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**Upper-body resistance training following soccer match play: Compatible, complementary, or contraindicated?**

# Upper body resistance training following soccer match play: compatible, complementary, or contraindicated?

Running head: Upper body resistance training in soccer

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Submission type: invited review
Word counts: 5410
References: 100
Table: 1
Figures: 4

# Abstract

***Purpose.*** During heavily congested schedules, professional soccer players can experience exacerbated fatigue responses which are thought to contribute to an increased risk of injury. Given match-induced residual fatigue can last up to 72 hours, many coaches naturally prioritise recovery in the days immediately following match-day. While it is intuitive for coaches and training staff to decrease the amount of auxiliary training practices to focus on recovery, prescribing upper body (UB) resistance training (RT) on the day after match-play (MD+1) has recently emerged as a specific training modality in this context. Whilst these sessions may be implemented to increase training stimulus, there is limited data available regarding the efficacy of such a practice to improve recovery kinetics.

***Methods.*** In this narrative review we look at the theoretical implications of performing UB RT on MD+1 on the status of various physiological and psychological systems including neuromuscular, metabolic, hormonal, perceptual, and immunological recovery.

***Results.*** The available evidence suggests that in most cases this practice, as currently implemented (i.e. low volume, low intensity), is unlikely complementary (i.e.does not accelerate recovery) but potentially compatible (i.e. does not impair recovery).

***Conclusion.*** Overall, since the perception of such sessions may be player-dependent, their programming requires an individualised approach and should take into account match dynamics (e.g. fixture scheduling, playing time, travel).


Key words: strength training; core training; soccer; team sports

# Introduction

During the regular European soccer season, professional soccer players can play in excess of 60 competitive matches over a 45-week season.[1] Many players represent their respective national teams in addition to their clubs both during and after the regular season, which may further exacerbate fatigue. Heavily congested periods have been reported to exacerbate fatigue,[2] which may in turn increase injury occurrence,[3] although there is a relative lack of data to confirm the latter. The term fatigue has long been understood as a disabling symptom in which physical and cognitive function is limited by performance fatigability and perceived fatigability.[4] The psycho-biological factors contributing to fatigue following a soccer match have been extensively investigated and include exercise-induced glycogen depletion, (central and peripheral) neuromuscular, and mental fatigue,[5] amongst others. Match-induced acute fatigue also has residual impacts on various indices for 24-72h, such as impaired physical- and skill-related performance, muscle damage, and ensuing immune and endocrine responses.[6,7] Consequently, coaches and training staff may decrease the amount of auxiliary training practices, such as resistance training, during heavily congested schedules, to focus on recovery.[8]

Practitioners tend to implement various recovery strategies in the 24h following match-play, with the most popular being nutrition, hydrotherapy, massage, foam rolling and various forms of active recovery.[8,9] Active recovery is in fact one of the commonly-employed recovery practices [8,9] and involves sequencing low-to-moderate intensity exercise, often of an aerobic nature, the day following match-play.[10] Although popular, mixed results have been reported with regard to the efficacy of active recovery for improving the temporal recovery of neuromuscular performance, markers of muscle damage, and inflammation.[11] While the activities performed as active recovery vary between practitioners, sports and context, it is common practice to try to limit any additional loading that could interfere with the recovery process. This includes the avoidance of any (training) load in general and more specifically, any type of work heavily involving the lower limbs (minimizing ground impact and neuromuscular/musculoskeletal work); for this reason, cycling, or sometimes swimming, is often preferred to running. Following this reasoning, upper body (UB) exercises may also be a suitable alternative (or at least be an addition to cycling), since they may be considered to trigger recovery mechanisms (e.g., increased blood flow, hormonal adjustments) without directly involving the muscle groups that need to recover.[12] UB sessions generally include arms and back exercises, and to a lesser extent core training and exercises aimed at improving pelvic control/stability (Table 1). Whilst a growing trend in elite soccer, using UB exercise as an active recovery strategy or as a means to increase training load during congested schedules remains essentially anecdotal in the field of soccer, and the mechanisms through which this practice may benefit post-match recovery and/or physical adaptations warrant examination.[13]

{Table 1}

Another challenge faced by practitioners with congested fixture schedules is the maintenance of physical qualities during the in-season, as auxiliary training practices are sacrificed to facilitate recovery.[8] In soccer, strength and conditioning practitioners typically prescribe less than two resistance-training (RT) sessions per week.[8] Recent studies have shown that as little as two RT sessions consisting of 3 sets of 10 repetitions at 70% 1-rep max (RM) per muscle group may be sufficient to develop strength and maintain power in the upper and lower body.[14] Therefore, it is unsurprising that the majority of physical conditioning practitioners in soccer report being dissatisfied with the current amount of RT being scheduled during the in-season micro-cycle.[8] Accordingly, it is important to explore scheduling practices that increase RT volume within the congested in-season micro-cycle, without compromising recovery kinetics.

The notion of scheduling UB RT within 24-hours post-match to enhance recovery kinetics was recently examined. A study by Abaidia and colleagues showed that performing 3 sets of 5 large compound UB exercises (70% 1RM to exhaustion) within 24-hours of lower body eccentric fatiguing exercises, accelerated the recovery of slow concentric hamstring force. Furthermore, the additional UB resistance training did not exacerbate plasma creatine kinase (an indirect measure of muscle damage).[13] Despite these particularly interesting findings, evidence remains limited to this single study, which had limited ecological validity in the context of soccer. Given the paucity of data, it is unknown whether UB RT on the day after match-play (MD+1) is compatible, complementary or contraindicated for temporal recovery kinetics in elite soccer players. Consequently, the aim of this review is to evaluate the current evidence and factors, including neuromuscular, metabolic, hormonal, perceptual, and immunological components, which may contribute to the suitability of scheduling UB RT on MD+1, with a view to providing preliminary recommendations (e.g., compatible, complementary, or contraindicated) for practice considering the current dearth of empirical evidence.

