

Bond University
Research Repository



The specificity of rugby union training sessions in preparation for match demands

Campbell, Patrick G.; Peake, Jonathan M.; Minett, Geoffrey M.

Published in:
International Journal of Sports Physiology and Performance

DOI:
[10.1123/ijsp.2017-0082](https://doi.org/10.1123/ijsp.2017-0082)

Licence:
Other

[Link to output in Bond University research repository.](#)

Recommended citation(APA):
Campbell, P. G., Peake, J. M., & Minett, G. M. (2018). The specificity of rugby union training sessions in preparation for match demands. *International Journal of Sports Physiology and Performance*, 13(4), 496-503. <https://doi.org/10.1123/ijsp.2017-0082>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

For more information, or if you believe that this document breaches copyright, please contact the Bond University research repository coordinator.

1 **Title:** The specificity of rugby union training sessions in
2 preparation for match demands

3 **Submission type:** Original Investigation

4 **Authors:** Patrick G Campbell^{1,2}, Jonathan M Peake^{2,3}, and
5 Geoffrey M Minett^{1,2}

6 **Affiliations:** ¹ School of Exercise and Nutrition Sciences,
7 Queensland University of Technology, Kelvin
8 Grove, QLD, Australia

9 ² Institute of Health and Biomedical Innovation,
10 Queensland University of Technology, Kelvin
11 Grove, QLD, Australia

12 ³ School of Biomedical Sciences, Queensland
13 University of Technology, Kelvin Grove, QLD,
14 Australia

15

16 **Correspondence:** Patrick Campbell
17 School of Exercise and Nutrition
18 Sciences
19 Faculty of Health
20 Queensland University of
21 Technology
22 Victoria Park Road, Kelvin
23 Grove QLD 4059

24

25

26

27

28 Running title: Comparison of training and match demands

29

30 **Keywords:** Physical preparation, team sport, athlete
31 development, time-motion analysis, game-specific skills

32

33 Word count: 3592

34 Abstract word count: 246

35 Number of figures: 2

36 Number of tables: 3

37

38 **Abstract**

39 Purpose: Investigations into the specificity of rugby union
40 training practices in preparation for competitive demands has
41 predominantly focussed on physical and physiological demands.
42 The evaluation of the contextual variance in perceptual strain or
43 skill requirements between training and matches in rugby union
44 is unclear, yet holistic understanding may assist to optimise
45 training design. This study evaluated the specificity of physical,
46 physiological, perceptual and skill demands of training sessions
47 compared with competitive match-play in pre-professional, elite
48 club rugby union. Methods: Global positioning system (GPS)
49 devices, video capture, heart rate (HR), and session ratings of
50 perceived exertion (sRPE) were used to assess movement
51 patterns, skill completions, physiologic, and perceptual
52 responses, respectively. Data were collected across a season
53 (training sessions n=29; matches n=14). Participants (n=32)
54 were grouped in playing positions as: outside backs, centres,
55 halves, loose forwards, lock forwards, and front row forwards.
56 Results: Greater total distance, low-intensity activity, maximal
57 speed and metres per min were apparent in matches compared to
58 training in all positions ($P<0.02$; $d>0.90$). Similarly, match HR,
59 and sRPE responses were higher than those recorded in training
60 ($P<0.05$; $d>0.8$). Key skill completions for forwards (i.e.,
61 scrums, rucks and lineouts) and backs (i.e., kicks) were greater
62 under match conditions than in training ($P<0.001$; $d>1.50$).
63 Conclusion: Considerable disparities exist between the
64 perceptual, physiological, and key skill demands of competitive
65 matches versus training sessions in pre-professional rugby union
66 players. Practitioners should consider the specificity of training
67 tasks for pre-professional rugby players to ensure the best
68 preparation for match demands.

69 **Introduction**

70 The specificity of training principle states that training
71 adaptations are closely related to the training stimulus, and is
72 considered important to optimise physical performance
73 ¹. Training practices in rugby union have predominantly
74 focussed on the physical and physiological demands of match-
75 play alone ²⁻⁴. Notably, this contrasts the multifaceted position-
76 specific demands of rugby union competition ^{5,6}. The differences
77 in physical and physiological characteristics of rugby union
78 training and competitive matches have been reported ^{3,4}, yet no
79 data exists to evaluate contextual variance in perceptual strain or
80 skill requirements. Omitting the considerable perceptual and
81 skill demands of rugby union provides a limited analysis of
82 training and match-play. Accordingly, additional analysis of
83 rugby union is required to understand the position-specific,
84 broad and multifactorial demands of rugby union. Of particular

85 importance is the specificity of current training practices in
86 preparation for competitive match demands.

87 Rugby coaching practices are anecdotally known to
88 extensively utilise strategies that remove the performance
89 context from the skill (e.g., unopposed or passive skills practice)
90 ⁷. It is unclear if this interpretation is justified, and if accurate,
91 whether these training practices differ from rugby union match
92 activities, as suggested in other sports ⁸. The current literature
93 clearly recommends designing skills-focused training sessions to
94 be representative of the competitive environment, which imitates
95 the variable nature of a match ^{7,9}. While some evidence suggests
96 that match-specific or games-based training has increased in
97 professional teams ^{3,4}, this may point to a difference in training
98 method used between elite and pre-elite coaches. Providing a
99 broad, multidisciplinary analysis of training and match demands
100 could afford insight into such a discrepancy between coaches
101 and playing standards. This data may have particular
102 implications for pre-professional players, because the
103 understanding of match demands is proposed as the first step in
104 the development of an elite rugby union player ¹⁰.

