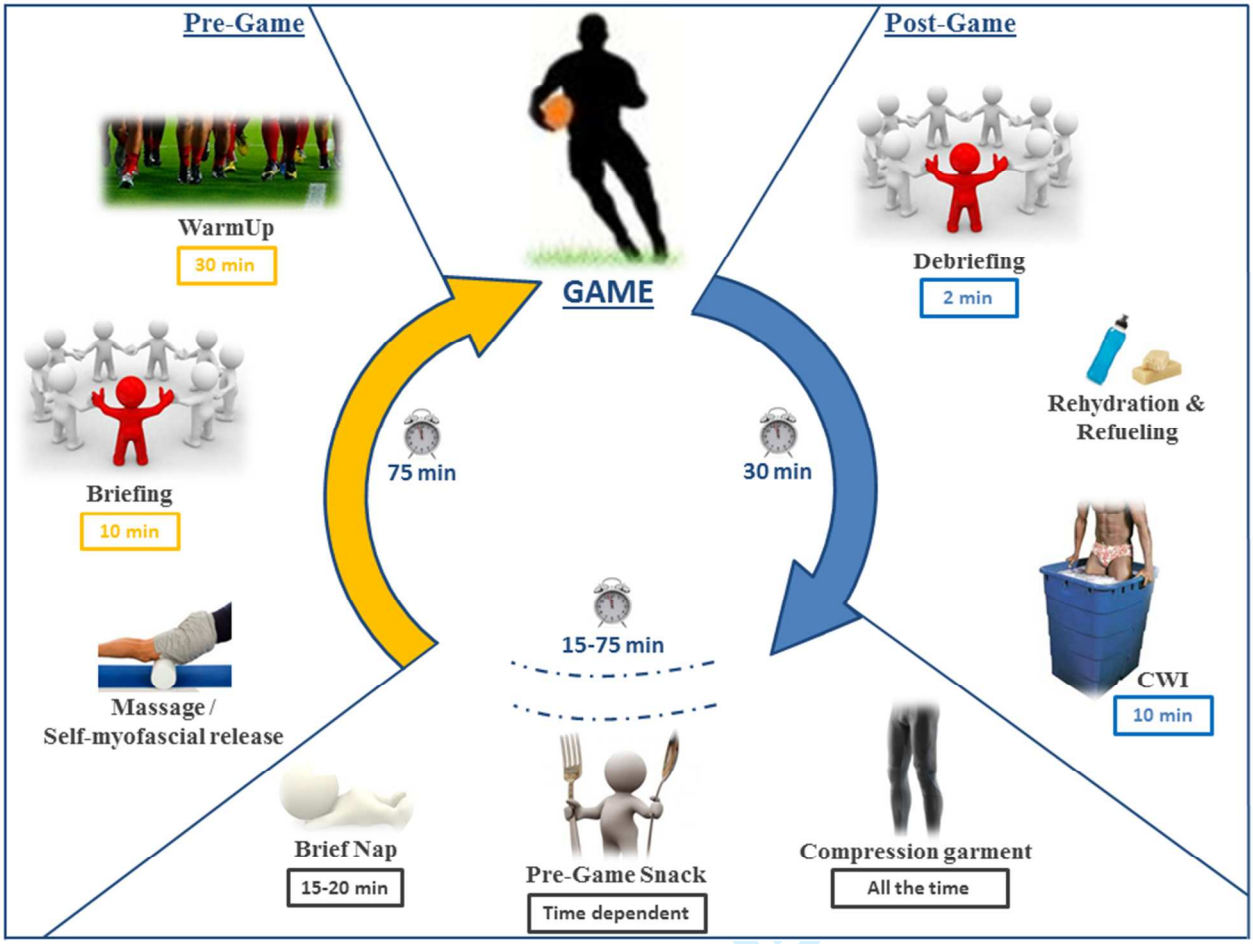
Figure 8. Between-game recovery strategies during Rugby Sevens tournament



For Review

References

1. Ross A, Gill N, Cronin J. The match demands of international rugby sevens. *J Sports Sci*. 2014;(January):37-41. doi:10.1080/02640414.2014.979858.

2. Furusawa K, Hill A, Parkinson J. Dynamics of "Sprint" Running. *Proc R Soc Britain*. 1927;102(10):29-42.

3. Higham DG, Pyne DB, Anson JM, Eddy A. Movement patterns in rugby sevens: effects of tournament level, fatigue and substitute players. *J Sci Med Sport*. 2012;15(3):277-282. doi:10.1016/j.jsams.2011.11.256.

