Returning to play after prolonged training restrictions in professional collision sports

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Abstract

The COVID-19 pandemic in 2020 has resulted in widespread training disruption in many sports. Some athletes have access to facilities and equipment, whilst others have limited or no access, severely limiting their training practices. A primary concern is that the maintenance of key physical qualities (e.g., strength, power, high-speed running ability, acceleration, deceleration and change of direction), game-specific contact skills (e.g., tackling) and decision-making ability, are challenged, impacting on performance and injury risk on resumption of training and competition. In extended periods of reduced training, without targeted intervention, changes in body composition and function can be profound. However, there are strategies that can dramatically mitigate potential losses, including resistance training to failure with lighter loads, plyometric training, exposure to high-speed running to ensure appropriate hamstring conditioning, and nutritional intervention. Athletes may require psychological support given the challenges associated with isolation and a change in regular training routine. Whilst training restrictions may result in a decrease in some physical and psychological qualities, athletes can return in a positive state following an enforced period of rest and recovery. On return to training, the focus should be on progression of all aspects of training, taking into account the status of individual athletes.

Keywords

COVID-19, Rugby, coronavirus, detraining, retraining, disuse

Introduction

Collision sports such as rugby union and rugby league (i.e., rugby) have different demands than many other team sports (e.g., soccer, hockey, cricket) due to multiple contact / collision game events [1]. Athletes require well-developed specific physical qualities to perform optimally [2] and mitigate the risk of injury. These physical qualities are typically developed through well-planned, periodised training programmes [3]. The preparation, maintenance and recovery of athletes is relatively well understood within a typical season [4,5], and practitioners have a wealth of experience in supporting athletes under normal circumstances.

In 2020, the spread of a coronavirus disease (COVID-19) resulted in a world-wide pandemic. As a consequence social measures have been implemented that preclude sports competition and many aspects of team sport training. A primary concern, and the motive for this review, is that development and maintenance of key physical qualities (e.g., strength, power, high-speed running ability, acceleration, deceleration and change of direction), game-specific contact skills (e.g., tackling) and decision-making ability, is challenged during physical distancing and movement restriction measures as a consequence of COVID-19. Players are unlikely to be able to train together as teams in any form, access training facilities or public gymnasiums, nor have routine access to coaching, conditioning and medical staff. Indeed, the majority of elite athletes will be attempting to train at home within the constraints of the equipment and space that they have available to them. Some players will have access to excellent training facilities in their home, some will have access to limited facilities, and some might have no access to equipment or adequate space at all. The variation in training activities that athletes can undertake during a period of restriction will likely present additional challenges when planning the resumption of team training. As such, the specific needs of each individual athlete will require consideration upon the return of training and competition.

Although the likely impact of the COVID-19 pandemic is unprecedented in scale, there are examples of the consequences of enforced restriction of access to training on returning to sport. For example, following a 20-week lockout in the National Football League in 2011, on returning to sport there were more frequent soft tissue injuries [6,7]. Therefore, with a focus on rugby league and rugby union, the purpose of this review is to examine the available evidence related to; potential changes to physical qualities and function during the period of modified training, strategies to mitigate this decline in function, and the time taken to return players and teams to "game ready" status. It is anticipated that many of the principles outlined in this review will be applicable to a broader range of collision sports (e.g., American football, Australian football). The final section provides practical recommendations that focus on restarting these sports after an extended break from training.

Physical qualities for rugby

The demands of rugby require athletes to have high levels of lower-body and upper-body strength and power [8]. Rugby players have high levels of lean mass [9], in comparison to other sports (e.g., soccer) [10], in addition to well-developed aerobic and anaerobic running capacities [11,12]. Strength and power are related to general athletic (e.g., speed, acceleration and change of direction) [13] and rugby specific (e.g., tackling) [14,15] qualities. The tackle and other contact events (e.g., ruck, maul, scrum) require high levels of strength and power to overcome resistant forces from opposition players.

Within rugby league and rugby union, strength and power have been shown to vary between age [16,17], and playing position [2,18]. Professional rugby league players have been shown to have greater strength and power than semi-professional or amateur players [17]. Strength appears similar for professional and semi-professional rugby union players, whereas professional players have greater power [8]. Furthermore, stronger players with higher levels of aerobic fitness have been shown to recover more quickly following rugby league match play [19].

Considerations for injury in relation to enforced modified training

There are numerous conceptual models that identify risk factors for injury (e.g., strength, training load, competition schedule, previous injury) [e.g., 20,21]. However, the evidence for proposed risk factors for injury in elite sports settings is often not as clear as might be expected, perhaps because athletes who are competing have usually reached an explicit or implicit minimum physical requirement for participation at a given level of play.

There is evidence of an association between strength of specific muscle groups and overuse shoulder injuries in throwing sports [e.g., 22] and groin injuries in a range of sports [e.g., 23]. In the case of hamstring injury risk, evidence of an association between strength and injury is mixed (for detailed review see [24]), although a combination of performing eccentric Nordic hamstring exercises [25] and regular exposure to high speed running [26-28] appear to be protective against hamstring injuries.

A high proportion of injuries in collision sports are associated with contact mechanisms, for example, the tackle is associated with ~50% of all injuries in professional rugby union [29,30]. Even in a training environment, the greatest incidence of injury is in full contact training [31]. Therefore the ability of tissues to withstand substantial acute external forces may be key. In a prospective cohort study of professional rugby league players, those with poorly developed high-speed running ability (hazard ratio (HR): 2.9, 95% confidence interval (CI) = 1.7-4.0) and upper-body strength (HR: 2.2, 95% CI = 1.3-3.7) had a higher incidence of contact injury [32].

A systematic literature review and meta-analysis [33] identified six studies that have examined the effect of strength training interventions on injury outcomes in military [34] and elite [35,36], amateur [36,37] and youth [38,39] soccer. All of the interventions reduced injuries, with 95% certainty of more than halving injury risk (average reduction, 66%, 95% CI 52% to 76%). These findings provide compelling evidence of a role for development of strength in injury prevention, although none of the studies were in professional collision sport settings. Similarly, rugby specific injury prevention exercise programmes that focus on strength, balance and proprioception [40] substantially reduced injury and concussion incidence in cluster randomised controlled trials in youth [41] and community adult [42] cohorts. Of particular interest in the context of these studies is the potential importance of neck strength in protecting against concussion [43].

A key concern arising from a period of enforced modified training due to COVID-19 is that athletes cannot maintain physical qualities that likely protect against injury. A twenty-week shutdown of the National Football League in 2011 was associated with a four-fold increase in Achilles tendon ruptures in the first 29 days of a condensed return to competition period [6]. Over the subsequent season, soft tissue injuries (considered to be conditioning-related injuries) were higher than preceding or subsequent seasons [7]. In professional rugby union, even after a short off-season typically lasting 4-5 weeks during which athletes have opportunities to train (e.g., access to gym and other training facilities), there is a greater frequency and burden of training injuries in the early, compared with later, period of preseason (Figure 1). This highlights one of the challenges when athletes return following an extended period of enforced modified training.

FIGURE 1 HERE

On resumption of competition, it is possible that multiple games per week are scheduled to make up for the time lost. Limited time between matches during periods of fixture congestion has been shown to be associated with more injuries in soccer [44]. Clearly, the timing and structure of reconditioning, and fixture scheduling upon resumption of the competitive season, have the potential to impact on injury outcomes.