## Part one: Typical UB sessions performed on MD+1 in soccer

The physical determinants of soccer have been widely reviewed and include essentially locomotor-related capacities such a speed, agility, and intermittent endurance.[15] For this reason, both the need to develop UB strength and the ‘culture’ of UB work are often not prioritised. Over time, this has led to the development of specific types of sessions (Table 1), which clearly differ from those performed in other team sports such as Rugby or Handball for example, where players tend to lift heavy and place a large emphasis on UB strength and power development.[16] For the purpose of the present review, a few typical MD+1 UB sessions performed in elite soccer are presented in Table 1. When analysed in relation to the typical type of RT sessions targeting either muscle growth, maximal strength or power (Figure 1),[17] it appears that the soccer sessions tend to fall outside optimal zones. This is related to the notion that the loads are either unlikely heavy enough in relation to the number of repetitions programmed, or vice-versa. While this practice may not elicit neuromuscular adaptations (i.e. "time filler sessions"), its utility may lie within the possible acceleration of post-match recovery. The underpinning theoretical frameworks and 'real-life' feasibility of using UB RT as a 'recovery' modality at MD+1 are discussed in parts 2 and 3 of this review, respectively.

{Table 1}

{Figure 1}

## Part two: Recovery kinetics following match-play and insights for the programming of UB RT sessions.

## Neuromuscular Recovery

Neuromuscular fatigue is commonly defined as a reduction in muscle force generating capacity.[18] The magnitude of force declines and the time-course to return to pre-match values largely depends on the movement task and the muscle groups examined, but full recovery to pre-match values occur between 24–96 hours following match-play.[6,19] Neuromuscular fatigue maybe classified according to two key components; peripheral and central fatigue.[18] Determining the origin of neuromuscular fatigue requires laboratory techniques infeasible for applied practice, but insights from research may inform our understanding of recovery kinetics, modalities and subsequent training prescription.

*Central response*

The central nervous system achieves force production through the activation of motor units via descending drive from the motor cortex.[18] During fatiguing exercise, motor unit firing rates decrease due to various factors; including decreases in the excitability of excitatory synaptic inputs and lower excitatory drive originating upstream of the motoneurons, resulting in various pertubations including lower discharge rates of motor units.[20] Competitive match-play has been shown to impair muscle and central nervous system function, requiring 24-48 hours to resolve, depending on the lower-limb muscle group examined.[21-23] Some researchers have proposed that match-induced impairments to the central nervous system play an integral role in the recovery kinetics of neuromuscular function following match-play.[24] Conversely, while there is evidence to suggest that central processes significantly contribute to match-induced neuromuscular fatigue, recovery is typically complete within 24–48 hours,[21-23] and resolution of peripheral fatigue is considered primarily accountable for the restoration of muscular function after match-play.[25]

*Peripheral response*

Peripheral fatigue occurs as a result of changes at or distal to the neuromuscular junction, which results in impaired transmission of muscle action potentials and decreased contractile capability of the muscle fibres.[18] Peripherally mediated reduction in muscle force production may be caused by a range (and complicated interplay) of factors such as skeletal muscle damage, inflammation, altered Ca++ or Na+-K+ pump function, and the accumulation of metabolic by-products.[18] Peripheral impairments in neuromuscular function have been demonstrated in the quadriceps and plantar flexors following competitive match-play, but return to baseline by 48 hours.[21-23] Interestingly, the complete time-course recovery of performance outcomes such as CMJ and 20m sprint occur despite residual muscle damage and inflammation.[6]

The eccentric nature of critical explosive movements in soccer match-play, such as accelerating, decelerating, collisions, and directional changes inflict mechanical muscle fibre disruptions.[26] The structural fibre damage permits myocellular protein (myoglobin) and enzyme (creatine kinase) efflux into serum and may reflect the degree of muscle damage post-match. Although circulating myoglobin returns to baseline within 24 hours post-match, creatine kinase (CK) often requires ≥72 hours.[6,19] The ensuing inflammatory response (measured via C-reactive protein and IL-6) also typically requires 72-hours for restoration.

A recent systematic review reported that active recovery techniques characterised by low-intensity concentric activities (upper and lower aquatic ergometry exercises) may further increase CK levels.[11] Additionally, an eccentric based lower-limb injury prevention program administered on MD+1 was shown to inhibit CK decay at 48 hours.[27] Consequently, and in the absence of available post-match data, it could be assumed that performing UB RT on MD+1 may exacerbate and/or prolong the CK response; however, considering the low load and intensity of UB RT prescription shown in Table 1 and Figure 1, any increase is likely to be small and transient.[13] Moreover, CK reflects a consequence rather than a cause, and the origin of skeletal muscle damage is unknown from serum-derived measurements.[28] Accordingly, an exacerbated CK response from UB RT may not hinder lower-limb muscle performance, since force generating capacity often returns to baseline before circulating CK.[27]

*Neuromuscular fatigue and active recovery modalities*

Despite typical active recovery protocols (low intensity, concentric based activity) being common practice amongst many physical conditioning practitioners,[8] the efficacy of these practices for accelerating neuromuscular recovery kinetics remains controversial as the limited available evidence has reported mixed results.[10,29] Furthermore, the potential mechanisms by which these active recovery practices may improve central and peripheral fatigue remain unknown. Despite this, it has been hypothesised that the clearance of exercise-induced intramuscular metabolic by-products limits the action of the afferent inhibitory feedback system on the neural drive, thereby improving recovery of CNS structures.[29] Steady-state sub-maximal active recovery protocols reportedly accelerate the removal of exercise-induced metabolic waste products, which may improve peripheral microcirculation and decrease the duration and/or severity of skeletal muscle damage and soreness.[30] Irrespective of the weak evidence base available regarding the efficacy of typical active recovery protocols to accelerate neuromuscular recovery kinetics, their purported underpinning theoretical mechanisms do not translate to UB RT, since it’s unlikely to enhance lower-limb muscle perfusion.