105 Although the physical and physiological demands of
106 professional ^{5,11} and adolescent ² rugby union matches have been
107 established, less is known about these demands at the pre-
108 professional standard. Importantly, elite club, pre-professional
109 rugby union provides a platform for the development of
110 emerging players. For example, current elite club rugby players
111 are often presently, or previously involved in professional clubs.
112 The Australian Rugby Union development and competition
113 pathway indicates elite club, pre-professional rugby as a
114 consistent component in player development. Identifying the
115 physical, physiological, perceptual and skill demands could have
116 important implications for players transitioning into professional
117 rugby union. Understanding specific skill outputs and physical
118 demands during matches may also assist in identifying potential
119 training limitations and providing opportunities to enhance
120 performance outcomes. The aim of this study was to examine the
121 position-specific physiological, perceptual and skill demand
122 requirements of pre-professional rugby players in matches and
123 training sessions. The specificity of current on-field rugby
124 training sessions was then compared with competitive match-
125 play demands.

126 **Methods**

127 Participants

128 Thirty-two male Premier Grade club rugby union players
129 volunteered to participate in this study (24 ± 4 y, 88 ± 20 kg, 177
130 ± 10 cm). At the time of data collection, participants were highly
131 trained individuals, free of injury and collectively had

132 experienced four different standards of representative rugby
133 union playing experience: a) Queensland Reds U20 ($n = 3$), b)
134 Australian U20 ($n = 3$), c) National Rugby Championship ($n =$
135 12), d) Super 15 Rugby experience ($n = 10$). Additionally,
136 participants were completing at least three rugby sessions (two
137 training, one match) and two to three resistance training sessions
138 per week (on-field training time = 147 ± 46.7 min-week⁻¹). All
139 participants provided written informed consent, and ethics
140 approval for study procedures was provided by the University
141 Human Research Ethics Committee.

142 Overview

143 An observational time-motion analysis study was conducted
144 throughout a season of a Premier Grade rugby union competition
145 (Brisbane, Australia) to examine the movement patterns, skill
146 demands and perceptual exertion required of pre-professional
147 players. Players were familiar with all measures as part of their
148 normal monitoring routine. Data were collected throughout the
149 competition period (spanning 19 weeks) to evaluate the key
150 physical (i.e., movement patterns, skill completions),
151 physiological (i.e., heart rate), and subjective markers (i.e.,
152 perceived exertion) of rugby union performance during on-field
153 rugby training sessions ($n = 29$; 294 observations) and
154 competitive matches ($n = 14$; 146 observations). Training
155 sessions typically consisted of the following elements: warm-up
156 (12.9 ± 7.1 min-week⁻¹), conditioning (19.4 ± 12.9 min-week⁻¹),
157 forward (24.8 ± 5.1 min-week⁻¹) and backs (20.8 ± 5.0 min-week⁻¹),
158 unit skills, captain's run (15.2 ± 7.9 min-week⁻¹), and modified
159 game periods (20.4 ± 7.2 min-week⁻¹).

160 Eleven injury-free Premier Grade squad players were randomly
161 selected for involvement each week to accommodate the limited
162 global positioning satellite (GPS) devices available to record
163 movement patterns. Participants wore the same GPS unit during
164 that week's training and match. The frequency of skill
165 completions was coded using video footage after each session.
166 Similarly, a session rating of perceived exertion (sRPE) was
167 recorded 30 min following training and match-play. Data were
168 divided into six position groups: outside backs ($n = 57$ training,
169 26 match (85.5 ± 9.5 min-match⁻¹) observations); wingers ($n =$
170 29 training, 13 match (88.4 ± 4.2 min-match⁻¹) observations);
171 centres ($n = 21$ training, 11 match (85.3 ± 12.6 min-match⁻¹)
172 observations); halves ($n = 53$ training, 25 match (87.2 ± 10.1
173 min-match⁻¹) observations); loose forwards ($n = 63$ training, 36
174 match (87.9 ± 5.6 min-match⁻¹) observations); lock forwards (n
175 = 36 training, 14 match (81.7 ± 16.2 min-match⁻¹) observations),
176 and front row forwards ($n = 64$ training, 34 match (80.8 ± 20.8
177 min-match⁻¹) observations) to allow for specific comparisons
178 between playing positions.

179 Measures

180 *External Load*

181 Participants wore a GPS device (15 Hz; SPI HPU GPSports,
182 Canberra, Australia) during all training sessions and competitive
183 matches. The devices were harnessed to the upper thoracic spine
184 between the superior sections of the scapulae. Raw GPS data
185 were downloaded post-session to a personal laptop running
186 specialised software (Team AMS, GPSports, Canberra,
187 Australia). This GPS device reportedly demonstrates a 1.9%
188 typical error of measurement (TEM) and -0.20 intra-class
189 correlation (ICC) for total distance measured, and a TEM of
190 8.1% and ICC of -0.14 for peak speed¹². The movement pattern
191 variables included for analysis comprised: total distance, mean
192 speed, sprint count and very high-intensity activity (VHIA; >20
193 $\text{km}\cdot\text{h}^{-1}$)^{13,14}. GPS variables were processed as both absolute
194 forms and relative to time.