The concept of preparedness for training and/or competition has been investigated in professional rugby union, with intermediate cumulative load over four weeks showing a likely beneficial reduction in injury risk compared with low or high four-week loads [45]. In the same study, sudden increases (or spikes) in training load were shown to increase the risk of injury [45]. Exposure to competitive matches also appears to influence injury risk in professional rugby union, with involvement in less than 15 or more than 35 games over a 12-month period associated with a greater injury risk than being involved in between 15 and 35 games [46]. An extended period without competition will result in more players having played a low number of games in 12 months, potentially increasing injury risk.

In returning players to competition, standard considerations around individual risk factors will be important to consider. A potential positive of a period of modified training practices and no matches, is that it may allow for prolonged rest that is rarely afforded to professional rugby players. Previous injury has consistently been shown to increase subsequent injury risk [47], and there may be opportunity to focus on full recovery and rehabilitation from previous injuries, although restricted access to appropriate rehabilitation modalities might limit any positive impact. Given that some subsequent injuries considered to be, in part, related to inadequate rehabilitation [47], individual management of athletes when returning to full training is required. The Strategic Assessment of Risk and Risk Tolerance (StARRT) framework may be helpful in this respect [48]. Some athletes may even have developed injuries during the period of restricted training due to enforced changes in training type, timing, load and surface. A further consideration is that athlete anxiety may be elevated by a number of facets of an extended period of modified training due to COVID-19, which might impact on injury risk when returning to play [49].

Under normal circumstances, most elite collision sport players will be conditioned to a level that is protective against injury. However, a sustained period of enforced modified training is likely to impact upon this conditioning and is likely to result in increased injury risk. It is important to consider strategies to mitigate losses in physical function and to develop appropriate reconditioning strategies. These should be considered on an athlete-by-athlete (e.g., training status and injury history), sport-by-sport (e.g., the stage of the season), and country-by-country (e.g., local government COVID-19 guidelines) basis.

Potential changes in physiological characteristics in response to reductions in training

Athletes' musculoskeletal, respiratory and cardiovascular systems are accustomed to a large volume and intensity of training stimulus, and any considerable reduction in habitual stimuli will lead to a degree of physiological system and tissue deconditioning, in turn reducing physical performance. There is limited evidence regarding detraining in elite athletic populations, but principles of deconditioning can be translated from human laboratory studies using extreme experimental models such as limb immobilisation (local disuse), bed rest (whole body disuse) or reduced step count (moderate decreases in physical activity) in previously 'healthy' individuals [50]. Regardless of the model, such studies reliably show that deconditioning is rapid and profound [50].

Physical inactivity quickly leads to a myriad of interrelated cardiovascular deconditioning responses. Experimental bedrest [51] and short term detraining in trained individuals [52] decreases plasma volume, reduces baroreflex sensitivity, impairs the sensitivity with which the vasculature can appropriately redistribute blood volume, interferes with heart rate and blood pressure regulation, induces cardiac muscle atrophy and impairs myocardial mechanics and stroke volume. Though the time course and severity of some of these responses has not been precisely delineated, their integrated nature rapidly impairs oxygen (and nutrient) delivery and tissue extraction, and can be expected within less than four weeks [52].

Skeletal muscle appears particularly susceptible tissue to disuse-induced deconditioning, with substantial impairments in markers of metabolic health (reflecting declining muscle tissue quantity and quality) within just one week [53,54]. Disuse also almost immediately reduces daily muscle protein synthesis rates [55], largely driven by a reduced ability of the inactive tissue to extract dietary derived amino acids from the circulation following each meal [56] and utilise them for the construction of new proteins [57]. The resulting loss of muscle mass can be nearly 100 g after only two days of limb immobilisation [55]. This increases to >250 g after one week, while one week of bed-rest results in ~1.5 kg of whole body muscle loss [53]. Strikingly, muscle strength and force generating capacity of a muscle group subjected to extreme disuse declines by ~1.5-2% per day [58], around 3-fold higher than the loss of muscle mass alone [59].

Muscles (groups) of a higher ‘training status’ *within an individual* (i.e., higher habitual gravitational loading and mechanical workload) typically decondition more rapidly. For example, the quadriceps atrophy more rapidly than the hamstrings [60] and the large postural and gross motor movement muscles of the legs, trunk and back atrophy more quickly than the arms or other smaller muscles more attuned to fine movements [61]. In the event that disuse is brought about by any type of acute injury, which would typically elicit a local and systemic inflammatory response, muscle loss may be further accelerated over rest alone [62]. At the single fibre level, muscle disuse atrophy is characterised by a decrease in cross sectional area of all muscle fibre types, though type II fibres appear particularly susceptible [63]. Skeletal muscle fibre atrophy is accompanied by considerable and disproportionately large declines in function at the level of the muscle fibre. Despite this, some evidence points towards deconditioning bringing about a ‘faster’ overall muscle phenotype, seemingly due to increased expression in the faster isoforms of muscle myosin heavy chain across fibre types [64] rather than any ‘fibre type switching’.

Bone demineralisation also occurs within a week of unloading [65], while tendon and connective tissues such as ligaments appear to be more resistant to short-term muscle disuse [66,67], likely due to considerably lower protein turnover rates. However, within a month of detraining, impairments in tendon and ligament tensile strength and functionality can be expected [68]. Deconditioning of the tendon and ligament tissue also impacts on metabolic and functional performance [66,67]. The crucial structural role of these collagen rich tissues within the musculoskeletal system (particularly within joint stabilisation) contributes heavily to movement and force generation, and therefore their deconditioning also contributes to degenerate physical performance.

It is clear that the extreme models of disuse described above do not reflect the experiences of athletes during most periods of training restriction. However, case-study data on elite footballers suggest that injury induced periods of disuse (e.g., Anterior cruciate ligament [ACL] surgery) lead to rapid tissue and performance detriments that reflect the changes seen in laboratory trials (e.g., loss of muscle mass and function, gain in fat tissue and alterations in metabolic rate) [69,70]. Such effects are evident despite 'best practice' in terms of nutritional and physical therapy countermeasures being applied. Furthermore, elite athletes reducing training at the end of their competitive season can expect rapid (within 5 weeks) declines in function, with the extent being related to the level of withdrawal from training [71]. Such data brings into stark focus the challenges that those involved in collision sports face if athletes undergo enforced periods of reduced or absent training load.

Maintaining muscle mass and function during enforced modified training

Fortunately, even in extreme physiological models of disuse, small amounts of exercise can mitigate losses in muscle size and function. For example, eighty-four days of bed rest in healthy men resulted in a 17% reduction in muscle size and around 40% reduction in muscle strength and power [72]. However, when maximal concentric supine squats were performed every third day, muscle size, strength and power were maintained [72]. In 60 days of bed rest, just three minutes of "supine jumps" on 5-6 days per week maintained leg lean mass and strength, compared with reductions of around 10% without exercise [73]. These examples are important in illustrating the concept of mitigating losses in muscle mass and function during deconditioning, but cannot be translated directly into sports settings.

A key question when access to training facilities is limited is whether heavy loads during resistance training are required for the development, or maintenance, of muscle mass and strength. During resistance exercise all motor units are recruited at momentary muscular failure, regardless of the load used [74]. In turn, rates of muscle protein synthesis for up to 24 hours after exercise were similar when healthy men performed knee extension at 30% of one repetition maximum (1RM) to failure compared with 90% 1RM to failure [75]. Taking this further, 10 weeks of knee-extension training to failure at 30% 1RM and 80% 1RM in healthy young men resulted in similar change in quadriceps volume (hypertrophy), although gains in strength as assessed by 1RM was significantly higher following training at 80% 1RM [76]. Other studies have also reported similar hypertrophy response in lower-load and higher-load resistance training, with smaller gains in strength in lower-load training [77,78]. Furthermore, 12 weeks of whole-body resistance training at either 30-50% 1RM or 75-90% 1RM in trained individuals resulted in similar changes in whole body lean mass [79]. However, in this study, 1RM strength was tested every third week, essentially allowing a small amount of high load training in both groups, and the strength outcomes were similar in all tests other than bench press for which there was a small but significantly superior gain in the 75-90% 1RM group. Incorporating plyometric training might also be beneficial, given that eccentric muscle actions have the potential to induce neural adaptations, even in the absence of heavy loads, and that both concentric and eccentric peak torque were better maintained during detraining following coupled concentric and eccentric resistance training than concentric training alone [80]. Furthermore, although evidence is mixed, meta-analysis showed small-to-moderate effects of plyometric training on maximal strength in healthy adults [81].