Following high load whole body,[31,32] or lower body RT,[33] the force generating capabilities of major muscle groups become temporarily impaired. The time-course for restoration is largely dependent upon the RT typology (strength/power/hypertrophy, Table 1 and Figure 1), intensity, volume and structure of the load (failure/non-failure). Although some studies have documented suppressed muscle function 24-hours post RT, they were characterised by high volume and/or repetitions to failure.[33] RT sessions designed for strength or power development often see performance recovery within 24-hours,[32] mediated by restoration of both central and peripheral neuromuscular function.[31,32] Considering the available RT research, and that central and peripheral factors of fatigue develop in an intensity-dependent manner,[17] it maybe considered unlikely that the UB RT prescription employed in Table 1 (examples for Club A and B) would impede the recovery kinetics of central and peripheral neuromuscular fatigue, given its moderate-intensity nature, low-volume prescribed, and the muscle groups targeted.[13] Equally, the current theoretical frameworks, in the absence of available empirical data, do not support a notion that scheduling UB RT on MD+1 accelerates neuromuscular recovery.

*Considerations: Potentialy compatible*

Soccer-related fatigue affects both, central and peripheral nervous system function, and requires up to 48-hours to resolve. The current available evidence suggests that typical aerobic-based active recovery protocols may not elicit meaningful improvements in neuromuscular recovery. Despite this, scheduling UB RT may help contribute RT volume/stimulus to the microcycle with a view to preserving UB strength (as RT is typically neglected during congested schedules). In this regard, the load of UB RT sessions may need to be increased to lead to substantial UB adaptations (Figure 1). In order to prevent further neuromuscular fatigue, coaches should carefully consider the goals of the athlete and the volume of work undertaken during match play, and other variables such as the time between match play when scheduling UB RT. Importantly, further research may be warranted to help establish a minimally effective UB RT dose (micro-dosing) for professional soccer players performing routinely within congested fixture schedules.

{Figure 2}

## Metabolic recovery

*Glycogen*

High-intensity intermittent exercise such as soccer relies heavily on glycogenolysis, with glycogen availability essential for ATP resynthesis.  In soccer, carbohydrates used to fuel muscles are primarily derived endogenously via glycogenolysis within the exercising muscles, with a subsidiary amount arising from the liver.[34] It is estimated, that between 40–90% of the exercising muscles glycogen stores are expended during a soccer match.[35] Match-induced fatigue is somewhat associated with lowered or full depletion of glycogen in some muscle fibres,[36] and physical performance can be enhanced with higher baseline muscle glycogen.[37] The time-course of muscle glycogen restoration post-match is dependent upon a myriad of factors such as the energy intake, carbohydrate replenishment strategy, active recovery, muscle fibre type etc.[38] Although one study showed a -27% change in baseline muscle glycogen content at 24-hours post-match,[39] another showed a return to baseline was possible at 24-h.[40] These discrepancies may be attributed to carbohydrate replenishment strategy and morphological differences between muscle fibres. For example, glycogen resynthesis has been observed to be incomplete in type II fibres at 48-hours post-match, despite ingestion of a high-carbohydrate and whey-protein diet.[40] This finding supports the notion that eccentric activities in soccer may inhibit muscle glycogen resynthesis in type II fibres,[41] which may have implications for MD+1 scheduling conditioning of players whose team roles or physical phenotypes are characterised by explosive actions.  Indeed, data from a recent case study suggested that elite players under-consume carbohydrate both immediately post-match, and on the subsequent day, particularly following an evening kick-off.[42]

While recent evidence has suggested that enhanced skeletal muscle adaptations (i.e. oxidative capacity) may occur when training with reduced muscle glycogen availability,[43] the type of work being performed during RT [44] and subsequent anabolic signalling responses [45] remain difficult to predict during this state. Therefore, it is currently unclear whether scheduling RT in a potentially low-glycogen state on MD+1 would be ergogenic, ergolytic, or would have no meaningful impact on session quality and resulting adaptations. Notwithstanding, muscle glycogen is an important substrate for resistance training,[46] resynthesising the phosphate pool during high-intensity contractions. High-volume moderate- to high-intensity RT to failure has been shown to reduce glycogen stores by 25-40% in an intensity-dependent manner, requiring up to 6 hours to replenish.[47] Glycogen utilisation is greatest in type II fibres during RT characterised by high repetitions of a moderate load.[47] In contrast, traditional low-intensity continuous active recovery modalities also delay glycogen resynthesis, but likely in type I as opposed to type II fibres.[48] Accordingly, scheduling RT on MD+1 may delay glycogen replenishment, particularly in type II fibres. However, as glycogen depletion is site-specific, whether UB RT (as outlined in table and figure 1) would impact replenishment of match-depleted lower-limb fibres is currently unknown, but somewhat questionable. Furthermore, appropriate nutritional strategies might be expected to restore glycogen stores so that subsequent match performance is not impaired during congested fixture schedules.

*Considerations: Potentialy compatible*

The rate of muscle and liver glycogen depletion occurs in a site- and load-dependent manner. Following adequate carbohydrate ingestion, glycogen is replenished in the muscle within ~48 hours and much quicker in the liver, however type II fibres may have delayed re-uptake. Coaches should consider the magnitude of explosive actions performed by the player (perhaps dependent upon positional role or the match minutes played), and the time between the end of the match and the scheduled UB RT, as it is likely that type II fibre glycogen replenishment in lower-body muscles remains incomplete on MD+1. As glycogen utilisation during RT is greatest in type II fibres the UB RT sessions should involve low-volume and low to moderate intensity resistance exercise as to not further delay muscle glycogen replenishment.