195 *Internal Load*

196 Players wore a heart rate (HR) transmitter belt (T34, Polar
197 Electro-Oy, Kempele, Finland), with the data recorded
198 synchronously with the GPS device and downloaded post-
199 session to a personal laptop running specialised software (Team
200 AMS, GPSports, Canberra, Australia). Recorded game and
201 training HR was categorised into six pre-determined HR zones.
202 The HR maximum, mean HR and HR Zone 4-6 were included in
203 the data analysis. The HR zones were categorised as: Zone 4
204 (160-170 $\text{beats}\cdot\text{min}^{-1}$), Zone 5 (170-180 $\text{beats}\cdot\text{min}^{-1}$) and Zone 6
205 (180-220 $\text{beats}\cdot\text{min}^{-1}$)¹⁵. HR Zones were presented as the time
206 spent within each zone throughout training and match-play.
207 Perceptual measures of internal load were collected using the
208 sRPE method¹⁶. Participants recorded sRPE (Borg's CR-10
209 scale) 30 min after all training and competitive matches using a
210 smartphone application (SportsMed Global, Newstead,
211 Australia).

212 *Skill Notational Analysis*

213 Video recordings of all sessions were performed using a digital
214 camcorder (Legria HF R506, Canon, Tokyo, Japan) positioned
215 on a stationary tripod 3–5 m above the height of the playing field.
216 The footage was taken from a vantage point 10–20 m from the
217 field either side of the 22 m and halfway lines. All video footage
218 was recorded onto a digital SD card (SDHC™ UHS-I, SanDisk,
219 Sydney, Australia). All video recordings were then analysed
220 post-session for frequency and volume of key match event
221 demands that are specific to backs and forwards^{6,11,17,18}. One
222 analyst performed coding of each video recording. The key
223 match event demands analysed in absolute form and relative to
224 time included: passes, ball carries, tackles, kicks, kicks under
225 pressure, rucks, lineouts (attack and defence), and scrums.
226 Analysis of ten match and training files were performed in

227 duplicate to ensure the reliability of the data. Reliability of all
228 notational skill variables demonstrate 0.0 – 8.5% standard error
229 of measurement and ICC equal to 0.93 – 1.0.

230 Statistical Analysis

231 Data are reported as a mean \pm standard deviation unless
232 otherwise specified. Movement pattern and skill variable values
233 were normalised to time and divided into positional playing
234 groups for both training and match comparisons. A one-way
235 analysis of variance with Tukey corrected post hoc analysis was
236 used to determine differences between training and match-play
237 data specific to playing positions. The analysis was performed
238 using Statistical Package for Social Sciences (IBM SPSS v.22,
239 Chicago, USA). Significance was accepted when $P < 0.05$.
240 Standardised effect sizes (Cohen's d) were calculated by
241 dividing the mean difference (between positional groups and
242 training versus matches) by the average of their standard
243 deviations. Effect sizes were then evaluated based on the
244 smallest worthwhile difference, whereby an effect size of ≤ 0.2 is
245 trivial, 0.2–0.49 is small, 0.5–0.79 is medium, and ≥ 0.8 is large
246 ¹⁹.

247 **Results**

248 External Load

249 *Differences between Positional Groups*

250 Running speed variables for matches and training are shown in
251 Table 1. Outside backs ($P < 0.001$; $d = 1.63$) and halves ($P = 0.02$;
252 $d = 1.13$) covered greater total distances than front row forwards
253 during match-play. Outside backs, centres and halves also
254 accumulated greater total distances than loose forwards and front
255 row forwards in training ($P < 0.001$ – 0.004 ; $d = 0.84$ – 1.47).
256 Outside backs completed more VHIA during competitive
257 matches than other playing positions ($P < 0.001$; $d = 1.54$ – 3.46),
258 with the exception of centres only ($P = 0.321$; $d = 0.8$). Similarly,
259 centres completed more VHIA than all forwards ($P < 0.001$ – 0.04 ;
260 $d = 1.51$ – 2.70), while halves also attained more VHIA than front
261 row forwards during competitive matches ($P < 0.001$; $d = 1.01$ –
262 2.47).

263 Outside backs and halves achieved greater maximum speeds
264 than loose forwards, lock forwards and front row forwards
265 during competitive matches ($P < 0.001$ – 0.01 ; $d = 1.35$ – 3.34).
266 Centres and loose forwards also attained higher speeds than front
267 row forwards during competitive match-play ($P < 0.009$; $d = 1.04$ –
268 2.29). Outside backs and halves maintained a higher average
269 speed than front row forwards during competitive match-play
270 ($P < 0.001$ – 0.01 ; $d = 1.09$ – 1.64). Centres and halves attained a
271 higher sprint count during competitive match-play than loose
272 forwards, lock forwards and front row forwards, while outside

273 backs were higher in both categories than front row forwards
274 ($P<0.001-0.02$; $d=0.98-2.90$). Notably, maximum speeds were
275 higher during matches for outside backs, centres, halves and
276 loose forwards than in training ($P<0.001-0.01$; $d=0.93-2.00$).