4. Morin JB, Samozino P, Edouard P, Tomazin K. Effect of fatigue on force production and force application technique during repeated sprints. *J Biomech*. 2011;44(15):2719-2723. doi:10.1016/j.jbiomech.2011.07.020.

5. Morin JB, Edouard P, Samonzino P. Technical Ability of Force Application as a Determinant Factor of Sprint Performance. *Med Sci Sport Exerc*. 2011;43(9):1680-1688. doi:10.1249/MSS.0b013e318216ea37.

6. Nummela A, Ker??nen T, Mikkelsson LO. Factors related to top running speed and economy. *Int J Sports Med*. 2007;28(8):655-661. doi:10.1055/s-2007-964896.

7. Impellizzeri FM, Rampinini E, Coutts AJ, Sassi A, Marcora SM. Use of RPE-based training load in soccer. *Med Sci Sports Exerc*. 2004;36(6):1042-1047. doi:10.1249/01.MSS.0000128199.23901.2F.

8. Baker DG, Sciences H. Comparison of strength levels between players from within the same club that were selected versus not-selected to play in the Grand Final of the National Rugby League competition. *Strength Cond J*. 2016. doi:10.1519/JSC.0000000000001604.

9. Suchomel TJ, Nimphius S, Stone MH. The Importance of Muscular Strength in Athletic Performance. *Sport Med*. 2016;46(10):1419-1449. doi:10.1007/s40279-016-0486-0.

10. Gabbet T, Ullah S, Finch C. Identifying risk factors for contact injury in professional rugby league players. *J Sci Med Sport*. 2012;15:496-504.

11. Gabbett T. Influence of Fatigue on Tackling Ability in Rugby League Players: Role of Muscular Strength, Endurance, and Aerobic Qualities. *PLOSOne*. 2016;11(10).

12. Ross A, Gill N, Cronin J, Malcata R. The relationship between physical characteristics and match performance in rugby sevens. *Eur J Sport Sci*. 2015;1391(April):1-7. doi:10.1080/17461391.2015.1029983.

13. Malone S, Roe M, Doran D, Gabbett T, Collins K. High chronic training loads and exposure to bouts of maximal velocity running reduce injury risk in elite Gaelic football. *J Sci Med Sport*. 2016;In Press.

14. Wall BT, Dirks ML, Snijders T, Senden JMG, Dolmans J, Van Loon LJC. Substantial skeletal muscle loss occurs during only 5 days of disuse. *Acta Physiol*. 2014;210(3):600-

For Peer Review

611. doi:10.1111/apha.12190.

15. Spencer M, Bishop D, Dawson B, Goodman C. Physiological and metabolic responses of repeated-sprint activities:specific to field-based team sports. *Sports Med*. 2005;35(12):1025-1044. doi:10.2165/00007256-200535120-00003.

16. Wehbe G, Hartwig T, Duncan C. Movement Analysis of Australian National League Soccer Players Using Global Positioning System Technology. *J Strength Cond Res*. 2013;28(3).

17. Austin D, Gabbett T, Jenkind D. The Physical Demands of Super 14 Rugby Union. *J Sci Med Sport*. 2011;14(3).

18. Gabbett T, Gahan C. Repeated High-Intensity Effort Activity in Relation to Tries Scored and Conceded during Rugby League Match Play. *Int J Sports Physiol Perform*. 2015;September.

19. Goodale TL, Gabbett TJ, Stellingwerff T, Tsai MC, Sheppard JM. Relationship Between Physical Qualities and Minutes Played in International Women's Rugby Sevens. *Int J Sports Physiol Perform*. 2015:1-44. doi:10.1123/ijspp.2014-0509.

20. Haugen T, Buchheit M. Sprint running performance monitoring : methodological and practical considerations Key points. *Sport Med*. 2015;(47). doi:10.1007/s40279-015-0446-0.

21. Morin JB, Slawinski J, Dorel S, et al. Acceleration capability in elite sprinters and ground impulse: Push more, brake less? *J Biomech*. 2015;In Press(December):1-6. doi:10.1016/j.jbiomech.2015.07.009.