## Hormonal recovery

*Testosterone*

Testosterone is a key anabolic hormone, which promotes protein synthesis, ameliorates protein degradation, and improves the capacity of skeletal muscle to generate power.[49] It is well accepted that high-intensity and/or high-volume resistance training increases circulating testosterone in a load–dependent manner.[50] Conversely, there are mixed reports regarding the effects of competitive sport on anabolic hormones, in which testosterone has been shown to both increase [6] and decrease [51] after match-play. Additionally, a separate study involving 7 professional soccer players showed that testosterone levels remained unchanged following match-play and continued steady for the total 72-hour monitoring period of the study.[7] A recent meta-analysis which pooled the results of 50 soccer players showed that on average, testosterone levels remained elevated up to and including 48-hours post-match.[6] While match-related changes in anabolic hormones, such as testosterone, remain a topic of great interest, the endocrine response is highly variable and appears to be mediated by psychophysiological factors such as match outcome and player experience.[52] For example, testosterone typically decreases following a loss but increases following victory.[53] The current available evidence suggests that testosterone levels remain largely unaltered during the recovery period following match play and therefore, the use of testosterone as a biomarker of recovery remains equivocal.[52]

*Cortisol*

Cortisol is a catabolic hormone that works antagonistically to testosterone by inhibiting the binding of testosterone to its androgen receptor and blocking anabolic pathways.[54] Cortisol increases in response to training load,[55] match-play, and psychological stress.[56] Soccer match-play has been shown to significantly increase cortisol levels requiring up to 72-hours to normalise.[7,52] Although the magnitude and/or duration of the cortisol response to soccer match-play varies between studies, the response is more consistent than that of testosterone. A recent systematic review assessing the hormonal response immediately following soccer match-play found that all available studies reported increases in cortisol levels, with an average increase of 32% in male soccer players, whilst testosterone was increased in two of three studies and by a much smaller magnitude (6% increase in males).[52] Together, these data suggest that cortisol response is more predictable than testosterone but there is a lack of high-quality data linking cortisol levels to decreased performance. This may be because variances in hormonal responses to exercise are indicative of physiological strain rather than maladaptation on the part of the athlete.[57]

The testosterone to cortisol (T:C) ratio is considered a more sensitive measure of endocrine status and recovery as it reportedly demonstrates the anabolic-catabolic balance of the athlete.[58] While a 30% decrease in T:C ratio has been proposed as an indicator of insufficient recovery,[59] there is conflicting evidence regarding the validity of T:C ratio in predicting overtraining,[58] or performance.[60] This may be because T:C varies throughout the season and is influenced by many psychophysiological factors such as the player's playing position,[61] match importance and outcome.[52] Consequently, designing evidence-based training regimens, or recovery programs informed by T:C is currently premature given the lack of available evidence.

In the event a soccer match does elicit sufficient anabolic stimulus, it is unclear whether sequencing RT on MD+1 would further increase testosterone levels and thereby improve recovery kinetics. As shown by Kraemer and colleagues, resistance training interventions resembling traditional body builder programs (e.g. moderate-load, high-volume protocols with short rest periods) often result in the greatest acute response in circulating testosterone and other anabolic hormones such as human growth hormone.[62] Consequently, a scenario of competing interests may arise when attempting to elicit an RT-induced hormonal response — as the intensity and/or volume required may further exacerbate the neuromuscular fatigue and already elevated cortisol levels incurred by match-play.[7] Finally, the evidence for muscle growth and strength increases being independently linked to acute exercise-induced increases in endogenous anabolic hormones is equivocal,[63] and as such, the acute hormonal responses of the proposed training practice (Table 1), if any, may not directly improve skeletal muscle strength nor muscle growth (and by extension, recovery).

*Considerations: Compatible if well programmed*

Coaches should employ caution when scheduling UB RT close to match play as cortisol levels, which are elevated following match play, are likely to be further increased following RT without clear evidence of the practice leading to elevations in testosterone or favourable testosterone:cortisol ratio. Furthermore, RT loads shown to elicit an anabolic response may exacerbate match-induced neuromuscular fatigue. Therefore, coaches should consider variables such as match location and minutes played as well as avoid high-intensity RT on MD+1 as to minimise the risk of inadequate recovery.

{Figure 3}

## Mental / Perceptual Recovery

Mental fatigue in soccer is characterised by subjective perceptions of impaired focus (concentration), motivation, and challenges responding to errors.[5] Competitive match-play may require prolonged cognitive focus in decision making and vigilance, supported by substantial ratings of mental fatigue [5] and technical/cognitive exertion immediately post-match.[64] Whilst limited data is available using elite-level players and ecologically valid experimental designs, controlled laboratory studies have shown acute negative effects of *a priori* mental fatigue upon soccer-related physical and technical performances.[65,66] However, the time-course of mental fatigue is not well understood, with just one recall-survey suggesting players are not recovered 24 hours post-match,[5] and the impacts of travel and sleep disturbances remain unknown.[19]

Given the current lack of empirical data regarding mental fatigue, insights regarding a player's perceptual readiness (freshness) to train on MD+1 may be informed from self-report measures of wellness (e.g., fatigue, soreness). Ratings of fatigue and soreness in elite players reduce by ~40% on MD+1, and are not recovered by MD+2,[67,68] although these responses may be more heavily influenced by the match-outcome, rather than its physical exertions.[67] Reduced player wellness before field-training has been shown to have subtle detriments on training load measures in various football codes,[67,69] but the effect magnitudes were generally deemed trivial.

With respect to the scheduling of UB RT on MD+1, to our knowledge there is no data available that suggests that residual mental fatigue or perceptual readiness impacts the work done or subsequent training adaptations. Following whole-body RT in trained individuals, self-reported fatigue and soreness ratings were restored to baseline by 48 hours.[31,32] Alternatively, traditional active recovery modalities (steady-state, low-intensity) have a large effect on reducing self-reported muscle soreness, but do not reduce perceived fatigue.[11] Collectively, these findings may suggest that RT delivered on MD+1 may delay recovery from mental fatigue or wellness. However, when eccentric-based lower-limb strengthening exercises were administered on MD+1, neither the magnitude nor the time-course of hamstring or quadriceps soreness recovery were impacted in comparison to a control (no training) condition.[27] This may suggest that any negative mental or wellness responses to MD+1 RT may be masked by the greater burden incurred from competitive matches. Moreover, there is evidence suggesting that a low training volume at a low to moderate intensity (40-50% 1 repetition maximum) can improve mood and affect,[70,71] and that UB RT may have a more positive affective response.[72]

*Considerations: Compatible at the individual level*

There are very limited data available pertaining to the time-course of mental fatigue and perceptual recovery in real-world elite soccer environments. In addition, the added complexity of fixture congestion, travel and its associated impacts upon sleep generates further challenges in translating research into applied practice, and are beyond the scope of the current review. Given the potential impact of residual mental fatigue upon physical and technical performances, the scheduling of UB RT on MD+1 may depend on a number of aforementioned circumstances. Indeed, the psychological responses to UB RT may be very individual, as they may/may not serve to boost the mood of players on MD+1; whether they may be deemed compatible for current practice has therefore to be examined at the individual level.