Focusing on elite athletes, bench press and bench pull performance were assessed in kayakers before and after five weeks of detraining following the World Championships [71]. Seven athletes discontinued all training, while seven completed a dramatically reduced volume of training that included one resistance training session per week. In those that discontinued training, bench press 1RM declined by 8.9% and bench pull by 7.8%, whereas in those completing one resistance training session per week, declines in strength were much smaller at 3.9% for bench press and 3.4% for bench pull. In addition, those that discontinued training suffered a reduction in VO_2max of 11.3%, whereas those that reduced training volume to just two endurance session per week experienced reductions of 5.6%. As a note of caution, in athletes for whom strength and power are key attributes, the possible interference effect of endurance training on strength adaptations should be considered [82,83]. This might be particularly relevant when running and cycling activities are possible, but access to resistance training facilities are limited.

From both a performance and injury prevention perspective, incorporating high speed running into training is likely to be beneficial. Sprint training has been demonstrated to have positive impacts on hamstring architecture and sprint performance [84], and regular exposure to maximal running velocity has the potential to reduce injury risk [26]. The addition of both eccentric hamstring training [25] and plyometric training [85] may also be appropriate.

Practically, strength and power trained athletes may find it difficult to match the loads needed to maintain size, strength and power. Performing resistance training to momentary failure, even with low loads, may mitigate some losses in muscle size, and if some training with high resistance can be incorporated, even if not at the usual frequency, it is possible to maintain strength characteristics. Alternatively, plyometric exercises might provide a sufficient neural stimulus to contribute to the maintenance of strength. Furthermore, given that neural adaptations might be retained for longer than 12 weeks in trained individuals [64], and that, even if this is not the case, neural adaptations occur early in response to resistance training [86], a focus on retaining as much muscle mass as possible during restricted training is recommended, followed by the re-introduction of high resistance in training once access to facilities and support is possible.

Psychological considerations during enforced modified training

The training limitations arising from COVID-19 present a number of psychological considerations which may influence preparation for, and subsequent return to, rugby competition. These include the impact of confinement and isolation, deconditioning effects, deterioration in skill execution/performance, and, the opportunity for recovery and posttraumatic growth.

In addition to the psychological effects from periods of confinement and isolation reported in the general public [87], such as post-traumatic stress symptoms (i.e., depression, anxiety, confusion, and anger), athletes may be at further risk due to the impact on their athletic identity. Athletic identity refers to the extent to which an individual identifies with their role as an athlete [88]. Any challenges to the ability to reinforce this identity through reduced capacity to train, play and achieve goals (typically seen in injured or retired athletes) are associated with feelings of loss, identity crisis and distress [89]. While engaging with social support networks is seen as a key resource to cope with potential threats to athletic identity arising from the restrictions, it is likely athletes will be socially isolated from those who contribute most to supporting their sense of athletic identity (teammates, staff, fan base). An extended period of isolation from fellow team mates is also likely to impact upon the social and psychological group process that underpin a team's effectiveness to work together (i.e., teamwork; [90]) and subsequently perform.

In contrast to the physiology literature, limited research has examined the psychological effects of a period of detraining or rest. While acute bouts of rest (e.g., 2-week mid-season break) improve subjective perceptions of some aspects of wellness, such as fatigue and muscle soreness [91], there is no evidence examining the chronic effects of deconditioning. In the professional practice literature, Bompa and Buzzichelli [92] suggest an abrupt cessation of training by highly trained athletes creates a phenomenon known as detraining syndrome, characterized by insomnia, anxiety, depression, alterations to cardiovascular function, and loss of appetite. These symptoms are usually not deemed pathological and can be reversed if training is resumed within a short time, however, with prolonged cessation, symptoms may become more pronounced.

The principle of reversibility dictates that athletes lose the beneficial effects of training on cessation/reduction in such activities [93]. A decline in skill execution/performance may therefore be expected from a lack of deliberate team or individual skill-based practice, and will vary with the nature and type of skill [94]. Offsetting skill reversibility will rely in part on the ability to assess the relevant elements of the required skill performances, and utility of the practice-based knowledge regarding retention or transfer effects that accompany practice of these skills [95]. The use of the cognitive technique of imagery, specifically mental rehearsal of the execution of individual skills/team strategies, can aid with physical skill learning or refinement [96]. However, no research has considered the role of imagery in skill retention following deconditioning or rest. Video-based observation (modelling) of existing skill execution or performance can also be used to promote physical skill learning and refinement, and can enhance both individual and teams confidence in their ability to execute the skill [97].

A period of abstinence from sport may also offer athletes an opportunity for mental rest and recovery, especially where restrictions occur towards the end of a competitive season. Recent research in professional rugby union [98] suggests advanced information regarding the timing and length of any competition break (i.e., off-season) can determine the level of autonomy players perceive over their break from the sport, and the subsequent degree of psychological recovery achieved. Given restrictions associated with the COVID-19 pandemic have meant a suspension (as opposed to termination) in the current competition season, athletes are being asked to engage in a level of interim individual training that does not align to a designated off-, pre- or in-season period, without any competition goal or outcome to pursue. This training 'limbo' may reduce players' ability to cognitively 'detach' [99] and negate any potential psychological benefit associated with time away from the sport.

In considering the human trauma associated with COVID-19 it is noteworthy that the consequences for mental health and wellbeing will not be inherently negative. Potential exists for growth in response to traumatic life experiences, where growth involves profound and transformative positive changes in cognitive and emotional life that are likely to have behavioural implications [100]. Research in sport has examined growth in relation to adverse intrapersonal experiences such as long term injury and sport retirement [101], and recently at the interpersonal and organizational level (see [102]). Both individual and collective psychological growth may be derived from the trauma and adversity athletes, teams and their staff face during the restrictions. The extent to which growth is likely occur will, however, be influenced by the amount and nature of the support provided before, during, and after the restrictions.

Nutritional considerations during enforced modified training and re-training

The overarching goal during a phase of restricted training is to maintain physical capacity via preservation of muscle mass, minimisation of unwanted body fat increase, support of immune function and maintenance of cardiovascular capacity. Energy expenditure may be reduced during a period of reduced training, although other factors may be increased contributing to overall energy expenditure. For example, Anderson et al. [103-105] suggests that with injured athletes who have a reduction in their absolute training intensity, increases in other factors (e.g., frequency of resistance training and rehabilitation) result in trivial changes in total daily energy expenditure (estimated reduction of 300 kcal$\cdot$d^{-1}). Therefore nutritionists should consider an individual's habitual physical activity level (e.g., dog walking, living and training logistics, active family) prior to suggesting a reduced total caloric intake. One of the main challenges for bespoke nutritional intervention during this period will be the accurate assessment of daily energy expenditure with a '*one-size fits all*' approach being particularly problematic. Rugby players have large inter-individual differences in daily energy expenditure when measured via doubly labelled water, even when the players appear to be undertaking similar training sessions (Table 1) [106-109]. This highlights the substantial contribution of activities away from the training ground on total daily energy expenditure and it is therefore essential that nutritionists attempt in some way to quantify the activities of the day during this period of training restriction.