277 *Differences between Training and Matches*

278 Comparisons between matches and training showed that outside
279 backs, loose forwards and front row forwards all covered greater
280 total distances compared with training ($P<0.001$; $d=1.01-2.05$).
281 Relative analyses ($\text{m}\cdot\text{min}^{-1}$) indicated that loose and front row
282 forwards completed higher activity output during competitive
283 match-play compared with full training sessions ($P=0.013-$
284 0.015 ; $d=1.70-1.82$). There were no differences observed in
285 absolute comparisons between competitive matches and training
286 for VHIA ($P=0.083-0.982$; $d=0.01-0.61$).

287 Internal Load

288 *Heart Rate*

289 Figure 1 indicates differences between competitive matches and
290 training for average HR and HR Zones 4-6. Results show more
291 time was spent within HR Zones 4, 5 and 6 during competitive
292 matches than training sessions in all positional groups, except
293 centres in HR Zone 4 ($P<0.001-0.02$; $d=0.80-2.62$).

294 *Session Rating of Perceived Exertion*

295 Higher sRPE values were reported after competitive matches
296 when compared to training for all positional groups (Figure 2,
297 $P<0.001-0.03$; $d=1.24-2.92$).

298 Skill Notational Analysis

299 *Differences between Positional Groups*

300 Skill completion frequencies for backs and forwards are
301 displayed in Table 2 and Table 3, respectively. All forward
302 positions completed more ruck involvements during matches
303 than any backline player ($P<0.001$; $d=1.42-4.96$), with lock
304 forwards completing more involvements than front row forwards
305 ($P=0.012$; $d=1.03$). Outside backs made more kicks than centres
306 and halves during competitive matches ($P<0.001$; $d=1.26-1.62$).
307 However, the halves made more kicks under pressure and passes
308 than the outside backs and centres ($P<0.008$; $d=1.14-2.52$).

309 *Differences between Training and Matches*

310 Competitive match-play involved greater quantities of opposed
311 rucking, scrum, lineout attack and lineout defence occurrences
312 ($P<0.001$; $d=1.62-8.25$) for all forward positions compared with
313 training sessions in absolute and relative conditions.
314 Competitive matches involved a higher number of kicks in
315 absolute and relative analyses for outside backs than training

316 ($P<0.001$; $d=1.52$). Likewise, centres accrued more kicks under
317 pressure in competitive matches than in training ($P<0.001$;
318 $d=1.28-1.71$).

319 **Discussion**

320 This study is the first to provide a broad, multidisciplinary
321 comparison of the physical, perceptual and skill demands
322 between training and matches in rugby union. The principal
323 finding is the consistently higher perceptual strain and key skill
324 completions during competitive pre-professional rugby union
325 matches than in training. These results may suggest a lack of
326 specificity in current rugby union training practices at the pre-
327 professional standard. The results of this study also provide
328 evidence reinforcing the requirement for position-specific
329 physiological, movement patterns and key skill demand training
330 practices. Comparisons with previous literature indicate that
331 differences are present between the physical and skill demands
332 of professional and pre-professional rugby union players^{5,13,20}.
333 This study may provide an evidence-based framework to assist
334 coaches in developing players transitioning into professional
335 players.

336 Comparisons of activity profiles between professional and pre-
337 professional players (5505 ± 433 indicate both similarities (5750
338 ± 295 and 5448 ± 733)^{6,11} and differences (5198 ± 652 and 6953)
339 ^{5,13} in total distances (m) covered during matches. There were
340 fewer in-match tackles (5.1 ± 1.9 vs. 23.1 ± 14), rucks (12.9 ± 2)
341 and mauls (3.1 ± 0.2) in this study compared with professional
342 players (combined rucks & mauls 66.9 ± 15.8)²¹. Further, scrum
343 frequencies in pre-professional players (22.2 ± 1) were
344 comparable to some previous reports (29 ± 6)²², but less than
345 others (38.1 ± 1.15)²¹. The findings of the present study show a
346 much higher number of lineout formations in pre-professional
347 (23.5 ± 0.7) when compared with professional rugby matches
348 (11 ± 4)²². These results indicate that pre-professional rugby
349 union is characterised by a similar number of scrums, and a
350 greater number of lineouts when compared with professional
351 rugby union players. This may be explained by differences in
352 skill level, and consequently tactics, within pre-professional
353 rugby players. The results reinforce the need for greater training
354 emphasis on forward-specific skill sets, using specific
355 competitive match practice of lineouts and scrummage situations
356 during training in pre-professional players. The differences in
357 physical and skill related demands may require specific training
358 strategies to prepare players for professional standards of rugby
359 union.

360 Similar to previous studies^{5,11,20}, the current findings highlight
361 important positional differences, which are indicative of specific
362 characteristics and reinforce the necessity to individualise
363 training prescriptions. Particularly apparent and consistent with

364 studies in professional players, positional differences were found
365 in maximum speed, sprint count and very-high-intensity activity
366 ranges. Backline players accumulated greater distances in these
367 zones due to their specific traits (e.g., greater speed) ^{6,22} and
368 game requirements (e.g., set-plays) that allows for higher
369 running speeds to be achieved. In contrast, match demands
370 experienced by forwards reflected greater amounts of physical
371 interactions (e.g., tackles, rucks, scrums and lineouts) compared
372 to the backs. Such observations might indicate a need for training
373 to incorporate repeated exposures to high-intensity activities
374 (static and dynamic), with a greater emphasis on speed and
375 endurance for backs, versus strength and physical contacts for
376 forwards.

