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Sabag, A, Lovell, R, Walsh, NP, Grantham, N, Lacombe, M and Buchheit, M (2021) Upper-body resistance training following soccer match play: Compatible, complementary, or contraindicated? International Journal of Sports Physiology and Performance. 16 (2). pp. 165-175. ISSN 1555-0273

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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

31 **Abstract**

32

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

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

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

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

51

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

53

54 **Introduction**

55

56 During the regular European soccer season, professional soccer players can play in excess of
57 60 competitive matches over a 45-week season.¹ Many players represent their respective
58 national teams in addition to their clubs both during and after the regular season, which may
59 further exacerbate fatigue. Heavily congested periods have been reported to exacerbate
60 fatigue,² which may in turn increase injury occurrence,³ although there is a relative lack of data
61 to confirm the latter. The term fatigue has long been understood as a disabling symptom in
62 which physical and cognitive function is limited by performance fatigability and perceived
63 fatigability.⁴ The psycho-biological factors contributing to fatigue following a soccer match
64 have been extensively investigated and include exercise-induced glycogen depletion, (central
65 and peripheral) neuromuscular, and mental fatigue,⁵ amongst others. Match-induced acute
66 fatigue also has residual impacts on various indices for 24-72h, such as impaired physical- and
67 skill-related performance, muscle damage, and ensuing immune and endocrine responses.^{6,7}
68 Consequently, coaches and training staff may decrease the amount of auxiliary training
69 practices, such as resistance training, during heavily congested schedules, to focus on
70 recovery.⁸

71

72 Practitioners tend to implement various recovery strategies in the 24h following match-play,
73 with the most popular being nutrition, hydrotherapy, massage, foam rolling and various forms
74 of active recovery.^{8,9} Active recovery is in fact one of the commonly-employed recovery
75 practices^{8,9} and involves sequencing low-to-moderate intensity exercise, often of an aerobic
76 nature, the day following match-play.¹⁰ Although popular, mixed results have been reported
77 with regard to the efficacy of active recovery for improving the temporal recovery of
78 neuromuscular performance, markers of muscle damage, and inflammation.¹¹ While the
79 activities performed as active recovery vary between practitioners, sports and context, it is

80 common practice to try to limit any additional loading that could interfere with the recovery
81 process. This includes the avoidance of any (training) load in general and more specifically,
82 any type of work heavily involving the lower limbs (minimizing ground impact and
83 neuromuscular/musculoskeletal work); for this reason, cycling, or sometimes swimming, is
84 often preferred to running. Following this reasoning, upper body (UB) exercises may also be a
85 suitable alternative (or at least be an addition to cycling), since they may be considered to
86 trigger recovery mechanisms (e.g., increased blood flow, hormonal adjustments) without
87 directly involving the muscle groups that need to recover.¹² UB sessions generally include arms
88 and back exercises, and to a lesser extent core training and exercises aimed at improving pelvic
89 control/stability (Table 1). Whilst a growing trend in elite soccer, using UB exercise as an
90 active recovery strategy or as a means to increase training load during congested schedules
91 remains essentially anecdotal in the field of soccer, and the mechanisms through which this
92 practice may benefit post-match recovery and/or physical adaptations warrant examination.¹³

93
94 {Table 1}

95
96 Another challenge faced by practitioners with congested fixture schedules is the maintenance
97 of physical qualities during the in-season, as auxiliary training practices are sacrificed to
98 facilitate recovery.⁸ In soccer, strength and conditioning practitioners typically prescribe less
99 than two resistance-training (RT) sessions per week.⁸ Recent studies have shown that as little
100 as two RT sessions consisting of 3 sets of 10 repetitions at 70% 1-rep max (RM) per muscle
101 group may be sufficient to develop strength and maintain power in the upper and lower body.¹⁴
102 Therefore, it is unsurprising that the majority of physical conditioning practitioners in soccer
103 report being dissatisfied with the current amount of RT being scheduled during the in-season
104 micro-cycle.⁸ Accordingly, it is important to explore scheduling practices that increase RT
105 volume within the congested in-season micro-cycle, without compromising recovery kinetics.