22. Buchheit M, Samozino P, Glynn JA, et al. Mechanical determinants of acceleration and maximal sprinting speed in highly trained young soccer players. *J Sports Sci*. 2014;32(20):1906-1913. doi:10.1080/02640414.2014.965191.

23. Morin JB, Bourdin M, Edouard P, Peyrot N, Samozino P, Lacour JR. Mechanical determinants of 100-m sprint running performance. *Eur J Appl Physiol*. 2012;112(MARCH):3921-3930. doi:10.1007/s00421-012-2379-8.

24. Morin J-B, Samozino P. Interpreting power-force-velocity profiles for individualized and specific training. *Int J Sports Physiol Perform*. 2015;Accepted D(February):1-10. doi:10.1017/CBO9781107415324.004.

25. Ross A, Gill N, Cronin J. The match demands of international rugby sevens. *J Sports Sci*. 2014;(January):37-41. doi:10.1080/02640414.2014.979858.

26. Suarez-Arrones L, Núñez J, Sáez de Villareal E, Gálvez J, Suarez-Sanchez G, Munguía-Izquierdo D. Repeated-High Intensity Running Activity and Internal Training Load of Elite Rugby Sevens Players During International Matches: A Comparison Between Halves. *Int J Sports Physiol Perform*. 2015;(August):1-44. doi:10.1123/ijspp.2014-0523.

27. Ross A, Gill ND, Cronin JB. A comparison of the match demands of international and

For Peer Review

provincial rugby sevens. *Int J Sports Physiol Perform*. 2015;10(6):786-790. doi:10.1123/ijspp.2014-0213.

28. Suarez-Arrones L, Arenas C, López G, Requena B, Terrill O, Mendez-Villanueva A. Positional differences in match running performance and physical collisions in men rugby sevens. *Int J Sports Physiol Perform*. 2014;9(2):316-323. doi:10.1123/IJSPP.2013-0069.

29. Ross A, Gill N, Cronin J, Malcata R. The relationship between physical characteristics and match performance in rugby sevens. *Eur J Sport Sci*. 2015;1391(April):1-7. doi:10.1080/17461391.2015.1029983.

30. Gabbet T. Changes in physiological and anthropometric characteristics of rugby league players during a competitive season. *J Strength Cond Res*. 2005;19(2).

31. Rumpf MC, Lockie RG, Cronin JB, Jalilvand F. *The Effect of Different Sprint Training Methods on Sprint Performance over Various Distances*.; 2015. doi:10.1519/JSC.0000000000001245.

32. Rabita G, Dorel S, Slawinski J, et al. Sprint mechanics in world-class athletes: a new insight into the limits of human locomotion. *Scand J Med Sci Sports*. 2015;(FEBRUARY):1-12. doi:10.1111/sms.12389.

33. Morin JB, Slawinski J, Dorel S, et al. Acceleration capability in elite sprinters and ground impulse: Push more, brake less? *J Biomech*. 2015;In Press(October):1-6. doi:10.1016/j.jbiomech.2015.07.009.

34. Weyand PG, Sternlight DB, Bellizzi MJ, Wright S. Faster top running speeds are achieved with greater ground forces not more rapid leg movements. *J Appl Physiol*. 2000;89(5):1991-1999. doi:Cited By (since 1996) 142\rExport Date 17 September 2012\rSource Scopus.

35. Clark K, Weyand P. Are Running Speeds Maximized with Simple Spring-Stance Mechanics? *J Appl Physiol*. 2014;117(6).

36. Cunningham D, West D, Owen N, et al. Strength and Power Predictors of Sprinting Performance in Professional Rugby Players. *J Sport Med Phys Fit*. 2013;53(2).

37. Baker D, Newton R. Comparison of Lower Body Strength, Power, Acceleration, Speed, Agility and Sprint Momentum to Describe and Compare Playing Rank Among Professional Rugby League Players. *J Strength Cond Res*. 2008;22(1).

38. Johnston RD, Gabbett TJ, Jenkins DG, Hulin BT. Influence of Fatigue on Tackling Technique in Rugby League Players. *J Strength Cond Res*. 2008;22(2):625-632. doi:10.1519/JSC.0b013e3181635a6a.

39. Sáez de Villarreal E, Suarez-Arrones L, Requena B, Haff GG, Ferrete C. Effects of Plyometric and Sprint Training on Physical and Technical Skill Performance in Adolescent Soccer Players. *J Strength Cond Res*. 2015;29(7):1894-1903. doi:10.1519/JSC.0000000000000838.