377 Interestingly, activity pattern data suggest that pre-professional
378 rugby union players may be well prepared for the high-intensity
379 and sprint running demands of match-play (Table 1). This result
380 is in contrast with existing literature typically reporting training
381 sessions to involve significantly less high-intensity running
382 demands than competition ^{2,3}. It is possible that this is an
383 example of differences in elite and pre-elite coaching practices,
384 whereby coaches of professional players may be more likely to
385 utilise games-based scenarios that are known to involve less
386 high-intensity running ⁴. Alternatively, these coaches may
387 implement a high volume of repeated sprint scenarios in training
388 based on evidence that repeat sprint ability is an important
389 quality for team sport performance ²³. These findings
390 demonstrate the need for more research providing comparisons
391 between matches and training.

392 Training approaches aim to develop specific athletic qualities
393 (e.g., physical, psychological, perceptual and technical/tactical
394 skills) to maximise preparedness for the competitive
395 environment. This is consistent with the longstanding belief
396 among team sport coaches that players should train the way they
397 play ²⁴. In practice, this requires training to simulate and
398 represent the inherently dynamic and variable nature of
399 competitive match-play ^{7,9,25}. However, clear differences in load
400 were apparent in the current data, with both heart rate (Figure 1)
401 and perceptual (sRPE; Figure 2) responses higher during
402 matches than in training. This may be reflective of the greater
403 physiological, skill-demand, emotional and psychological
404 stressors involved in decision-making scenarios occurring
405 throughout competitive matches ¹³. Rugby matches involve
406 substantial incidences and time spent within intense static or
407 low-movement situations (e.g., rucks, scrums). These bouts of
408 physical effort will register as low-intensity activity by a GPS;
409 however, intense static muscular contractions will produce
410 marked HR responses¹³. The results of the study appear to
411 substantiate this, with players experiencing greater absolute and
412 relative incidences of skill scenarios such as contested kicking,

413 lineouts, ruck and scrums during matches when compared with
414 training (Table 2 and 3).

415 These findings appear to support the anecdotal belief that
416 training sessions largely consist of skills performed in isolated
417 environments removed from performance contexts⁸. From a
418 match skill demand perspective, previous research has shown
419 changes in decision making based on player positioning²⁶ and
420 variations in movement based on specific task constraints²⁷. The
421 results of the present study would appear to support the need for
422 rugby union training to incorporate greater volume and
423 specificity of skill demands (e.g., contested/opposed lineouts,
424 scrums, rucking and kicking practice).

425 Despite evidence emphasising the importance of training
426 specificity in improving performance^{1,3}, it should be expected
427 that competitive matches include aspects that are different to
428 training sessions. Attempts to precisely replicate match-play
429 during training would likely both decrease skill acquisition and
430 overgeneralise the complex multifactorial strategies of position-
431 specific physical, psychological, technical and tactical
432 development. Coaches are also reluctant to place athletes at
433 further risk of injury during training sessions, particularly
434 throughout in-season periods²⁴. Although a balance between the
435 risk (i.e., fatigue and injury) and reward (i.e., match
436 performance) must be managed, the specificity of current rugby
437 union training practices may be inadequate to elicit optimal
438 training adaptations in a specific practice environment that align
439 with the competitive match-play^{3,7}.

440 Training approaches could be developed that are centred on the
441 integrative and concurrent development of necessary qualities.
442 For example, previous recommendations of skill-based
443 conditioning games and tactical metabolic conditioning
444 scenarios can be periodised into training practices²⁸. This
445 affords the development of a combined tactical and technical
446 approach within environments that imitate competitive matches.
447 The use of modified games requires players to adapt to changing
448 environmental and task constraints (i.e., the positioning of other
449 players, ball positioning, opposition, referee, the wind, sunlight,
450 etc.)^{26,27} and make modifications to their decisions and
451 consequent actions. Additional benefits may be seen while
452 training in a fatigued state, as this has been shown to impair
453 cognitive decision-making skills, and is effective in replicating
454 match-play scenarios^{5,29}.

455 The development of practical solutions to both address the lack
456 of representative match scenarios during training sessions, and
457 to assuage injury risk concerns by coaches is clearly required²⁴.
458 The use of personal protective gear (body armour/padding) and
459 a modification of the skill or situation could provide methods to
460 prepare for these scenarios, and decrease potential injury risk.

461 While careful interpretation of the findings should be applied,
462 alongside practical considerations, it is clear that improvements
463 can be made to pre-professional rugby union training practices.

464 Practical Applications

465 Comparisons between competitive matches and training provide
466 frameworks to develop specific training stimuli, which should
467 efficiently and effectively prepare players for competitive
468 demands. The current study findings indicate the specificity of
469 current rugby union training practices may be inadequate to elicit
470 optimal training adaptations in a specific practice environment
471 that matches competitive demands^{3,7}. Previous research
472 identifying that successful teams win more lineouts on the
473 oppositions throw and are effective at stealing the ball in rucking
474 situations, may provide greater emphasis to these findings^{17,18}.
475 Coaches should attempt to provide position-specific training
476 methodologies to prepare pre-professional rugby union players
477 for competitive match demands. The authors acknowledge the
478 study is limited by data from a single club and season. Future
479 work attempting to assess the efficacy of traditional practice
480 methods, including unopposed training against a constraints-
481 based approach to training in multiple pre-professional rugby
482 union players should be undertaken. This may provide a
483 scientific framework for developing pre-professional players
484 and improving insights into the relative importance of training
485 specificity in contact sports.