TABLE 1 HERE

Research has shown decreased insulin sensitivity, attenuation of postprandial lipid metabolism, and an increase in fat mass as a consequence of simply reducing step count (~1300 from ~10000) for 2-3 weeks [110] alongside increases in visceral adiposity [111]. If athletes reduce their daily activities, there is a requirement to reduce calorific intake versus 'normal' habitual competition, however it is important to maintain habitual protein intake. Although the majority of research has focused on middle- and older-aged males [112,113], targeted nutrition, specifically dietary protein intake, has been shown to mitigate the consequences of reduced activity, even in younger adults [114,115]. One specific essential amino acid that may play the most pivotal role in the attenuation of anabolic resistance as a result of disuse is leucine, a potent stimulator of mTOR and thus muscle protein synthesis [116]. It is therefore suggested that athletes maintain a high protein diet rich in leucine, consuming approximately 0.4 $g \cdot kg^{-1}$ body of protein regularly (every 4 hours) throughout the day [117]. The reduction in calories will therefore come from reduced carbohydrate and fat intake utilising a periodized carbohydrate model based on the demands of the training day [118]. It is important however that sufficient carbohydrates are consumed during this period and that athletes do not adopt a ketogenic style diet given the strong links between carbohydrates, stress hormone responses and the immune function (discussed further in [119-121]). Protein is often used in conjunction with creatine monohydrate to support maintenance/gains in strength and lean mass. Supplementation has been shown to attenuate loss of upper arm mass and strength, specifically during times of disuse (limb immobilisation), as well as increase muscle hypertrophy following lower limb immobilisation [122,123].

From an immune support perspective, research has shown that protein may also have a pivotal role in supporting the immune function, specifically antibody response to infection [124,125] again highlighting the need to maintain sufficient protein intakes. Other nutritional factors that may aid with microbe 'resistance'/'tolerance' during this specific period include supplementation of 500-1000 mg vitamin C [126], 1000-4000 iU daily vitamin D_3 [127,128] and ~20 billion CFU multistrain probiotic [120,129-131]. For a full review of nutrition and immune tolerance the reader is referred to Walsh [120].

Reconditioning considerations on return to training

Extended periods of restricted or modified training create a challenge for athletes when returning to sport ready to perform and with a low risk of injury. Following the National Football League "lockout" in 2011 it is not known whether the athletes returned in good physical condition or not, but the increased incidence of Achilles tendon injuries [6] suggests that athletes may not have been physically ready for the demands of the game or the return to play protocols were not thorough and progressive enough.

Some physical qualities are likely easier to maintain (e.g., strength, power, aerobic and anaerobic capacity and linear speed) with minimal equipment, although on return to training, all require consideration. In many cases players have to train alone without access to equipment, appropriate space or expertise, leading to an inability to maintain the required intensity of training. This will vary between countries, given variations in government-enforced physical distancing protocols. The most difficult aspect of rugby training to replicate when training individually are the "intricacies" of the sport. These include the sport-specific physical and mental demands, such as changes in direction while running at speed, running with ball in hand, attempting to evade would-be tacklers and then being tackled, lineout jumping, cutting, tackling, scrummaging, ruck clearance and mauling [132]. In this context, decision-making can only be practiced when training with others. Typically, athletes would return to structured preparation after a 3- to 6-week off-season and progress to playing the game over 6 to 12 weeks.

It is vital that athletes returning to rugby following a period away from team training undertake a well-planned, progressive return to play programme to prepare to perform and to decrease the risk of injury (see [133]). High-speed (or sprinting) running is one specific consideration on return to training, given the concurrent benefit to performance (e.g., acceleration and maximum sprint speed [134]) and injury prevention [135]. High-speed running exposure should be managed carefully as an excess or rapid increase in training load may increase soft tissue injury risk [21]. In sprinters, the training phase (e.g., following the off-season) and transition phase between the preparation period and competitive season appear to be vulnerable periods for injury [136]. That said, high-speed running is paramount for sprint performance enhancement [137] and the morphological and architectural lower limb qualities [84] suggesting it should be incorporated into reconditioning training programmes. On return to match play, if the difference between training speed and competition speed is large, this may also increase injury risk [85], although empirical evidence does not exist to support this.

For athletes that have had limited or reduced exposure to high-speed running, the initial weeks of training should focus on the re-familiarisation of the intensity and duration required for training and competition, which should be progressed gradually [85]. No clear recommendations exist on sprint exposure for rugby players, although general principles such as avoiding high-speed running on consecutive days do exist [85]. These should be considered alongside other training modalities rugby players are exposed to [138] and their potential interaction (e.g., avoiding high velocity sprinting following fatiguing lower-body resistance training). As a guide, athletes should be exposed to a range of sprint distances, to allow the development of acceleration (10-50 m, >98% intensity, total session volume 100-300 m), maximal velocity from a flying start (10-30 m and >98% intensity, total session volume 50-150 m) and sprint-specific endurance (80-150 m and >95% intensity, total session volume 300-900 m) (see [85]). Resisted sled sprint training may also be beneficial (see [139]). Given high-speed running exposure will be one of a number of qualities practitioners will aim to retrain, it may be more prudent to focus of the quality of the high-speed running exposure, as opposed to volume *per se*. For example, practitioners should end a high-speed running session when there is a drop off in performance, and/or technical error is observed, and 1-2 minutes of recovery can be provided for every second spent maximal sprinting between repetitions [85,140].

Preparing for the rugby specific actions is also a key consideration for athletes and practitioners. This is best achieved through performing such actions during ‘practice’ involving the performance of the fundamentals of the game with teammates in either ‘opposed’ or ‘unopposed’ situations. For example, simple skills such as catch and pass, game plan understanding, tackle progressions, and the changes in direction that occur during normal practice are part of preparing to play the game.

Another example of how to integrate injury prevention and progressive exposure to game play is change of direction and agility. These are important facets to evade tacklers and create an open field of play [141]. An athlete's agility performance is strongly influenced by the ability to rapidly decelerate and reaccelerate while adjusting his or her momentum to either pursue or elude opponents [142]. While athletes could be working on change of direction, acceleration, deceleration and agility by themselves (e.g., practice sharp changes in direction while running at high speeds, and including rapid acceleration and deceleration), once they return to training with team members and return to play progressions, the key is to gradually build in layers of intensity (e.g., speed of run and sharpness of direction change) and decision making.

As described previously, the tackle poses the highest injury risk in rugby, accounting for around 50% of injuries [29,30]. Therefore it is important that athletes have the required physical and technical skill set to perform safely and effectively. The development of specific tackle skills have received little attention within the scientific literature [143], but poor tackle technique has been shown to result in a higher injury risk [144,145], and fatigue has been shown to alter tackle technique [146,147]. Several frameworks have been proposed on how to train the tackle [148,149], although the effectiveness of these is yet to be determined. It is likely that following a prolonged period of non-contact training, due to the enforced physical distancing players will require a graded exposure to both the technical and physical components of the tackle [148]. Following a typical 3-6-week off-season and 6-12 weeks pre-season, athletes will start to engage in contact and tackle training during week 3-6, with progressions over 2-6 weeks. It is likely athletes will need at least 3-4 weeks of progressions and exposure to tackle and contact skill training to prepare for matches.

The simplest way to prepare for the explosive demands of the game is to ensure all activities follow well-planned progressions (Figure 2). Such progressions are dependent on the sport specific task in question and the position demands for each individual. In the specific context of return to training in relation to COVID-19, local government policy and risk assessments based on potential for COVID-19 transmission in any given activity or session will impact upon decisions regarding the choice and rate of progressions.