## Immunological recovery

Infections of the respiratory or gastrointestinal tract are widely considered to decrease training availability and performance in Olympic athletes, particularly endurance athletes.[73,74] Whether professional soccer players experience more frequent, and/or more severe, infections than non-players remains a matter of contention: limited empirical evidence indicates a relatively low illness burden in professional soccer players.[55,75,76] For example, a study from the 2010 FIFA World Cup reported that 12% of all players experienced an illness, with the most frequent diagnoses being upper respiratory tract infection (31.3%) and gastroenteritis (21.2%). [77] Importantly, most of the illnesses did not result in absence from training or match. Shortcomings of studies include a lack of experimental control and unstandardised methods for reporting infection symptoms; for example, studies have relied on players presenting to the team medical practitioner with infection symptoms, likely underrepresenting the true burden of illness symptoms in professional soccer.[78]

Infection risk in professional soccer players is likely increased, by a multitude of risk factors, just like in the wider population, including wintertime (common cold and influenza season);[79] high levels of psychological stress, anxiety or depression;[79] poor sleep and long-haul travel;[79,80] in addition, increases in training stress might also raise infection risk.[81] Psychological stress, sleep disturbances and physical exertion all influence immunity via activation of the hypothalamic–pituitary–adrenal axis and the sympathetic nervous-system; giving rise to increases in circulating catecholamines and glucocorticoid hormones (e.g., cortisol) widely acknowledged to modulate immune function.[79]

Over a period spanning almost 40 years, exercise immunologists have focused their research endeavours to better understanding whether heavy exercise temporarily decreases immunity, providing an 'open window' for respiratory infections.[82,83] Readers are directed elsewhere for an overview of the immune system,[84] and a recent debate about whether heavy exercise can raise the risk of infections, in line with the 'open window' theory.[85] Empirical evidence indicates that innate and acquired immunity decrease transiently during the recovery period after prolonged heavy exertion (such as following a soccer match); typically of the order 15–70%.[79,86] Whether these transient changes in immunity with acute heavy exercise and intensified training performed on the following days (i.e., MD+1) are sufficient to increase infection susceptibility, in accordance with the 'open window' theory, has been disputed for some time.[87]

Studies involving 90–120 minutes of intermittent exercise, including soccer-specific shuttle run tests, have shown rather subtle and short-lived effects on immunoendocrine outcome measures (lasting only a matter of hours) e.g., circulating cortisol, leukocyte counts and subsets, phagocytic function, lymphocyte proliferation, natural killer cell activity, mucosal immunity (e.g., saliva immunoglobulin-A) and inflammatory cytokine responses.[88,89] Immune health appears to be well maintained in elite soccer players across a competitive season;[55,90] however, times of high overall stress and limited recovery, e.g., intensive training camps and congested fixture schedules, have been shown to influence immunity. For example, a 5-day intensive training camp reduced circulating T-helper lymphocytes, T-cytotoxic lymphocytes and B-lymphocytes in elite soccer players, potentially weakening infection resistance.[91] Congested fixture schedules (e.g., 3-game week) exacerbated the circulating cortisol response post-match,[92] and reduced circulating natural killer cell and monocyte numbers [93] and saliva immunoglobulin-A levels in professional soccer players.[94]

On the one hand, these 'real-world' studies of immunity in elite soccer players are important because they include the full spectrum of lifestyle stressors, beyond the effects of physical training stress: psychological stress and anxiety influence the immune response to exercise and susceptibility to infection.[95,96] On the other hand, these studies did not account for an influence of lifestyle factors on immunity (e.g., travel, sleep disruption, psychological stress), and whether the observed changes in immunity translate to increased susceptibility to infection. Recent work points to a more prominent role for lifestyle factors (e.g. stress and anxiety, long-haul travel) than training-related factors (e.g. training load) in raising infection risk in athletes,[79,97] however, further studies are required to elucidate the relative importance of load and lifestyle factors on immune function during congested fixture schedules.

*Recommendation: Compatible*

Incorporating low-to-moderate intensity and volume UB RT on MD+1 is unlikely to directly benefit or negatively impact immune health in soccer players. Cellular immune responses and inflammation tend to be more subtle after RT compared with endurance exercise;[98] and whether the immune alterations with heavy, prolonged endurance exercise translate to altered infection risk remains a moot point.[85,99] To date, there is only limited empirical evidence to support the myriad of purported post-exercise, immune recovery strategies for athletes; including, nutritional interventions, cryotherapy, nonsteroidal anti-inflammatory drugs, compression garments and active recovery interventions.[86,99]

## Part 3: Sequencing a resistance training session on matchday+1 during the weekly macrocycle: insights from real life scenarios.

Based on the literature review and abovementioned considerations, it can be concluded from a theoretical standpoint that typical UB RT sessions, as currently performed in elite soccer (Table 1, examples of clubs A and B and C), are 1) unlikely (in isolation) to substantially improve upper body strength or muscle mass (hypertrophy), 2) unlikely to affect neuromuscular recovery, 3) unlikely to improve or exacerbate metabolic perturbances, 4) unlikely to elicit a favourable hormonal response, 5) unlikely to escalate mental fatigue, 6) unlikely to directly benefit or negatively impact immune health. With variables considered and when employed by experienced coaches, these sequences might therefore be qualified as "unlikely complementary" but "potentialy compatible"; however, they may still be "contraindicated" in some very specific circumstances.