106
107 The notion of scheduling UB RT within 24-hours post-match to enhance recovery kinetics
108 was recently examined. A study by Abaidia and colleagues showed that performing 3 sets of
109 5 large compound UB exercises (70% 1RM to exhaustion) within 24-hours of lower body
110 eccentric fatiguing exercises, accelerated the recovery of slow concentric hamstring force.
111 Furthermore, the additional UB resistance training did not exacerbate plasma creatine kinase
112 (an indirect measure of muscle damage).¹³ Despite these particularly interesting findings,
113 evidence remains limited to this single study, which had limited ecological validity in the
114 context of soccer. Given the paucity of data, it is unknown whether UB RT on the day after
115 match-play (MD+1) is compatible, complementary or contraindicated for temporal recovery
116 kinetics in elite soccer players. Consequently, the aim of this review is to evaluate the current
117 evidence and factors, including neuromuscular, metabolic, hormonal, perceptual, and
118 immunological components, which may contribute to the suitability of scheduling UB RT on
119 MD+1, with a view to providing preliminary recommendations (e.g., compatible,
120 complementary, or contraindicated) for practice considering the current dearth of empirical
121 evidence.

122 123 **Part one: Typical UB sessions performed on MD+1 in soccer**

124
125 The physical determinants of soccer have been widely reviewed and include essentially
126 locomotor-related capacities such as speed, agility, and intermittent endurance.¹⁵ For this
127 reason, both the need to develop UB strength and the ‘culture’ of UB work are often not
128 prioritised. Over time, this has led to the development of specific types of sessions (Table 1),
129 which clearly differ from those performed in other team sports such as Rugby or Handball for

130 example, where players tend to lift heavy and place a large emphasis on UB strength and power
131 development.¹⁶ For the purpose of the present review, a few typical MD+1 UB sessions
132 performed in elite soccer are presented in Table 1. When analysed in relation to the typical type
133 of RT sessions targeting either muscle growth, maximal strength or power (Figure 1),¹⁷ it
134 appears that the soccer sessions tend to fall outside optimal zones. This is related to the notion
135 that the loads are either unlikely heavy enough in relation to the number of repetitions
136 programmed, or vice-versa. While this practice may not elicit neuromuscular adaptations (i.e.
137 “time filler sessions”), its utility may lie within the possible acceleration of post-match
138 recovery. The underpinning theoretical frameworks and ‘real-life’ feasibility of using UB RT
139 as a ‘recovery’ modality at MD+1 are discussed in parts 2 and 3 of this review, respectively.

140
141 {Table 1}

142
143 {Figure 1}

144

145 **Part two: Recovery kinetics following match-play and insights for the** 146 **programming of UB RT sessions.**

147

148 **Neuromuscular Recovery**

149

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

158

159 *Central response*

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

173

174 *Peripheral response*

175 Peripheral fatigue occurs as a result of changes at or distal to the neuromuscular junction, which
176 results in impaired transmission of muscle action potentials and decreased contractile
177 capability of the muscle fibres.¹⁸ Peripherally mediated reduction in muscle force production
178 may be caused by a range (and complicated interplay) of factors such as skeletal muscle

179 damage, inflammation, altered Ca⁺⁺ or Na⁺-K⁺ pump function, and the accumulation of
180 metabolic by-products.¹⁸ Peripheral impairments in neuromuscular function have been
181 demonstrated in the quadriceps and plantar flexors following competitive match-play, but
182 return to baseline by 48 hours.²¹⁻²³ Interestingly, the complete time-course recovery of
183 performance outcomes such as CMJ and 20m sprint occur despite residual muscle damage and
184 inflammation.⁶

185

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

193

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

205

206 *Neuromuscular fatigue and active recovery modalities*

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

221

222 Following high load whole body,^{31,32} or lower body RT,³³ the force generating capabilities of
223 major muscle groups become temporarily impaired. The time-course for restoration is largely
224 dependent upon the RT typology (strength/power/hypertrophy, Table 1 and Figure 1), intensity,
225 volume and structure of the load (failure/non-failure). Although some studies have documented
226 suppressed muscle function 24-hours post RT, they were characterised by high volume and/or
227 repetitions to failure.³³ RT sessions designed for strength or power development often see
228 performance recovery within 24-hours,³² mediated by restoration of both central and peripheral

229 neuromuscular function.^{31,32} Considering the available RT research, and that central and
230 peripheral factors of fatigue develop in an intensity-dependent manner,¹⁷ it maybe considered
231 unlikely that the UB RT prescription employed in Table 1 (examples for Club A and B) would
232 impede the recovery kinetics of central and peripheral neuromuscular fatigue, given its
233 moderate-intensity nature, low-volume prescribed, and the muscle groups targeted.¹³ Equally,
234 the current theoretical frameworks, in the absence of available empirical data, do not support a
235 notion that scheduling UB RT on MD+1 accelerates neuromuscular recovery.