FIGURE 2 HERE

Development of strength and power on return to training

Rates of change in power and strength are influenced by the intensity (percentage of maximal), volume (sets x repetitions) and frequency of resistance training, with relatively small changes in maximal strength and power in elite athletes, due to their previous training status [3] (Tables 2 and 3). In a meta-analysis, maximal strength was reported to increase at a rate of 1.8% weekly [3]. Similary, Issurin [150] reported that elite kayakers improved their maximal strength by 5.9% over the first 3-weeks of a 20-week training cycle, an average improvement of 1.93% a week. However, during the second 3-week week phase of training average change in strength was only 0.53% a week, and continuation of the programme resulted in minimal improvements in maximal strength, with the final 14-weeks resulting in a further total increase of only 1.82%. These results suggest that only the first 6-weeks of a strength training cycle provides positive adaptations for elite athletes. The changes in strength and power during a professional rugby season also demonstrated that the majority of strength changes occur early in a programme [5]. Improvements in strength during the first 12-weeks of training were 2.7±1.1%. During the second 21 weeks of training, strength gains were on average 1.9±1.1%. These changes are considerably lower than reported by McMaster et al. [3], however these results reflect changes in force production during an isometric squat rather than specific lifts (e.g., squat) that also improve due to familiarity of the exercise task, and technique changes. It is worthwhile noting that the greatest changes in strength in professional rugby players in England coincided with the highest volumes of strength training, during the second phase average strength loads were 63% of those utilised in the first phase [5].

TABLE 2 HERE

TABLE 3 HERE

The potential rate for gains in power for athletes in collision sports appear relatively low, however, the protocols utilised in studies examining power changes are more suited to induce changes in maximal strength than power [151,152]. Over a season of professional rugby, the greatest improvements in power were observed in the early competition phase, when strength training frequency decreased, training intensity remained high, and total volume load was reduced [5].

Rugby players are typically assessed for strength and power at various stages within the season. Whilst published data are not available, unpublished data (Bennett, Unpublished; Table 4) demonstrate the changes in strength and power exercises from 26 male Tier 1 International rugby union players over a 5-week physical training phase after a 5-week break from organised strength and power training (2-week end-of-season tour and 3-week recovery). These data provide a reference point for expected strength and power development rates following extended breaks in training, such as that resulting from the COVID-19 pandemic.

TABLE 4 HERE

Table 5 presents the changes in a male professional rugby union team (35 players) in the first 4-week training block, after a 4-week off-season (Bennett, Unpublished). Of note in both the data on the professional players and also the international players, considerably greater changes in lower body strength are observed in comparison to upper body strength in both instances. This could rbe a similar response to the muscle-specific atrophy described in response to extreme models of disuse [60,61]. Alternatively, it could be related to players favoured training options when away from an organised environment (e.g., undertaking unsupervised upper-body, as opposed to lower-body resistance training).

TABLE 5 HERE

Neural adaptations appear to provide a greater contribution to strength increases than muscular hypertrophy early in training [86], but changes in power and maximal strength that occur from detraining are a likely a result of both neural adaptations and a decrease in cross-sectional area of the muscle [153]. That said, there is evidence to suggest that neural changes from heavy strength training are long lasting and can extend beyond 12-weeks of detraining [64]. These findings suggest that on return to club training, hypertrophy of muscle fibres should be the primary focus, especially in those players who have lost significant muscle mass. Some evidence is present in the literature with regard to “muscle memory” a phenomena where previously trained musculature retains a considerable proportion of relevant adaptations and does not return to its pre-trained state, even after a considerable period of detraining (for review see [154]). It has been shown that individuals with a substantial strength training background can regain previous muscle fibre hypertrophy and strength levels in a relatively short period of time, as much as 32-weeks of detraining can be reversed with 6-weeks of strength and power training [155]. This, alongside a maximal window of 6-weeks before the rate of return on strength training is minimised [150], would suggest a 6-week training block is sufficient for professional rugby players to regain previous physiological adaptations.

Considerations for athletes returning to training after suspected or confirmed COVID-19 infection

Any discussion or guidance regarding re-conditioning in athletes needs to acknowledge and reflect the general principles informing return to play after acute medical illness. This is particularly important for athletes with confirmed or suspected COVID-19 infection. In many cases, an athlete will only have been given a presumptive diagnosis, based on the presence of typical clinical features (e.g., dry persistent cough and febrile illness) leading to a 7- or 14-day period of self-isolation. Many suspected cases will not have undergone formal testing due to local testing procedures and policies. Indeed, for most young, fit individuals, acute COVID-19 infection is associated with very few overt systemic features, typically only very mild upper airway symptoms (e.g., anosmia), and the athlete may often not feel unwell. A very small number of previously fit young people will develop moderate to severe disease and may require acute medical care, including in some cases, the provision of hospital-level support, and possibly ventilatory support [156]. In this latter group, data series indicate an almost ubiquitous presence of pulmonary infiltrate (on either a chest x-ray [CXR] or computerised tomography [CT] scan) and a high prevalence (8-28%) of elevated markers of cardiac dysfunction (e.g., troponin rise) that may manifest acutely as myocarditis, heart failure, cardiac arrhythmias and acute coronary syndrome [157,158]. There also appears to be an increased risk of thromboembolic events, which need to be considered in the differential diagnosis in any clinical presentations encountered in athletes recovering from COVID-19 infection; i.e., consider deep vein thrombosis in an athlete reporting calf pain.

Historically, the most widely adopted return to play approach in athletes recovering from respiratory tract infection, is based on the 'neck check' approach [159]. Using this approach, athletes are advised that they may continue to exercise if their symptoms and clinical signs are confined to the upper airway (e.g., only coryzal symptoms) and a short sub-maximal exercise trial does not exacerbate symptoms. The scientific basis for this recommendation is weak, and there is long-standing concern of the potential risk of athletes with respiratory tract infection developing other clinically significant end-organ complications on their return to vigorous exercise. Of these risks, the most important is the risk of myocarditis or myocardial damage, which could be highly relevant in relation to COVID-19. The current COVID-19 pandemic, particularly challenges the 'neck check' approach, in that there is reported variability and an almost 'biphasic' recovery pattern, such that infected individuals can appear to transiently improve, only to deteriorate at a later stage; approximately one week after the onset of symptoms. In addition, and as outlined above, there is concern from emerging data, that myocardial irritation and frank myocarditis may be both prevalent and an important manifestation of this novel infection [157,158,160]. It is not yet clear if this is the case in those with clinically mild disease (i.e., in those not hospitalised), however, given the considerable cardiovascular challenge of participating in elite sport, consideration of this risk should form a key part of an individual's return to play assessment. It is with these considerations in mind, that clinicians generally adopt a more conservative approach in planning a post COVID-19 return to play strategy for confirmed and suspected cases at the current time. Expert groups (e.g., in cardiology and respiratory medicine specialities) are starting to provide guidance for specific follow-up based on small data series of the general population and expert opinion and this will undoubtedly evolve as peer-reviewed data from the athletic population becomes increasingly available.

It is recommended that medical practitioners such as Sports Physicians, overseeing the return to training, should consider utilising an approach that incorporates and considers 'risk' stratification. It may also be possible to assess physiological markers including resting, exercising and recovery heart rates, beat to beat variability, ratings of perceived exertion and other indicators of reduced cardiopulmonary function. In addition, ongoing understanding of the condition may point to other markers of wider organ involvement that form part of the elite sport training monitoring such as exaggerated rises in blood creatine kinase [161] and lactate concentrations. Furthermore, a graded return to activity, perhaps akin to that used in under-recovery unexplained-under-performance syndrome [162] could be employed to guide a careful progression, whilst our understanding of the most appropriate post-COVID progression develops. In the meantime, clinicians can use Figure 3 to help inform return to play risk stratification.