486 Conclusion

487 This study provides the first insight into position-specific
488 physiological, perceptual and key match event requirements of
489 pre-professional rugby union training practices and competitive
490 matches. The results emphasise the discrepancies between match
491 demands and training sessions, particularly involving rucking,
492 scrummaging, lineouts and kicking situations. There is clearly
493 an apparent lack of specificity within on-field rugby union
494 training sessions, which may potentially impede training
495 attempts to maximise competitive performance. It is important
496 however to consider the practicalities in replicating match
497 demands during training sessions and the potential negative costs
498 involved. Nonetheless, the results indicate current rugby union
499 training strategies are sub-optimal in preparing players for
500 competitive demands, and new strategies may need to be
501 developed.

502 Acknowledgements

503 The authors have no conflicts of interest to declare. We would
504 like to thank Bryon Davis and Anita Sirotic for their support of
505 this project (SportsMed Corp, Newstead, Australia). Further, we
506 acknowledge Grant Jenkins (GPS Rugby Union Club, Ashgrove,
507 Australia) for his assistance in facilitating data collection, as well

508 as the participants for their cooperation and allowing this
509 research to be conducted.

510 References

- 511 1. Reilly T, Morris T, Whyte G. The specificity of training
512 prescription and physiological assessment: A review. *J*
513 *Sports Sci.* 2009;27(6):575-589.
- 514 2. Hartwig TB, Naughton G, Searl J. Motion analyses of
515 adolescent rugby union players: a comparison of
516 training and game demands. *J Strength Cond Res.*
517 2011;25(4):966-972.
- 518 3. Higham DG, Pyne DB, Anson JM, Hopkins WG, Eddy
519 A. Comparison of activity profiles and physiological
520 demands between international rugby sevens matches
521 and training. *J Strength Cond Res.* 2016;30(5):1287-
522 1294.
- 523 4. Tee JC, Lambert MI, Coopoo Y. GPS comparison of
524 training activities and game demands of professional
525 rugby union. *Int J Sports Sci Coach.* 2016;11(2):200-
526 211.
- 527 5. Roberts SP, Trewartha G, Higgitt RJ, El-Abd J, Stokes
528 KA. The physical demands of elite English rugby union.
529 *J Sports Sci.* 2008;26(8):825-833.
- 530 6. Quarrie KL, Hopkins WG, Anthony MJ, Gill ND.
531 Positional demands of international rugby union:
532 Evaluation of player actions and movements. *J Sci Med*
533 *Sport.* 2013;16(4):353-359.
- 534 7. Passos P, Araújo D, Davids K, Shuttleworth R.
535 Manipulating constraints to train decision making in
536 rugby union. *Int J Sports Sci Coach.* 2008;3(1):125-
537 140.
- 538 8. Phillips E, Davids K, Renshaw I, Portus M. Expert
539 performance in sport and the dynamics of talent
540 development. *Sports Med.* 2010;40(4):271-283.
- 541 9. Pinder RA, Davids KW, Renshaw I, Araújo D.
542 Representative learning design and functionality of
543 research and practice in sport. *J Sport Exerc Psychol.*
544 2011;33(1):146-155.
- 545 10. Duthie GM. A framework for the physical development
546 of elite rugby union players. *Int J Sports Physiol*
547 *Performance.* 2006;1(1):2.
- 548 11. Jones MR, West DJ, Crewther BT, Cook CJ, Kilduff
549 LP. Quantifying positional and temporal movement
550 patterns in professional rugby union using global
551 positioning system. *Eur J Sport Sci.* 2015;15(6):488-
552 496.
- 553 12. Johnston RJ, Watsford ML, Kelly SJ, Pine MJ, Spurrs
554 RW. Validity and interunit reliability of 10 Hz and 15
555 Hz GPS units for assessing athlete movement demands.
556 *J Strength Cond Res.* 2014;28(6):1649-1655