236

237 *Considerations: Potentially compatible*

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

250

251 {Figure 2}

252

253 **Metabolic recovery**

254

255 *Glycogen*

256 High-intensity intermittent exercise such as soccer relies heavily on glycogenolysis, with
257 glycogen availability essential for ATP resynthesis. In soccer, carbohydrates used to fuel
258 muscles are primarily derived endogenously via glycogenolysis within the exercising
259 muscles, with a subsidiary amount arising from the liver.³⁴ It is estimated, that between 40–
260 90% of the exercising muscles glycogen stores are expended during a soccer match.³⁵
261 Match-induced fatigue is somewhat associated with lowered or full depletion of glycogen in
262 some muscle fibres,³⁶ and physical performance can be enhanced with higher baseline muscle
263 glycogen.³⁷ The time-course of muscle glycogen restoration post-match is dependent upon a
264 myriad of factors such as the energy intake, carbohydrate replenishment strategy, active
265 recovery, muscle fibre type etc.³⁸ Although one study showed a -27% change in baseline
266 muscle glycogen content at 24-hours post-match,³⁹ another showed a return to baseline was
267 possible at 24-h.⁴⁰ These discrepancies may be attributed to carbohydrate replenishment
268 strategy and morphological differences between muscle fibres. For example, glycogen
269 resynthesis has been observed to be incomplete in type II fibres at 48-hours post-match,
270 despite ingestion of a high-carbohydrate and whey-protein diet.⁴⁰ This finding supports the
271 notion that eccentric activities in soccer may inhibit muscle glycogen resynthesis in type II
272 fibres,⁴¹ which may have implications for MD+1 scheduling conditioning of players whose
273 team roles or physical phenotypes are characterised by explosive actions. Indeed, data from a
274 recent case study suggested that elite players under-consume carbohydrate both immediately
275 post-match, and on the subsequent day, particularly following an evening kick-off.⁴²

276

277

278 While recent evidence has suggested that enhanced skeletal muscle adaptations (i.e. oxidative
279 capacity) may occur when training with reduced muscle glycogen availability,⁴³ the type of
280 work being performed during RT⁴⁴ and subsequent anabolic signalling responses⁴⁵ remain
281 difficult to predict during this state. Therefore, it is currently unclear whether scheduling RT
282 in a potentially low-glycogen state on MD+1 would be ergogenic, ergolytic, or would have
283 no meaningful impact on session quality and resulting adaptations. Notwithstanding, muscle
284 glycogen is an important substrate for resistance training,⁴⁶ resynthesising the phosphate pool
285 during high-intensity contractions. High-volume moderate- to high-intensity RT to failure
286 has been shown to reduce glycogen stores by 25-40% in an intensity-dependent manner,
287 requiring up to 6 hours to replenish.⁴⁷ Glycogen utilisation is greatest in type II fibres during
288 RT characterised by high repetitions of a moderate load.⁴⁷ In contrast, traditional low-
289 intensity continuous active recovery modalities also delay glycogen resynthesis, but likely in
290 type I as opposed to type II fibres.⁴⁸ Accordingly, scheduling RT on MD+1 may delay
291 glycogen replenishment, particularly in type II fibres. However, as glycogen depletion is
292 site-specific, whether UB RT (as outlined in table and figure 1) would impact replenishment
293 of match-depleted lower-limb fibres is currently unknown, but somewhat questionable.
294 Furthermore, appropriate nutritional strategies might be expected to restore glycogen stores
295 so that subsequent match performance is not impaired during congested fixture schedules.
296

297 *Considerations: Potentially compatible*

298 The rate of muscle and liver glycogen depletion occurs in a site- and load-dependent manner.
299 Following adequate carbohydrate ingestion, glycogen is replenished in the muscle within ~48
300 hours and much quicker in the liver, however type II fibres may have delayed re-uptake.
301 Coaches should consider the magnitude of explosive actions performed by the player
302 (perhaps dependent upon positional role or the match minutes played), and the time between
303 the end of the match and the scheduled UB RT, as it is likely that type II fibre glycogen
304 replenishment in lower-body muscles remains incomplete on MD+1. As glycogen utilisation
305 during RT is greatest in type II fibres the UB RT sessions should involve low-volume and
306 low to moderate intensity resistance exercise as to not further delay muscle glycogen
307 replenishment.
308