FIGURE 3 HERE

Considerations for at risk groups during enforced modified training and re-training

As a result of the extended period of training restriction, there will be some athletes who are at a significantly higher risk of injury when they return to training. Although specific evidence in this area is limited due to the uncommon nature of such a period of restriction in elite sports, broader evidence available concerning predisposition for injury may assist in the identification of these at-risk groupings. For example, evidence has shown previous injury to be a strong risk factor for further injury [47]. This is particularly important to consider when the ability to a) rehabilitate and pro-actively manage any existing injuries and b) continue prehabilitation programmes for injury prevention is reduced during restriction. It is also noteworthy that following the National Football League lockout in 2011, the Achilles tendon injured group in the early phase of return to competition were, on average, younger and had a lower exposure to the NFL environment than Achilles tendon injured players in other years, suggesting specific risk [6]. Alongside the physical health of the athlete, their mental wellbeing may also be affected, highlighting the need for well-defined and accessible support structures for athletes and staff both during and after isolation. Furthermore, and as a direct result of this extraordinary time, the best practice management of athletes who either present with COVID-19 symptoms or are returning to activity following a suspected or confirmed case of COVID-19 is clearly of huge importance. Of note is the risk of long-term effects on the respiratory and cardiovascular systems if these individuals are not managed correctly.

Figure 4 summarises those groups considered 'at-risk'. It is recommended that athletes that fall into these groups are given careful consideration when planning their reintegration into normal training practice. It might be suitable to utilise physical and psychological screening tools to establish a baseline upon return to the club environment and to provide practitioners with information upon which to base their periodisation and programming. Overall, an individualised approach to the at-risk groups is recommended.

FIGURE 4 HERE

Challenges and practical recommendations for collision sports

The COVID-19 pandemic has created a unique scenario for all major sports with respect to the highly unusual period of training restriction. All sporting National Governing Bodies and competition organisers will need to consider how they plan the return of training activities, and ultimately competition, balancing a range of drivers to restart sport as quickly as possible with how they best manage the welfare of their athletes. These will differ between countries (e.g., England versus New Zealand) and sports (e.g., rugby league versus rugby union) given the varying level of impact COVID-19 has had on training restrictions and modification, and the varying stages of the season athletes were in. In collision sports, the resumption of training following a period of modified isolated training will arguably be harder to manage than other sports. This is due to a number of factors which include the high-risk nature of participation and the importance of strength and power, which may be affected by restricted access to training equipment and space. In addition, the importance of skill execution in high risk areas of the game, such as the tackle, and the lack of opportunity available to train these skills during a period of restriction also requires special consideration. Even on the resumption of training, factors such as limits on the number of players that can train together and limits on the amount of time it is acceptable for players to be in close contact with on another players will influence possible training progressions. That said, the unprecedented period of non-contact training may provide a positive period for physical and psychological rest and recovery. With the application of appropriate and progressive reconditioning practices on return to training, this may improve an athletes' performance and wellbeing.

Athletes may also be afforded the opportunity to target the development of specific physical weaknesses, without the challenges of preparing for weekly competitive matches.

Monitoring of athletes' training during the period of training restriction may be beneficial when making decisions regarding initial load and progressions when group-based training resumes. Player load monitoring should be appropriate to capture the range of stresses (e.g., volume, intensity, resistance training, running) athletes have been exposed to [163]. Microtechnology is commonly used within rugby to collect objective external load measures, but access to both hardware and software is likely to be limited when training away from club environments. Session rating of perceived exertion (sRPE; [164]) offers a practical method of monitoring player load, regardless of the exercise modality. Remote monitoring of sRPE has been shown to be valid in comparison to recall with 30 minutes of exercise cessation when collected 24 to 48 hours [165] following an activity, but not at 72 hours [166] or when collected as part of a weekly self-reported training load diary [167]. As such, athletes should aim to report their sRPE at least every 48 hrs. In addition, it might be prudent to capture information about exposure to specific training, such as high speed running. In the absence of regular monitoring during the period of training restriction, screening prior to the resumption of group-based training should capture information about the training that has been carried out by each individual athlete.

It is also logical to think that the risk of infectious transmission in contact sports is higher than in non-contact sports and so the development of medical policy to mitigate the risk of transmission alongside suspected case management is critical. Furthermore, there will be a need to assess the risk of COVID-19 transmission in close contact elements of training, and to introduce these in a graded fashion that minimises risk. Table 6 summarises the focus areas, challenges and practical recommendations that have been identified in this review that the teams and major stakeholders of elite collision sports need to consider when managing athletes during this unprecedented period of restriction and when planning the resumption of training and competition.

TABLE 6 HERE

Conclusion

The COVID-19 pandemic has created unprecedented challenges in sport, resulting in restrictions to competition and many aspects of training. These restrictions have led to concerns about the ability of athletes in collision sports to maintain key physical attributes (e.g., strength, power, high-speed running ability, acceleration, deceleration and change of direction), game-specific contact skills (e.g., tackling) and decision-making ability. Any decay in these attributes has the potential to impact on performance and injury risk on resumption of training and competition. However, with appropriate management it is possible to benefit from a rare opportunity for extended recovery and for athletes to maintain and even develop many aspects of physical and psychological function. In contrast, some physical, psychological and sport-specific attributes are challenging to affect during periods when athletes are only able to train on their own. Fortunately, a period of around 6 weeks of preparation is likely to be sufficient for most athletes to return to being competition ready, although this will ultimately depend on the length of governmental social distancing policies, which differ by country. Returning athletes to competition-ready status will require the application of broad principles of progression with the added dimension of assessing the risk of infection transmission in group training activities. Individual player circumstances should be considered from a performance and welfare perspective, particularly in the case of those athletes considered to be at higher risk of poor performance or injury.

Conflicts of Interest

No funding was received for the preparation of this review. KAS, GLC, AMK, SPTK and BS are employed by the Rugby Football Union. BJ is employed by the Rugby Football League. MB is employed by the Rugby Union of Russia. NG is employed by New Zealand Rugby Union. MC is employed by Premiership Rugby. The review was prepared based on the ethical standards of the International Journal of Sports Medicine [168]

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Figure legends

Figure 1. Incidence (A: injuries per 1000 hours) and burden (B: days lost per 1000 hours) of training injuries during the pre-season and early competition period in the English Premiership (2014-15 to 2018-19 seasons)

Figure 2. Training considerations following return to play after the period of restricted training due to COVID-19. Reintroduction of group training will require progressions and structure of training to be developed with reference to risk of COVID-19 transmission.

Figure 3. Return to play risk stratification for athletes following COVID-19 symptoms.

Figure 4. A summary of ‘at risk’ athletes following modified training due to COVID-19.

Table legends

Table 1. Energy expenditures of professional and elite male rugby players during various stages of the season, measured via doubly labelled water (DLW).

Table 2. Most effective intensity and volume for strength and power in collision sports and the expected percentage change in maximal strength and power per training session conducted (data from McMaster et al., [3]).

Table 3. The impact of training frequency weekly strength and power changes (data from McMaster et al., [3]).

Table 4. Rate of changes in strength and power markers in a tier 1 international rugby union team over 5-weeks (n=26 players).

Table 5. Changes in strength markers in a professional rugby union team over 4-weeks (n=35 players).

Table 6. Challenges and practical recommendations for sports during and following COVID-19.