- 557 13. Cunniffe B, Proctor W, Baker JS, Davies B. An
558 evaluation of the physiological demands of elite rugby
559 union using global positioning system tracking
560 software. *J Strength Cond Res.* 2009;23(4):1195-1203.
- 561 14. Rampinini E, Coutts A, Castagna C, Sassi R,
562 Impellizzeri F. Variation in top level soccer match
563 performance. *Int J Sports Med.* 2007(28):1018-1024.
- 564 15. Portillo J, Abián P, Navia JA, Sánchez M, Abian-Vicen
565 J. Movement patterns in under-19 rugby union players:
566 Evaluation of physical demands by playing position. *Int*
567 *J Perform Anal Sport.* 2014;14(3):934-945.
- 568 16. Foster C, Florhaug JA, Franklin J, et al. A new
569 approach to monitoring exercise training. *J Strength*
570 *Cond Res.* 2001;15(1):109-115.
- 571 17. Vaz L, Van Rooyen M, Sampaio J. Rugby game-related
572 statistics that discriminate between winning and losing
573 teams in IRB and Super twelve close games.
574 *J Sports Sci Med.* 2010;9(1):51..
- 575 18. Jones NM, Mellalieu SD, James N. Team performance
576 indicators as a function of winning and losing in rugby
577 union. *Int J Perform Anal Sport.* 2004;4(1):61-71.
- 578 19. Cohen J. *Statistical power analysis for the behavioral*
579 *sciences (rev.* Lawrence Erlbaum Associates, Inc; 1977.
- 580 20. Austin D, Gabbett T, Jenkins D. The physical demands
581 of Super 14 rugby union. *J Sci Med Sport.*
582 2011;14(3):259-263.
- 583 21. Deutsch M, Kearney G, Rehrer N. Time–motion
584 analysis of professional rugby union players during
585 match-play. *J Sports Sci.* 2007;25(4):461-472.
- 586 22. Eaton C, George K. Position specific rehabilitation for
587 rugby union players. Part I: Empirical movement
588 analysis data. *Phys Ther Sport .* 2006;7(1):22-29.
- 589 23. Spencer M, Bishop D, Dawson B, Goodman C.
590 Physiological and metabolic responses of repeated-
591 sprint activities. *Sports Med.* 2005;35(12):1025-1044.
- 592 24. Dawson B, Hopkinson R, Appleby B, Stewart G,
593 Roberts C. Comparison of training activities and game
594 demands in the Australian Football League. *J Sci Med*
595 *Sport.* 2004;7(3):292-301.
- 596 25. Renshaw I, Chow JY, Davids K, Hammond J. A
597 constraints-led perspective to understanding skill
598 acquisition and game play: A basis for integration of
599 motor learning theory and physical education praxis?
600 *Phys Educ Sport Pedagogy.* 2010;15(2):117-137.
- 601 26. Passos P, Cordovil R, Fernandes O, Barreiros J.
602 Perceiving affordances in rugby union. *J Sports Sci.*
603 2012;30(11):1175-1182.
- 604 27. Pinder RA, Davids K, Renshaw I, Araújo D.
605 Manipulating informational constraints shapes

- 606 movement reorganization in interceptive actions. *Atten*
607 *Percept Psychophys.* 2011;73(4):1242-1254.
- 608 28. Gamble P. Periodization of Training for Team Sports
609 Athletes. *Strength Cond J.* 2006;28(5):56-66.
- 610 29. Gabbett TJ. Skill-based conditioning games as an
611 alternative to traditional conditioning for rugby league
612 players. *J Strength Cond Res.* 2006;20(2):306-315.
- 613

Table Headings.

Table 1. Mean \pm SD for backs and forwards of total distance, metres per minute, very high intensity activity, maximum speed, sprint count and sprints per minute for competitive matches and training sessions.

* Significant difference and large effect size compared to the match ($P < 0.05$; $d > 0.80$).

^a Significant difference compared with outside backs ($P < 0.05$).

^b Significant difference compared with centres ($P < 0.05$).

^c Significant difference compared with halves ($P < 0.05$).

^d Significant difference compared with loose forwards ($P < 0.05$).

^e Significant difference compared with lock forwards ($P < 0.05$).

¹ Large effect size compared with outside backs ($d > 0.80$).

² Large effect size compared with centres ($d > 0.80$).

³ Large effect size compared with halves ($d > 0.80$).

⁴ Large effect size compared with loose forwards ($d > 0.80$).

⁵ Large effect size compared with lock forwards ($d > 0.80$).

Table 2.

Notational Analysis (Mean \pm SD) displayed in absolute and relative values during competitive matches and training sessions for backs.

* Significant difference and large effect size compared to the match ($P < 0.05$; $d > 0.80$).

^a Significant difference compared with outside backs ($P < 0.05$).

^b Significant difference compared with centres ($P < 0.05$).

¹ Large effect size compared with outside backs ($d > 0.80$).

² Large effect size compared with centres ($d > 0.80$).

Table 3. Notational Analysis (Mean \pm SD) displayed in absolute and relative values during competitive matches and training sessions for forwards.

* Significant difference and large effect size compared to the match ($P < 0.05$; $d > 0.80$).

Figure Headings.

Figure 1. A comparison of competitive match and training session heart rate values.

* Significant difference and large effect size compared to the match ($P < 0.05$; $d > 0.80$).

Figure 2. A comparison of competitive match and training session sRPE values.

^a Significant difference between matches and training sessions ($P < 0.05$).

¹ Large effect size between matches and training sessions ($d > 0.80$).

Table 1. Mean \pm SD for backs and forwards of total distance, metres per minute, very high intensity activity, maximum speed, sprint count and sprints per minute for competitive matches and training sessions.