For Peer Review

40. Gabbett TJ, Wheeler AJ. Predictors of repeated high-intensity effort ability in rugby league players. *Int J Sport Physiol Performace*. 2014;20(127).

41. Cormie P, Mcguigan M, Newton RU. Developing maximal neuromuscular power part 2-Training considerations for improving maximal power production. *Sport Med*. 2011;24(1):573-580. doi:10.2165/11536850-000000000-00000.

42. Thomasson ML, Comfort P. Occurrence of fatigue during sets of static squat jumps performed at a variety of loads. *J Strength Cond Res*. 2012;26(3):677-683. doi:10.1519/JSC.0b013e31822a61b5.

43. Baker DG, Newton RU. Change in power output across a high-repetition set of bench throws and jump squats in highly trained athletes. *J Strength Cond Res*. 2007;21(4):1007-1011. doi:10.1519/R-22376.1.

44. Hatfield DL, Kraemer WJ, Volek JS, Rubin MR. T H E Effects of Carbohydrate Loading on. *Methods*. 2006;20(1):167-171.

45. Hester GM, Conchola EC, Thiele RM, DeFreitas JM. Power output during a high-volume power-oriented back squat protocol. *J Strength Cond Res*. 2014;28(10):2801-2805. doi:10.1519/JSC.0000000000000484.

46. Volek JS, Kraemer WJ, Bush JA, et al. Creatine supplementation enhances muscular performance during high- intensity resistance exercise. *J Am Diet Assoc*. 1997;97(7):765-770. doi:10.1016/S0002-8223(97)00189-2.

47. Mosey T. Power endurance and strength training methods of the Australian lightweight men's four. *J Aust Strength Cond*. 2011;19(1):9-19.

48. Gonzalo-Skok O, Tous-Fajardo J, Arjol-Serrano JL, Suarez-Arrones L, Casajús JA, Mendez-Villanueva A. Low-volume Repeated Maximal Power Training Improves Repeated Sprint Ability and Horizontal Jumping Performance in Elite Young Basketball Players. *Int J Sports Physiol Perform*. 2015;(December). doi:10.1123/ijspp.2014-0612.

49. Bosco C, Cotelli F, Bonomi R. Seasonal fluctuations of selected physiological characteristics of elite alpine skiers. 1994:71-74.

50. Apanukul S, Suwannathada S. The Effects of Combined Weight and Pneumatic Training to Enhance Power Endurance in Tennis Players. *J Exerc Physiol*. 2015;18(2):8-17.

51. Gonzalo-Skok O, Tous-Fajardo J, Arjol-Serrano J, Suarez-Arrones L, Casajús J, Mendez-Villanueva A. Low-volume Repeated Maximal Power Training Improves Repeated Sprint Ability and Horizontal Jumping Performance in Elite Young Basketball Players. *Int J Sport Physiol Perform*. 2015;(December). doi:10.1123/ijspp.2014-0612.

52. Gabbett TJ, Wheeler AJ. Predictors of repeated high-intensity-effort ability in rugby league players. *Int J Sports Physiol Perform*. 2015;10(6):718-724. doi:10.1123/ijspp.2014-0127.

53. Gabbett TJ, Domrow N. Relationships between training load, injury, and fitness in sub-

For Peer Review

elite collision sport athletes. *J Sports Sci*. 2007;25(September 2014):1507-1519. doi:10.1080/02640410701215066.

54. Gabbett TJ. The training-injury prevention paradox: should athletes be training smarter and harder? *Br J Sports Med*. 2016:1-9. doi:10.1136/bjsports-2015-095788.

55. Gabbett T. Reductions in Pre-Season Training Loads Reduce Training Injury Rates in Rugby League Players. *Br J Sports Med*. 2004;38.

56. Gabbett TJ, Ullah S. Relationship between running loads and soft-tissue injury in elite team sport athletes. *J Strength Cond Res*. 2012;26(4):953-960. doi:10.1519/JSC.0b013e3182302023.

57. Gabbett TJ, Ullah S, Finch CF. Identifying risk factors for contact injury in professional rugby league players - Application of a frailty model for recurrent injury. *J Sci Med Sport*. 2012;15(6):496-504. doi:10.1016/j.jsams.2012.03.017.

58. Murray N, Gabbett T, Townshend A, Hulin B, McLellan C. Individual and combined effects of acute and chronic running loads on injury risk in elite Australian footballers. *Scand J Med Sci Sports*.