309

310 **Hormonal recovery**

311

312 *Testosterone*

313 Testosterone is a key anabolic hormone, which promotes protein synthesis, ameliorates protein
314 degradation, and improves the capacity of skeletal muscle to generate power.⁴⁹ It is well
315 accepted that high-intensity and/or high-volume resistance training increases circulating
316 testosterone in a load-dependent manner.⁵⁰ Conversely, there are mixed reports regarding the
317 effects of competitive sport on anabolic hormones, in which testosterone has been shown to
318 both increase⁶ and decrease⁵¹ after match-play. Additionally, a separate study involving 7
319 professional soccer players showed that testosterone levels remained unchanged following
320 match-play and continued steady for the total 72-hour monitoring period of the study.⁷ A recent
321 meta-analysis which pooled the results of 50 soccer players showed that on average,
322 testosterone levels remained elevated up to and including 48-hours post-match.⁶ While match-
323 related changes in anabolic hormones, such as testosterone, remain a topic of great interest, the
324 endocrine response is highly variable and appears to be mediated by psychophysiological
325 factors such as match outcome and player experience.⁵² For example, testosterone typically
326 decreases following a loss but increases following victory.⁵³ The current available evidence
327 suggests that testosterone levels remain largely unaltered during the recovery period following

328 match play and therefore, the use of testosterone as a biomarker of recovery remains equivocal.
329 ⁵²

331 *Cortisol*

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

346
347 The testosterone to cortisol (T:C) ratio is considered a more sensitive measure of endocrine
348 status and recovery as it reportedly demonstrates the anabolic-catabolic balance of the athlete.⁵⁸
349 While a 30% decrease in T:C ratio has been proposed as an indicator of insufficient recovery,⁵⁹
350 there is conflicting evidence regarding the validity of T:C ratio in predicting overtraining,⁵⁸ or
351 performance.⁶⁰ This may be because T:C varies throughout the season and is influenced by
352 many psychophysiological factors such as the player's playing position,⁶¹ match importance
353 and outcome.⁵² Consequently, designing evidence-based training regimens, or recovery
354 programs informed by T:C is currently premature given the lack of available evidence.

355
356 In the event a soccer match does elicit sufficient anabolic stimulus, it is unclear whether
357 sequencing RT on MD+1 would further increase testosterone levels and thereby improve
358 recovery kinetics. As shown by Kraemer and colleagues, resistance training interventions
359 resembling traditional body builder programs (e.g. moderate-load, high-volume protocols with
360 short rest periods) often result in the greatest acute response in circulating testosterone and
361 other anabolic hormones such as human growth hormone.⁶² Consequently, a scenario of
362 competing interests may arise when attempting to elicit an RT-induced hormonal response —
363 as the intensity and/or volume required may further exacerbate the neuromuscular fatigue and
364 already elevated cortisol levels incurred by match-play.⁷ Finally, the evidence for muscle
365 growth and strength increases being independently linked to acute exercise-induced increases
366 in endogenous anabolic hormones is equivocal,⁶³ and as such, the acute hormonal responses of
367 the proposed training practice (Table 1), if any, may not directly improve skeletal muscle
368 strength nor muscle growth (and by extension, recovery).

369 *Considerations: Compatible if well programmed*

370
371 Coaches should employ caution when scheduling UB RT close to match play as cortisol levels,
372 which are elevated following match play, are likely to be further increased following RT
373 without clear evidence of the practice leading to elevations in testosterone or favourable
374 testosterone:cortisol ratio. Furthermore, RT loads shown to elicit an anabolic response may
375 exacerbate match-induced neuromuscular fatigue. Therefore, coaches should consider
376 variables such as match location and minutes played as well as avoid high-intensity RT on
377 MD+1 as to minimise the risk of inadequate recovery.

378
379 {Figure 3}

380 381 **Mental / Perceptual Recovery**

382
383 Mental fatigue in soccer is characterised by subjective perceptions of impaired focus
384 (concentration), motivation, and challenges responding to errors.⁵ Competitive match-play
385 may require prolonged cognitive focus in decision making and vigilance, supported by
386 substantial ratings of mental fatigue⁵ and technical/cognitive exertion immediately post-
387 match.⁶⁴ Whilst limited data is available using elite-level players and ecologically valid
388 experimental designs, controlled laboratory studies have shown acute negative effects of *a*
389 *priori* mental fatigue upon soccer-related physical and technical performances.^{65,66} However,
390 the time-course of mental fatigue is not well understood, with just one recall-survey suggesting
391 players are not recovered 24 hours post-match,⁵ and the impacts of travel and sleep
392 disturbances remain unknown.¹⁹

393
394 Given the current lack of empirical data regarding mental fatigue, insights regarding a player's
395 perceptual readiness (freshness) to train on MD+1 may be informed from self-report measures
396 of wellness (e.g., fatigue, soreness). Ratings of fatigue and soreness in elite players reduce by
397 ~40% on MD+1, and are not recovered by MD+2,^{67,68} although these responses may be more
398 heavily influenced by the match-outcome, rather than its physical exertions.⁶⁷ Reduced player
399 wellness before field-training has been shown to have subtle detriments on training load
400 measures in various football codes,^{67,69} but the effect magnitudes were generally deemed
401 trivial.