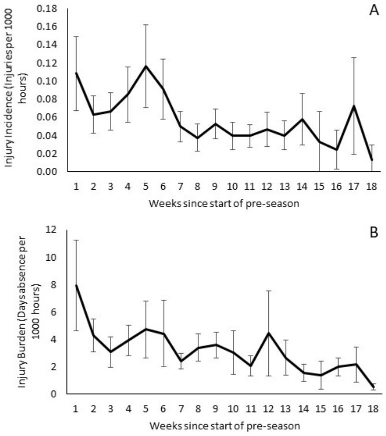

Figure 1. Incidence (A: injuries per 1000 hours) and burden (B: days lost per 1000 hours) of training injuries during the pre-season and early competition period in the English Premiership (2014-15 to 2018-19 seasons)

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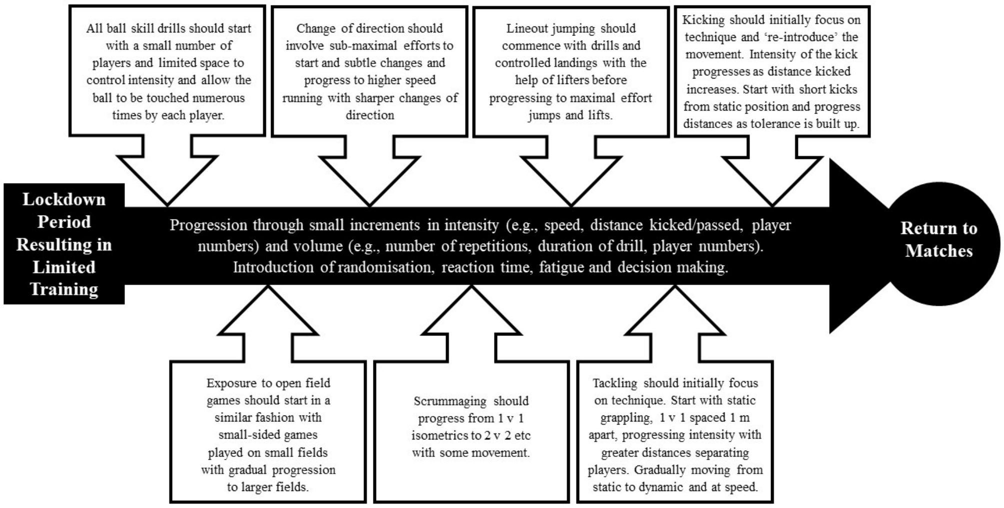

All ball skill drills should start with a small number of players and limited space to control intensity and allow the ball to be touched numerous times by each player.

Change of direction should involve sub-maximal efforts to start and subtle changes and progress to higher speed running with sharper changes of direction

Lineout jumping should commence with drills and controlled landings with the help of lifters before progressing to maximal effort jumps and lifts.

Kicking should initially focus on technique and 're-introduce' the movement. Intensity of the kick progresses as distance kicked increases. Start with short kicks from static position and progress distances as tolerance is built up.

Progression through small increments in intensity (e.g., speed, distance kicked/passed, player numbers) and volume (e.g., number of repetitions, duration of drill, player numbers). Introduction of randomisation, reaction time, fatigue and decision making.

Exposure to open field games should start in a similar fashion with small-sided games played on small fields with gradual progression to larger fields.

Scrummaging should progress from 1 v 1 isometrics to 2 v 2 etc with some movement.

Tackling should initially focus on technique. Start with static grappling, 1 v 1 spaced 1 m apart, progressing intensity with greater distances separating players. Gradually moving from static to dynamic and at speed.

Figure 2. Training considerations following return to play after the period of restricted training due to COVID-19. Reintroduction of group training will require progressions and structure of training to be developed with reference to risk of COVID-19 transmission.

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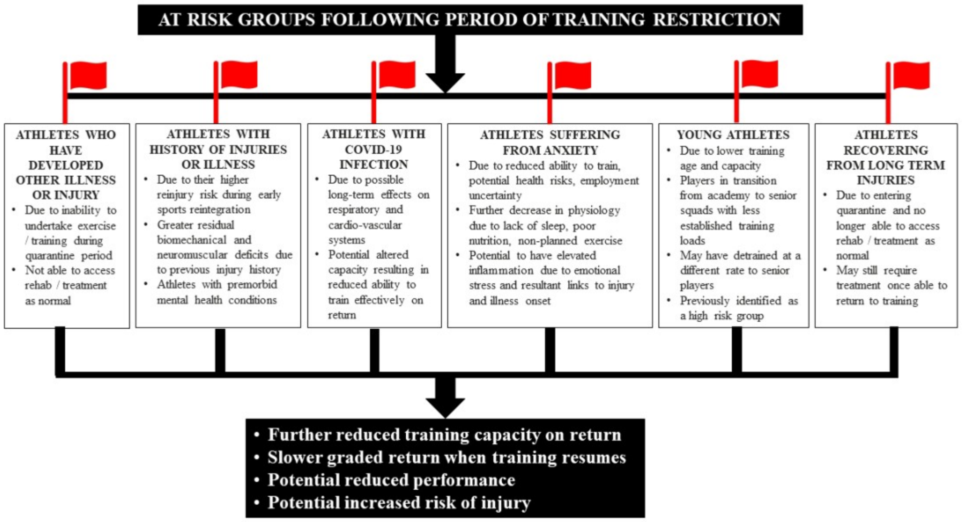

Figure 3. Return to play risk stratification for athletes following COVID-19 symptoms.

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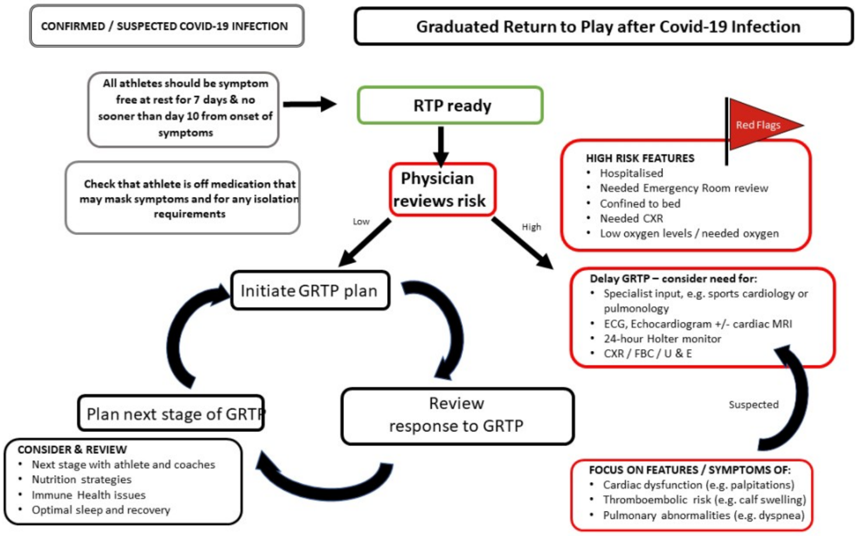

Figure 4. A summary of ‘at risk’ athletes following modified training due to COVID-19.

108x60mm (300 x 300 DPI)

Table 1. Energy expenditures of professional and elite male rugby players during various stages of the season, measured via doubly labelled water (DLW).