59. Hulin B, Gabbet T, Blanch P, Chapman P, Bailey D, Orchard J. Spikes in acute workload are associate with increased injury risk in elite cricket fast bowlers. *Br J Sports Med*. 2014;48:708-712.

60. Hulin B, Gabbett T, Caputi P, Lawson D, Sampson J. The acute:chronic workload ratio predicts injury: High chronic workload may decrease injury risk in elite rugby league players. *Br J Sports Med*. 2016;50:231-236.

61. Soligard T, Schwellnus M, Alonso J, et al. How much is too much ? (Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. *Br J Sports Med*. 2016;(Part 1):1030-1041. doi:10.1136/bjsports-2016-096581.

62. Schwellnus M, Soligard T, Alonso J, et al. How much is too much ? (Part 2) International Olympic Committee consensus statement on load in sport and risk of illness. *Br J Sports Med*. 2016;(Part 2):1043-1052. doi:10.1136/bjsports-2016-096572.

63. Gabbett HT, Windt J, Gabbett TJ. Cost-benefit analysis underlies training decisions in elite sport. *Br J Sports Med*. 2016;0(0):bjsports-2016-096079. doi:10.1136/bjsports-2016-096079.

64. Windt J, Gabbett T, Ferris D, Khan K. Training Load-Injury Paradox: Is Greater Preseason Participation Associated With Lower In-Season Injury Risk In Elite Rugby League Players? *Br J Sports Med*. 2016;March.

65. Blanch P, Gabbett TJ. Has the athlete trained enough to return to play safely ? The acute : chronic workload ratio permits clinicians to quantify a player ' s risk of subsequent injury. *Br J Sports Med*. 2015;(September 2016):1-5. doi:10.1136/bjsports-2015-095445.

66. Furlan N, Waldron M, Shorter K, et al. Running-intensity fluctuations in elite rugby

For Peer Review

sevens performance. *Int J Sports Physiol Perform*. 2015;10(6):802-807. doi:10.1123/ijspp.2014-0315.

67. Kristensen G, van den Tillaar R, G E. Velocity Specificity in Early-Phase Sprint Training. *J Strength Cond Res*. 2006;November(4):833-837.

68. Saw AE, Main LC, Gastin PB. Monitoring the athlete training response: subjective self-reported measures trump commonly used objective measures: a systematic review. *Br J Sports Med*. 2015;(May 2014):bjsports-2015-094758. doi:10.1136/bjsports-2015-094758.

69. Mujika I, Padilla S. Scientific bases for precompetition tapering strategies. *Med Sci Sports Exerc*. 2003;35(7):1182-1187. doi:10.1249/01.MSS.0000074448.73931.11.

70. Gorostiaga EM, Izquierdo M, Iturralde P, Ruesta M, Ibanez J. Effects of heavy resistance training on maximal and explosive force production, endurance and serum hormones in adolescent handball players (Effets d'un entrainement de resistance lourd sur la production de force explosive et maximale, sur l'endurance et . *EurJApplPhysiol*. 1999;80(5):485-493. http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=SPHS-640629&lang=es&site=ehost-live.

71. Bosquet L, Montpetit J, Arvisais D, Mujika I. Effects of tapering on performance: A meta-analysis. *Med Sci Sports Exerc*. 2007;39(8):1358-1365. doi:10.1249/mss.0b013e31806010e0.

72. Kraemer WJ, Hooper DR, Kupchak BR, et al. The Effects of a Roundtrip Trans-American Jet Travel on Physiological Stress, Neuromuscular Performance and Recovery. *J Appl Physiol*. 2016:jap.00429.2016. doi:10.1152/japplphysiol.00429.2016.

73. Neary JP, Martin TP, Reid DC, Burnham R, Quinney HA. The effects of a reduced exercise duration taper programme on performance and muscle enzymes of endurance cyclists. *Eur J Appl Physiol Occup Physiol*. 1992;65(1):30-36. doi:10.1007/BF01466271.

74. Trappe S, Costill D, Thomas R. Effect of swim taper on whole muscle and single muscle fiber contractile properties. *MedSciSports Exerc*. 2000;32(0195-9131):48-56. doi:10.1097/00005768-200101000-00009.