402
403 With respect to the scheduling of UB RT on MD+1, to our knowledge there is no data available
404 that suggests that residual mental fatigue or perceptual readiness impacts the work done or
405 subsequent training adaptations. Following whole-body RT in trained individuals, self-
406 reported fatigue and soreness ratings were restored to baseline by 48 hours.^{31,32} Alternatively,
407 traditional active recovery modalities (steady-state, low-intensity) have a large effect on
408 reducing self-reported muscle soreness, but do not reduce perceived fatigue.¹¹ Collectively,
409 these findings may suggest that RT delivered on MD+1 may delay recovery from mental
410 fatigue or wellness. However, when eccentric-based lower-limb strengthening exercises were
411 administered on MD+1, neither the magnitude nor the time-course of hamstring or quadriceps
412 soreness recovery were impacted in comparison to a control (no training) condition.²⁷ This may
413 suggest that any negative mental or wellness responses to MD+1 RT may be masked by the
414 greater burden incurred from competitive matches. Moreover, there is evidence suggesting
415 that a low training volume at a low to moderate intensity (40-50% 1 repetition maximum) can
416 improve mood and affect,^{70,71} and that UB RT may have a more positive affective response.⁷²

417
418 *Considerations: Compatible at the individual level*

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

428

429 **Immunological recovery**

430

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

443

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

452

453 Over a period spanning almost 40 years, exercise immunologists have focused their research
454 endeavours to better understanding whether heavy exercise temporarily decreases immunity,
455 providing an ‘open window’ for respiratory infections.^{82,83} Readers are directed elsewhere for
456 an overview of the immune system,⁸⁴ and a recent debate about whether heavy exercise can
457 raise the risk of infections, in line with the ‘open window’ theory.⁸⁵ Empirical evidence
458 indicates that innate and acquired immunity decrease transiently during the recovery period
459 after prolonged heavy exertion (such as following a soccer match); typically of the order 15–
460 70%.^{79,86} Whether these transient changes in immunity with acute heavy exercise and
461 intensified training performed on the following days (i.e., MD+1) are sufficient to increase
462 infection susceptibility, in accordance with the ‘open window’ theory, has been disputed for
463 some time.⁸⁷

464

465 Studies involving 90–120 minutes of intermittent exercise, including soccer-specific shuttle
466 run tests, have shown rather subtle and short-lived effects on immunoendocrine outcome
467 measures (lasting only a matter of hours) e.g., circulating cortisol, leukocyte counts and
468 subsets, phagocytic function, lymphocyte proliferation, natural killer cell activity, mucosal
469 immunity (e.g., saliva immunoglobulin-A) and inflammatory cytokine responses.^{88,89}
470 Immune health appears to be well maintained in elite soccer players across a competitive
471 season;^{55,90} however, times of high overall stress and limited recovery, e.g., intensive training
472 camps and congested fixture schedules, have been shown to influence immunity. For
473 example, a 5-day intensive training camp reduced circulating T-helper lymphocytes, T-
474 cytotoxic lymphocytes and B-lymphocytes in elite soccer players, potentially weakening
475 infection resistance.⁹¹ Congested fixture schedules (e.g., 3-game week) exacerbated the
476 circulating cortisol response post-match,⁹² and reduced circulating natural killer cell and
477 monocyte numbers⁹³ and saliva immunoglobulin-A levels in professional soccer players.⁹⁴

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

488 *Recommendation: Compatible*

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

497

498 **Part 3: Sequencing a resistance training session on matchday+1 during the** 499 **weekly macrocycle: insights from real life scenarios.**

500

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

511

512 In fact, further than their effect, or lack thereof, on UB strength and the kinetics of biological
513 recovery, RT sessions scheduled on MD+1 (Table 1) may have various impacts on mental
514 health, which shouldn’t be overlooked. Preserving and promoting (mental) freshness for the
515 next match should, without a doubt, be one of the key objectives during the post-recovery
516 process (as discussed above). While this type of recovery may be more difficult to monitor
517 with objective data (i.e., limited to questionnaires), the psychological aspect of such UB RT
518 sessions is likely highly player-dependent. For some players, UB sessions may be an
519 additional training constraint that adds to the already high mental load of congested fixtures.
520 In this context, match minutes, match location (home vs away) and the timing of the next
521 match (i.e., microcycle lengths, days between matches) may be used as objective indicators to
522 help practitioners decide whether to schedule an UB session for those more ‘reluctant’
523 players. In Figure 4, we offer a simple decision tree based upon the theoretical frameworks
524 outlined in Part B to help practitioners decide on the scheduling of such sessions based on
525 those variables (at the team level at least, and in the absence of available evidence). For other
526 types of players, such ‘cosmetic sessions’ (given the low load and their objectives) may
527