In fact, further than their effect, or lack thereof, on UB strength and the kinetics of biological recovery, RT sessions scheduled on MD+1 (Table 1) may have various impacts on mental health, which shouldn't be overlooked. Preserving and promoting (mental) freshness for the next match should, without a doubt, be one of the key objectives during the post-recovery process (as discussed above). While this type of recovery may be more difficult to monitor with objective data (i.e., limited to questionnaires), the psychological aspect of such UB RT sessions is likely highly player-dependent. For some players, UB sessions may be an additional training constraint that adds to the already high mental load of congested fixtures. In this context, match minutes, match location (home vs away) and the timing of the next match (i.e., microcyle lengths, days between matches) may be used as objective indicators to help practitioners decide whether to schedule an UB session for those more 'reluctant' players. In Figure 4, we offer a simple decision tree based upon the theoretical frameworks outlined in Part B to help practitioners decide on the scheduling of such sessions based on those variables (at the team level at least, and in the absence of available evidence). For other types of players, such 'cosmetic sessions' (given the low load and their objectives) may rather be an integral part of their overall wellness (e.g., feeling- and looking-good, readiness to compete etc.), who may get a rather beneficial and greater mental than physiological benefit from them. This suggests that players physical profile, origins, habits, previous experience should in fact be considered as important factors as those described in Figure 2 when it comes to programming these UB sessions. Practitioners are therefore left with the decision about what and when to offer RT to individual players, which often requires a holistic understanding of players needs that goes beyond the theoretical concepts discussed in this paper.

{Figure 4}

## Practical applications

In this review we looked at the theoretical implications of performing UB RT on MD+1 on the status of various psycho-biological systems including neuromuscular, metabolic, hormonal, perceptual, and immunological recovery. The available information suggests that in most cases these sessions, as currently implemented (i.e., low volume, low intensity), are 1) unlikely to substantially improve upper body strength or muscle mass (at least in isolation), 2) unlikely to affect neuromuscular recovery, 3) unlikely to improve or exacerbate metabolic perturbances, 4) unlikely to elicit a favourable hormonal response, 5) unlikely to exacerbate mental fatigue, 6) unlikely to directly benefit or negatively impact immune health. Therefore, based on the appraisal of available literature, these sequences can therefore be qualified as unlikely complementary (i.e. not accelerating recovery) but perhaps potentialy compatible (i.e. not impairing recovery). In certain circumstances, such as players' perceived readiness which limit adherence, these practices may still be "contraindicated".

It is worth noting however that the above-mentionned recommendations are specific to typical low-volume and low-intensity UB RT sessions (Table 1); in the few cases where UB RT sessions would be of higher volume and/or higher intensity, there practices may be systematically "contraindicated", especially when matches are only separated by a few days (Figure 4).

## Conclusions

Overall, since the beneficial perception of those sessions may be player-dependent, their programming requires an individualised approach and should take into account players' perceptions and match dynamics (e.g. match minutes palyed, number of recovery days between matches, travels).

## Compliance with Ethical Standards

### Funding

No sources of funding were used to assist in the preparation of this article.

### Conflict of interest

Angelo Sabag, Ric Lovell, Neil P. Walsh, Nick Grantham, Mathieu Lacome, and Martin Buchheit declare that they have no conflicts of interest relevant to the content of this review.

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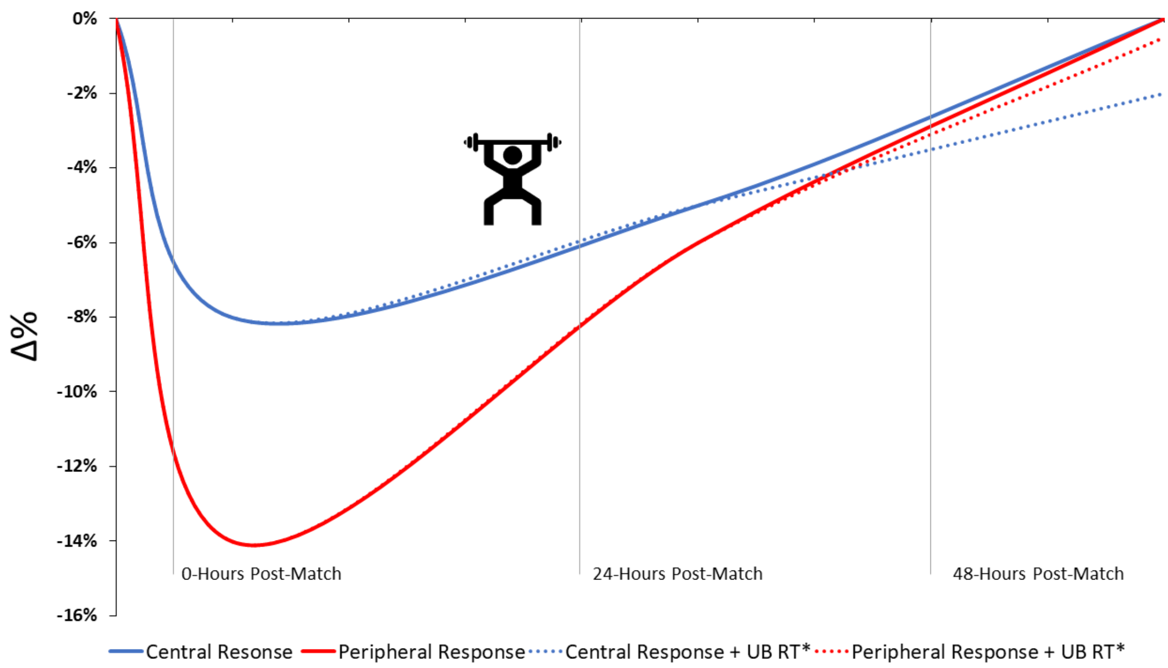
| Club | Physiological objectives | When | Sets | Exercise #1 Reps (Load) | Exercise #2 Reps (Load) | Exercise #3 Reps (Load) | Exercise #4 Reps (Load) | Exercise #5 Reps (Load) | Exercise #6 Reps (Load) |
|---|---|---|---|---|---|---|---|---|---|
| **A** | Unclear | D+3/D-3 | 3-4 | Dumbbell triceps extension 10x (5-10 kg) | Assisted Chin-up with bands 12x | Dead Bug with swiss ball 10x | Supinated triceps pushdown 10x (15kg) | Alternating renegade row 10x (6kg) | Half kneeling cable chop – lateral pull 10x (15 kg) |
| **A** | Unclear | D+1 | 2-3 | Crunches 20x | Inclined Fly 10x (16-20 kg) | Lat pulldown 10x (30 kg) | Push ups on a reversed Bosu 10x | 1-arm inclined press with dumbbell 10x (15 kg each) | Superman on a Swiss ball 8x (5 kg per arm) |
| **B** | Unclear | D+1 | 2-3 | Barbell Bench press 5x (75% 1RM) | Half kneeling cable chop – frontal pull 10x (15 kg) | Dumbbell lateral raise 12x (5kg) | Ab wheel rollout 12x | TRX Push-up 12x | T-bar row 12x (20 kg) |
| **C** | Hypertrophy (Repeated efforts) | Periodized, individual needs | 4-5 | Alternating dumbbell bench Press 8x (20-25 kg each) | Push-up 12x | Dumbbell bent over row 8x (15 kg each) | TRX Row 12x | Standing dumbbell curl to overhead press 8x (15kg each) | Bodyweight Dip 8x |
| **C** | Strength (Repeated efforts) | Periodized, individual needs | 4-5 | Barbell Bench press 5x (85% 1RM) | Plyometric Push-up 12x | Dumbbell bent over row 5x (20 kg each) | Single arm supine row 5x (body weight) | Bodyweight Chin-up 5x | |