Cohort	**Total Energy Expenditure (MJ·day^{-1})**	**Observational Period**	**Reference**
Senior RL (*n* = 6)	22.5 ± 2.7	In season	Morehen et al., [105]
Senior RL (*n* = 6)	18.7 ± 6.1	In season	Smith et al., [106]
Senior RU (*n* = 6)	21.2 ± 7.3	In season	Smith et al., [106]
U20 RL (*n* = 6)	18.7 ± 3.1	In season	Smith et al., [106]
U20 RU (*n* = 6)	18.2 ± 3.0	In season	Smith et al., [106]
U16 RL (*n* = 6)	17.5 ± 4.0	In season	Smith et al., [106]
U16 RU (*n* = 6)	16.1 ± 2.2	In season	Smith et al., [106]
U18 RL (*n* = 6)	19.0*	Preseason (inc. contact training)	Costello et al., [108]
U18 RL (*n* = 6)	18.1**	Preseason (exc. contact training)	Costello et al., [108]
U18 RL (*n* = 6)	18.4 ± 3.1	Preseason period	Costello et al., [107]

RL = rugby league, RU = rugby union, *calculated from reported 5-day energy expenditure (95.1 ± 16.7 MJ·five-day^{-1}), **calculated from reported 5-day energy expenditure (90.3 ± 17.0 MJ·five-day^{-1}).

Table 2. Most effective intensity and volume for strength and power in collision sports and the expected percentage change in maximal strength and power per training session conducted (data from McMaster et al., [3]).

	Intensity (%RM)	Sets	Repetitions	Δ% per Training Session
Maximal strength	77 ± 7	3.4 ± 1.2	6.5 ± 3.3	0.55%
Power	81 ± 2	4.3 ± 0.3	7.0 ± 0.9	0.20%

RM = repetition maximum, Δ% = percentage change

Table 3. The impact of training frequency weekly strength and power changes (data from McMaster et al., [3]).

	2 x weekly	3 x weekly	4 x weekly
Maximal strength	0.9%	1.8%	1.3%
Power	0.1%	0.3%	0.7%

Table 4. Rate of changes in strength and power markers in a tier 1 international rugby union team over 5-weeks (n=26 players)

	Start	**End**	**Δ%**	**Δ% per Week**
Squat (kg)	165.4 ± 20.0	206.7 ± 22.26	25.6 ± 9.7%	5.1 ± 1.9%
Bench Press (kg)	139.3 ± 12.6	150.3 ± 11.8	8.1 ± 5.6%	2.6 ± 1.1%
Prone Row (kg)	114.0 ± 10.9	129.3 ± 10.3	13.8 ± 7.1%	3.8 ± 1.4%
Countermovement Jump Height (cm)	61.5 ± 7.6	68.9 ± 7.6	12.1 ± 5.3%	2.4 ± 1.1%

Δ = change; Δ% = percentage change

Table 5. Changes in strength markers in a professional rugby union team over 4-weeks (n=35 players)

	Start	End	Δ%	Δ% per Week
Squat (kg)	167.3 ± 26.6	190.4 ± 27.8	14.4 ± 10.6%	3.6 ± 1.9%
Bench Press (kg)	131.7 ± 13.1	137.2 ± 13.1	4.3 ± 3.8%	1.1 ± 1.0%
Prone Row (kg)	112.0 ± 8.9	116.3 ± 8.4	4.0 ± 3.3%	1.0 ± 0.8%

Δ = change; Δ% = percentage change

Table 6. Challenges and practical recommendations for sports during and following COVID-19

Focus Area	Challenges as a Result of Training Restriction (COVID-19)	Practical Recommendations
Physical Qualities	• Variable access to training facilities (equipment and/or space) • Variable ability to train under heavy loads • Strength likely to decrease significantly if restrictions last beyond 12 weeks • Decreased tolerance to specific activities (e.g., high-speed running)	• Continue to undertake periodised and planned training where possible during restriction • Maintain exposure to high-speed running and sprinting during restriction • Training to failure with lower loads may have some benefit for mitigating losses to muscle mass and strength • Performing eccentric muscle actions and plyometric training may help maintain and improve all neuromuscular indices related to an athlete's performance • Identify and correct weaknesses to maximise performance and reduce risk of injury on return to training • When it is safe to do so, athletes should resume formalised resistance training as soon as possible within a gym environment • Focus on building muscle hypertrophy when able to return to training, if significant losses of muscle mass observed • Individualised approach to nutritional needs (see nutrition section below for specific considerations)
Skill Execution/Sports Specific Actions	• Lack of deliberate or individual skill-based practice • Lack of competition is likely to cause a deterioration of performance	• Cognitive-based techniques (mental imagery and video-based observation) to offset deterioration in skill execution and to enhance preparedness for return • Ring-fenced practice time available before re-commencing competition to prioritise fundamental skills, including exposure to contact/collision training • Due to its high risk of injury, re-familiarisation of and technically focussed training on the tackle should be prioritised • To best prepare for the explosive demands of the game, progress all key activities from proactive to reactive drills
Psychological Wellbeing	• Isolation and confinement • Training in 'limbo' scenario • Psychological impact of deconditioning • Chronic stress acting as an immunosuppressor	• Ensure appropriate support networks are available for athletes to access to help manage any potential negative psychological experiences during and after any period of isolation • Seek to maintain/nurture team processes (e.g., teamwork) through designated team task (e.g., opposition analysis) and social activities throughout • Utilise the opportunity for 'reset' of physical and mental health away from the stress of formal training and competition. Build in rest periods within training routines to manage this and engage in other personal and social activities via available technology to enhance psychological wellbeing
Nutrition	☐ Reduced/modified energy expenditure ☐ The necessity for nutrition to support immune function during COVID-19 ☐ Difficult to maintain a sports specific body composition	• Attempt to assess changes in daily energy expenditure and make dietary changes accordingly if required (e.g., tracking body mass change) • Periodise carbohydrates (and thus calories) not only to training but also daily lifestyle • Consume a high protein diet rich in leucine, consuming protein regularly (every 4 hours) throughout the day • Keep protein high aiming at 0.4 g·kg^{-1} per meal regularly throughout the day ☐ Seek sunlight if possible and if not consider supplementing 1000-4000 iU per day vitamin D3 ☐ Consider supplementing with 500-1000 mg vitamin C, as well as probiotics to aid with immune resistance and tolerance

Injury Risk Management	• Reduction in protective strength qualities and fitness capacity during restriction • Reduced intensity and volume of training during restriction • Less opportunity for structured and guided prehabilitation and rehabilitation programmes	• Athletes should focus on the training of known weaknesses (physical and/or technical) where possible during the period of restriction • The use of load monitoring tools (e.g., sRPE during and after restriction will help manage the transition period from restriction to training) • An individualised approach should be taken to an athlete's return to sport and return to play strength and conditioning programming. The use of physical and psychological screening tools may help provide information to support appropriate planning and programming. This is especially important for at risk groups (see section below). • Maintain regular exposure to high speed running during restriction and afterwards where possible • Training loads should be increased gradually and spikes in load avoided • A 6-week training block is likely sufficient for professional rugby players to regain previous physiological adaptations, if significant detraining has occurred
Suspected Case Management	• High risk of person to person transmission • Lack of available scientific evidence and understanding of novel virus • Myocardial irritation and frank myocarditis may be both prevalent and an important manifestation of COVID-19	• Employ a risk stratification approach to the management of players and return to play. Undertake an individualised graded return to activity • Aim to assess and monitor where possible physiological markers including resting, exercising and recovery heart rates, beat to beat variability, RPE and other indicators of reduced cardiopulmonary function • All athletes with either confirmed or suspected COVID-19 infection should be symptom free for 7 days and RTP no sooner than day 10 of the infection • Medical practitioners should consider a cardiology assessment for previously symptomatic players with confirmed or suspected COVID-19 prior to returning to training • Additional data collection of COVID-19 specific illness fields into sports injury surveillance systems to aid best practice management and our understanding of the risk of this novel virus