528 rather be an integral part of their overall wellness (e.g., feeling- and looking-good, readiness
529 to compete etc.), who may get a rather beneficial and greater mental than physiological
530 benefit from them. This suggests that players physical profile, origins, habits, previous
531 experience should in fact be considered as important factors as those described in Figure 2
532 when it comes to programming these UB sessions. Practitioners are therefore left with the
533 decision about what and when to offer RT to individual players, which often requires a
534 holistic understanding of players needs that goes beyond the theoretical concepts discussed in
535 this paper.

536

537 {Figure 4}

538

539 **Practical applications**

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

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

557

558 **Conclusions**

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

563

564

565 **Compliance with Ethical Standards**

566

567 **Funding**

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

569

570 **Conflict of interest**

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

573

574

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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

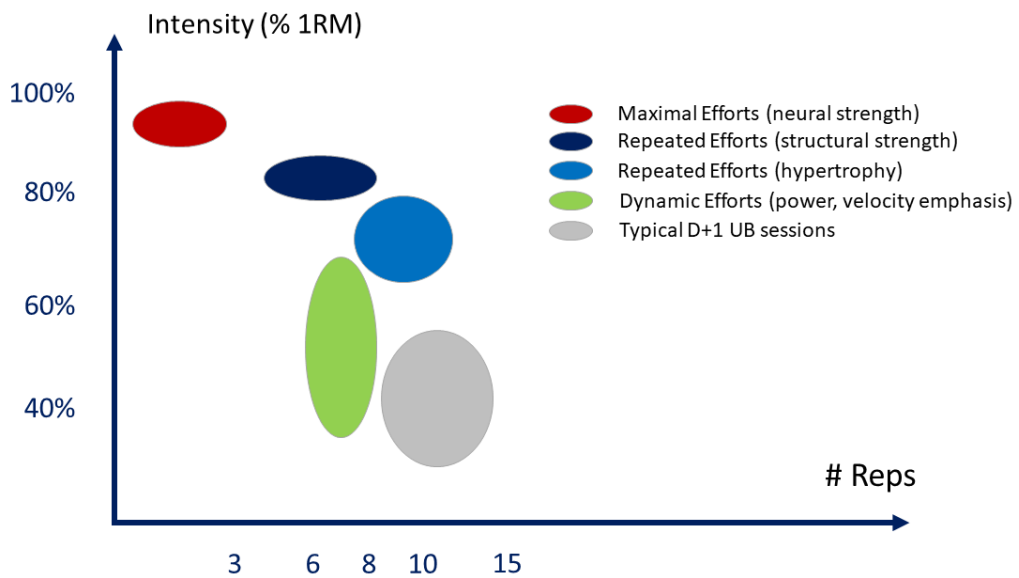
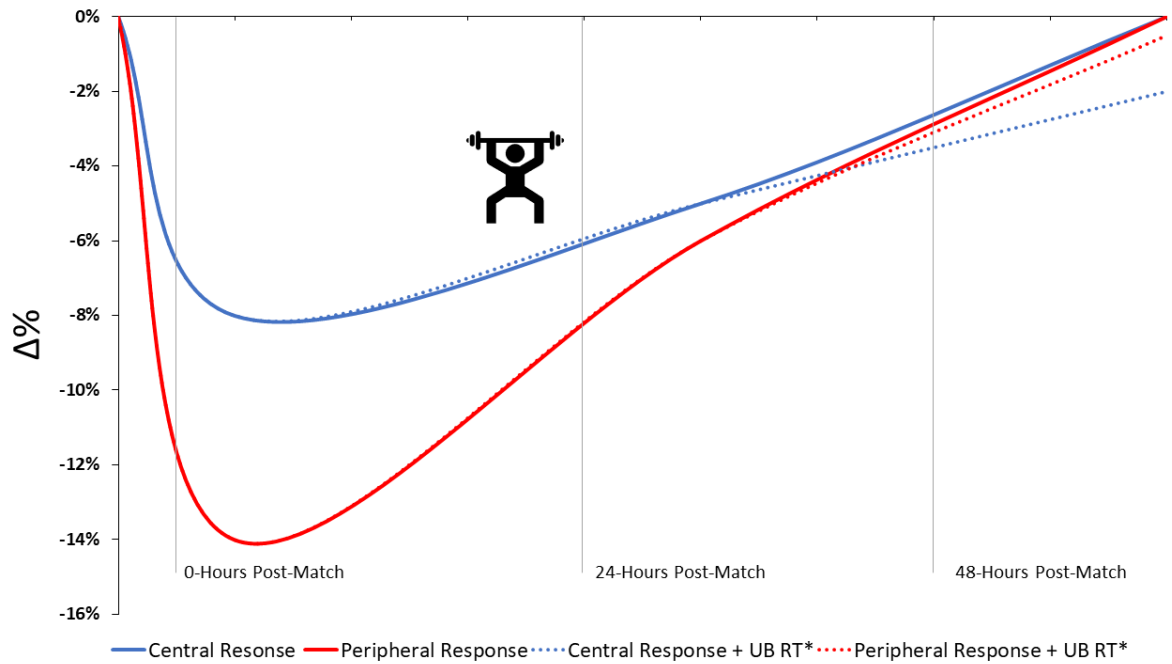