**Table 1.** Example of typical upper body resistance training sessions performed in 3 different elite soccer clubs participating in the European Champions league, as provided by their Head of Performance. The coloured ovals refer to the types of sessions objectives shown in figure 1.

# Figure Legends



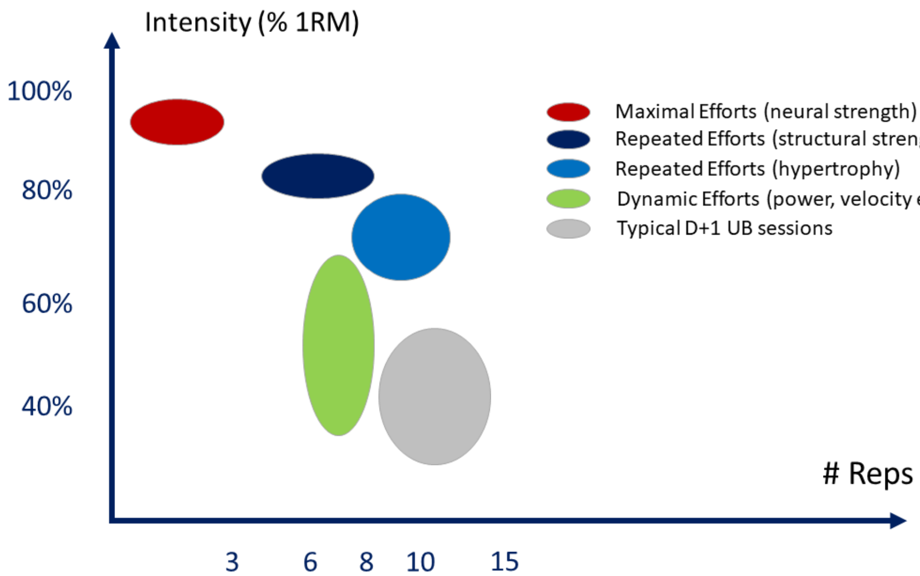




**Fig. 1** Classification of typical resistance training sessions in relation to intensity (% 1RM) and volume (number of repetitions). Adapted from Zatsiorsky and Kraemer. 2006.[17] The typical MD+1 UB sessions performed in soccer (Table 1) fall outside these 'optimal' zones, which question their effectiveness with respect to neuromuscular adaptations. 1RM, one-repetition max. MD+1, day after match-play. UB, upper body.