75. Fessi MS, Zarrouk N, Di Salvo V, Filetti C, Barker AR, Moalla W. Effects of tapering on physical match activities in professional soccer players. *J Sports Sci*. 2016;414(April):1-6. doi:10.1080/02640414.2016.1171891.

76. West DJ, Cook CJ, Stokes KA, et al. Profiling the time-course changes in neuromuscular function and muscle damage over two consecutive tournament stages in elite rugby sevens players. *J Sci Med Sport*. 2014;17(6):688-692. doi:10.1016/j.jsams.2013.11.003.

77. Ferrauti A, Oh S, Droscher S, et al. Effects of preloading exercise intensity on physical and cognitive performance in soccer. *ECSS Liverpool*. 2011.

78. Suarez-sanchez G. Repeated-High Intensity Running Activity and Internal Training Load of Elite Rugby Sevens Players During International Matches: A Comparison Between

Human Kinetics, 1607 N Market St, Champaign, IL 61825

For peer review

Halves. *Int J Sports Physiol Perform*. 2015.

79. Fuller CW, Taylor AE, Raftery M. Should player fatigue be the focus of injury prevention strategies for international rugby sevens tournaments? *Br J Sports Med*. 2016;50(11):682-687. doi:10.1136/bjsports-2016-096043.

80. Sawka M, Burke L, Eichner E, Maughan R, Montain S, Stachenfeld N. American College of Sports Medicine Position Stand: Exericse and Fluid Replacement. *Med Sci Sport Exerc*. 2007;39(2).

81. Ihsan M, Watson G, Abbiss CR. What are the Physiological Mechanisms for Post-Exercise Cold Water Immersion in the Recovery from Prolonged Endurance and Intermittent Exercise ? *Sport Med*. 2016. doi:10.1007/s40279-016-0483-3.

82. Douglas J, Plews DJ, Handcock PJ, Rehrer NJ. The Beneficial Effect of Parasympathetic Reactivation on Sympathetic Drive During Simulated Rugby Sevens. 2016:480-488.

83. Broatch JR, Petersen A, Bishop DJ. Postexercise cold water immersion benefits are not greater than the placebo effect. *Med Sci Sports Exerc*. 2014;46(11):2139-2147. doi:10.1249/MSS.0000000000000348.

84. Poppendieck W, Faude O, Wegmann M, Meyer T. Cooling and performance recovery of trained athletes: A meta-analytical review. *Int J Sports Physiol Perform*. 2013;8(3):227-242.

85. Poppendieck W, Wegmann M, Ferrauti A. Massage and Performance Recovery : A Meta-Analytical Review. *Sport Med*. 2016;46(2):183-204. doi:10.1007/s40279-015-0420-x.

86. Cheatham SW, Kolber MJ, Cain M, Lee M. The effects of self-myofascial release using a foam roll or roller massager on joint range of motion, muscle recovery, and performance: a systematic review. *Int J Sport Phys Ther*. 2015;10(6):827-838.

87. Hill J, Howatson G, van Someren K, Leeder J, Pedlar C. Compression garments and recovery from exercise-induced muscle damage: a meta-analysis. *Br J Sports Med*. 2013;48(18):1-7. doi:10.1136/bjsports-2013-092456.

88. Azad F, Holmberg EH, Sperlich B. Is There Evidence that Runners can Benefit from Wearing Compression Clothing ? *Sport Med*. 2016. doi:10.1007/s40279-016-0546-5.

89. Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. *J Acad Nutr Diet*. 2016;116(3):501-528. doi:10.1016/j.jand.2015.12.006.

90. Roberts SP, Stokes K a, Trewartha G, Doyle J, Hogben P, Thompson D. Effects of carbohydrate and caffeine ingestion on performance during a rugby union simulation protocol. *J Sports Sci*. 2010;28(8):833-842. doi:10.1080/02640414.2010.484069.

91. Dziedzic C, Higham D. Performance nutrition guidelines for international rugby sevens tournaments. *Int J Sport Nutirion Exerc Metab*. 2014;24(3).

Human Kinetics, 1607 N Market St, Champaign, IL 61825

For Peer Review

92. Hilditch C, Dorrian J, Siobhan B. Time to wake up: Reactive countermeasures to sleep intertia. *Ind Health*. 2016.

93. Waterhouse J, Al E. The role of a short post-lunch nap in improving cognitive, motor, and sprint performance in participants with partial sleep deprivation. *J Sports Sci*. 2007;25(14):1557-1566.

For Peer Review