Fig. 1 Classification of typical resistance training sessions in relation to intensity (% 1RM) and volume (number of repetitions). Adapted from Zatsiorsky and Kraemer, 2006.¹⁷ The typical MD+1 UB sessions performed in soccer (Table 1) fall outside these 'optimal' zones, which question their effectiveness with respect to neuromuscular adaptations. 1RM, one-repetition max. MD+1, day after match-play. UB, upper body.

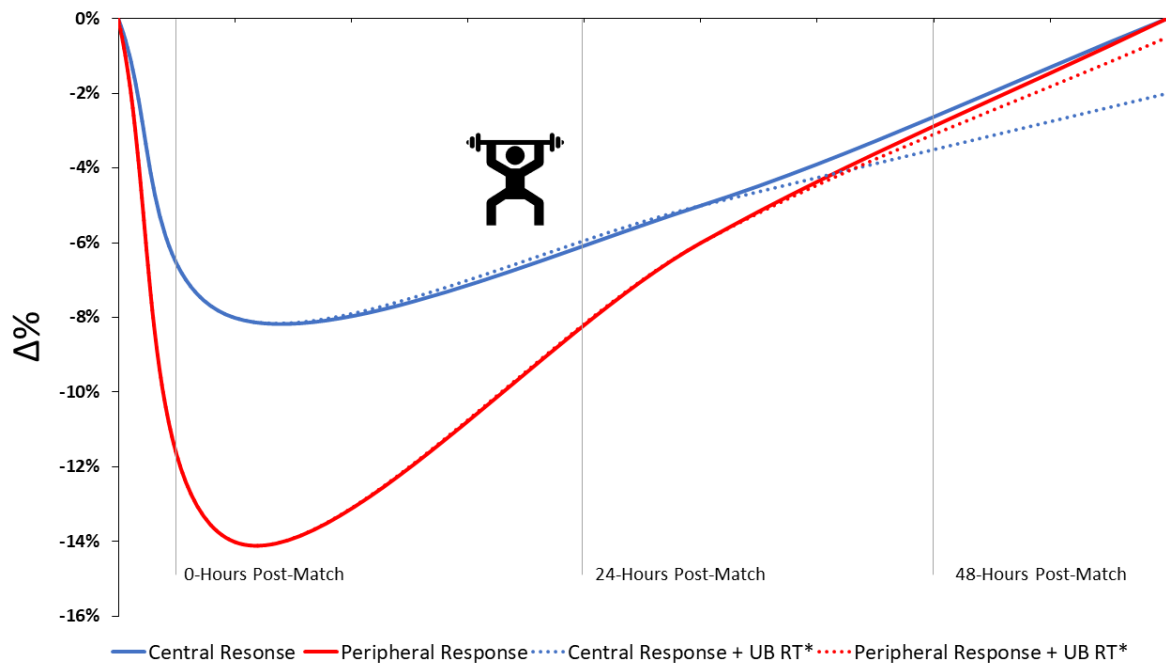


Fig. 2 Schematic change (%) in central and peripheral performance \pm upper body session. Adapted from Brownstein et al. 2017.²¹ The addition of UB RT on MD+1 may slightly impair central recovery and, to a lesser degree, peripheral recovery, however these are unlikely to affect performance outcomes. 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.