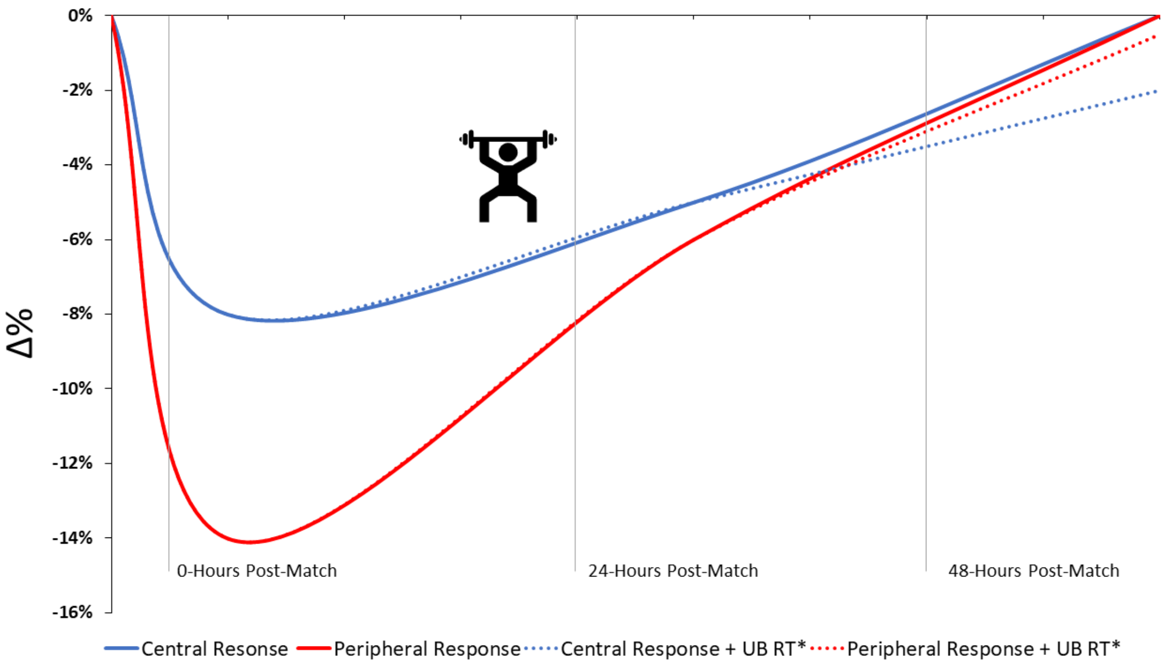



**Fig. 2** Schematic change (%) in central and peripheral performance ± upper body session. Adapted from Brownstein et al. 2017.[21] The addition of UB RT on MD+1 may slightly impair central recovery and, to a lesser degree, peripheral recovery, however these are unlikely to affect performance outcomes. Central response = inferred from voluntary activation data. Peripheral response = inferred from potentiated twitch force data. UB, upper body. RT, resistance training. *Broken lines indicate theoretical projections.

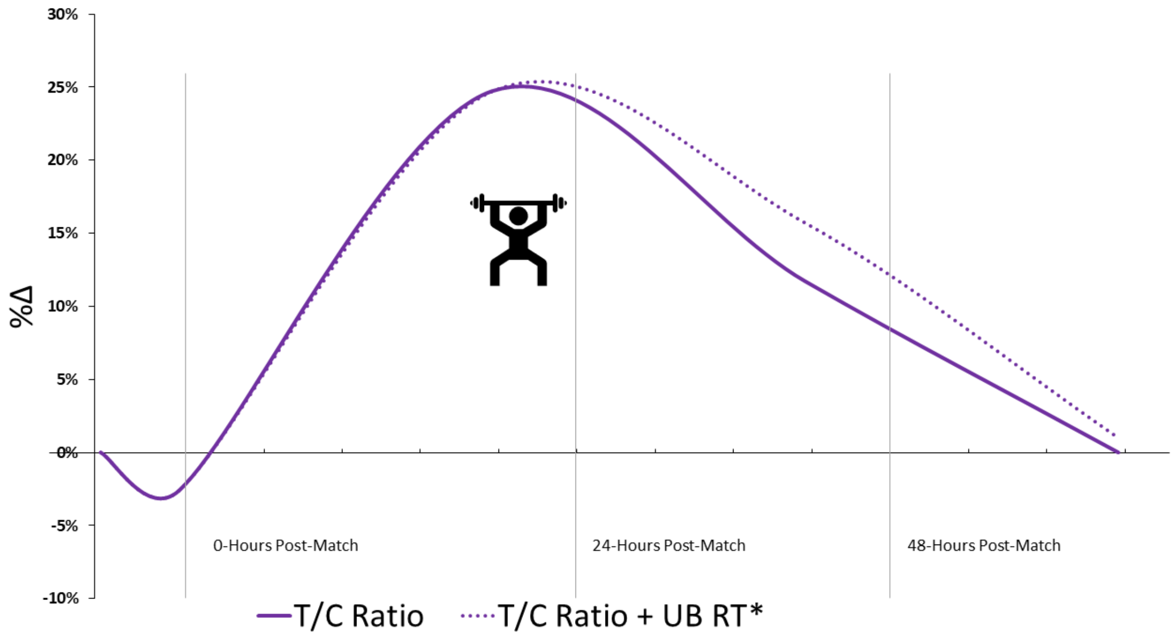



**Fig. 3** Schematic change (%) in transient free testosterone:Cortisol ratio ± upper body session. Adapted from Romagnoli et al. 2016.[100] The addition of UB RT on MD+1 may induce favourable improvements in T:C ratio, however these changes are likely to be minimal due to the nature of the UB sessions. UB, upper body. RT, resistance training. *Broken lines indicate theoretical projections.

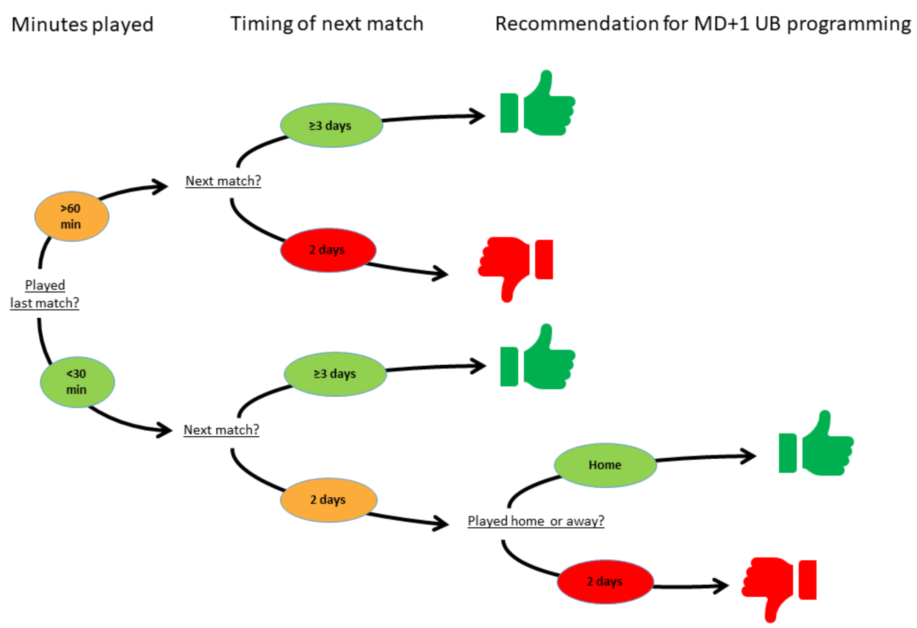



**Fig. 4** Proposed decision tree to help practitioners decide on the scheduling of such sessions based on match minutes, match location (home vs away) and the timing of the next match (i.e., microcyle lengths, days between matches).