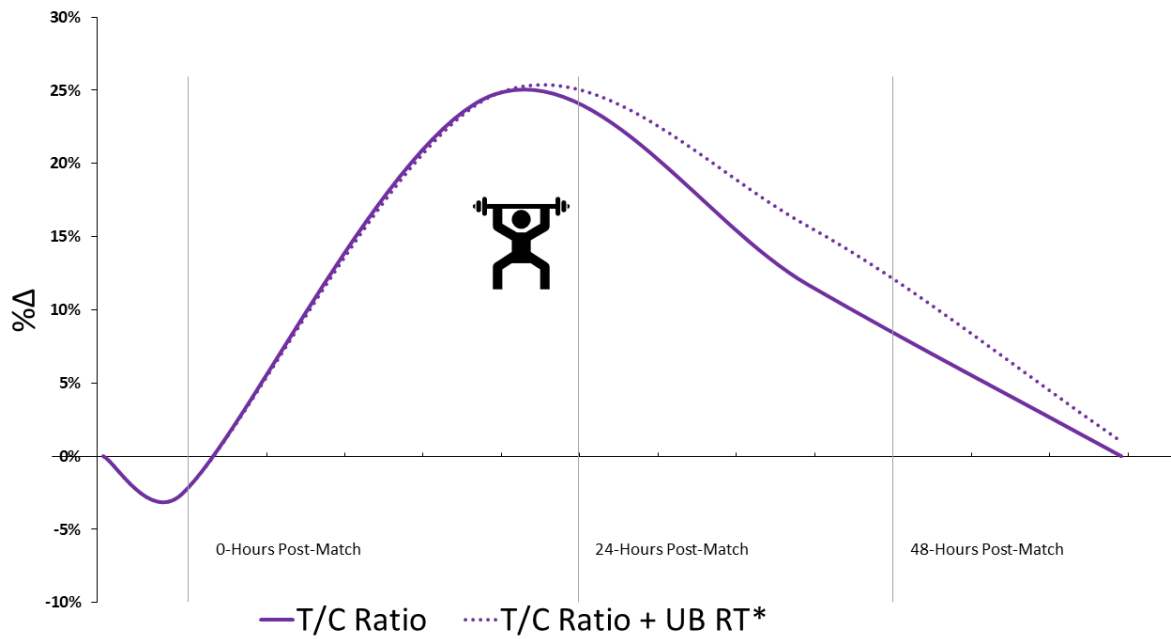


Fig. 3 Schematic change (%) in transient free testosterone:Cortisol ratio \pm upper body session. Adapted from Romagnoli et al. 2016.¹⁰⁰ The addition of UB RT on MD+1 may induce favourable improvements in T:C ratio, however these changes are likely to be minimal due to the nature of the UB sessions. UB, upper body. RT, resistance training. *Broken lines indicate theoretical projections.

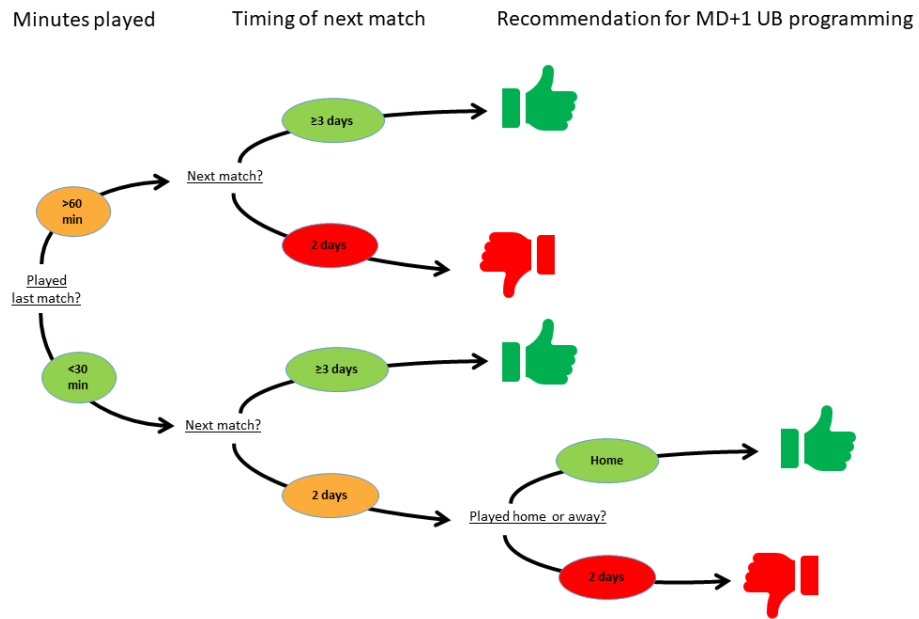


Fig. 4 Proposed decision tree to help practitioners decide on the scheduling of such sessions based on match minutes, match location (home vs away) and the timing of the next match (i.e., microcycle lengths, days between matches).