Position	Variable	Distance (m)	Total (m·min ⁻¹)	VHIA (m)	VHIA (m·min ⁻¹)	Max Speed (km·h ⁻¹)	Sprint Count (n)	Sprint (m·min ⁻¹)
Outside Backs	Match	6166 \pm 929	70.8 \pm 8.1	400 \pm 170	4.5 \pm 1.8	30.5 \pm 2.4	21.8 \pm 8.3	0.2 \pm 0.09
	Training	4978 \pm 1203*	59.7 \pm 12.5	320 \pm 202	3.8 \pm 2.4	27.4 \pm 1.8*	31.1 \pm 17.9*	0.3 \pm 0.20 ¹
Centres	Match	5482 \pm 1151 ¹	64.0 \pm 7.7	308 \pm 152 ¹	3.5 \pm 1.5	28.4 \pm 2.4 ¹	28 \pm 8.6 ¹	0.3 \pm 0.07
	Training	5217 \pm 1208	59.7 \pm 8.6	307 \pm 173	3.4 \pm 1.6	26.6 \pm 1.4*	40.5 \pm 15.5*	0.4 \pm 0.17 ²
Halves	Match	5760 \pm 885	66.2 \pm 7.7	244 \pm 110 ^{a1}	2.7 \pm 1.2	28.8 \pm 2.2 ¹	27.4 \pm 8.3 ¹	0.3 \pm 0.09
	Training	5259 \pm 1345	60.8 \pm 12.3	227 \pm 230	2.6 \pm 3.0	26 \pm 2.1 ^{*a1}	42.8 \pm 18.3 ^{*a1}	0.4 \pm 0.19 ³
Loose-Forwards	Match	5457 \pm 748 ¹	62.0 \pm 7.8	159 \pm 124 ^{a1,3}	1.8 \pm 1.4	26.1 \pm 3.2 ^{a1,c3,2}	19.2 \pm 8.5 ^{b2,c3}	0.2 \pm 0.09
	Training	4173 \pm 1003 ^{*a1,b2,c3}	48.4 \pm 12.6*	129 \pm 156 ^{a1,b2}	1.4 \pm 1.6	24.4 \pm 2.0 ^{*a1,b2,c3}	25.7 \pm 19.4 ^{b2,c3}	0.2 \pm 0.22
Locks	Match	5278 \pm 1250 ¹	64.1 \pm 6.2	159 \pm 124 ^{a1,b2,3}	1.9 \pm 1.4	25.7 \pm 2.8 ^{a1,c3,2}	16.6 \pm 7.9 ^{b2,c3,1}	0.1 \pm 0.08
	Training	4698 \pm 1120	54.1 \pm 14.9	211 \pm 208	2.3 \pm 2.1	24.8 \pm 2.2 ^{a1,b2}	33.8 \pm 21.2*	0.3 \pm 0.24 ⁵
Front Rows	Match	4885 \pm 1272 ^{a1,c3}	61.6 \pm 8.7	78 \pm 76.3 ^{a1,b2,c3,4,5}	0.9 \pm 0.8	23.8 \pm 3.2 ^{a1,b2,c3,d4,5}	12.6 \pm 6.9 ^{a1,b2,c3,d4}	0.1 \pm 0.07
	Training	4074 \pm 974 ^{*a1,b2,c3,5}	48.7 \pm 12.4*	91.1 \pm 80.2 ^{a1,b2,c3,e5}	1.0 \pm 0.9	23.3 \pm 2.1 ^{a1,b2,c3,d4,e5}	25.3 \pm 19.2 ^{*b2,c3}	0.2 \pm 0.20 ⁶

* Significant difference and large effect size compared to the match ($P < 0.05$; $d > 0.80$).

^a Significant difference compared with outside backs ($P < 0.05$).

^b Significant difference compared with centres ($P < 0.05$).

^c Significant difference compared with halves ($P < 0.05$).

^d Significant difference compared with loose forwards ($P < 0.05$).

^e Significant difference compared with lock forwards ($P < 0.05$).

¹ Large effect size compared with outside backs ($d > 0.80$).

² Large effect size compared with centres ($d > 0.80$).

³ Large effect size compared with halves ($d > 0.80$).

⁴ Large effect size compared with loose forwards ($d > 0.80$).

⁵ Large effect size compared with lock forwards ($d > 0.80$).

Table 2. Notational Analysis (Mean \pm SD) displayed in absolute and relative values during competitive matches and training sessions for backs.

Position	Outside Backs		Centres		Halves	
Variable	Match	Training	Match	Training	Match	Training
Tackles	1.5 \pm 1.0	1.1 \pm 1.5	5.7 \pm 2.6 ^{a1}	2.9 \pm 3.1 ^{*1}	4.5 \pm 2.4 ^{a1,b2}	1.8 \pm 2.2 [*]
Tackles·min ⁻¹	0.01 \pm 0.01	0.01 \pm 0.01	0.06 \pm 0.02	0.03 \pm 0.04	0.05 \pm 0.02	0.02 \pm 0.02
Kicks	6.6 \pm 8.2	0.3 \pm 0.9 [*]	0.2 \pm 0.8 ^{a1}	0.1 \pm 0.4	1.1 \pm 2.9 ^{a1}	0.6 \pm 1.1
Kicks·min ⁻¹	0.07 \pm 0.09	0.004 \pm 0.01 [*]	0.003 \pm 0.01	0.001 \pm 0.004	0.01 \pm 0.03	0.006 \pm 0.01
Kicks under pressure	1.1 \pm 1.9	0.1 \pm 0.4 [*]	0.6 \pm 0.7	0 \pm 0 ^{*1}	3.0 \pm 2.4 ^{a1,b2}	0.6 \pm 1.1 ^{*a1}
Kicks under pressure·min ⁻¹	0.01 \pm 0.02	0.001 \pm 0.004	0.006 \pm 0.007	0.001 \pm 0.004 [*]	0.03 \pm 0.02	0.008 \pm 0.01
Passes	3.3 \pm 2.2	8.6 \pm 8.4 [*]	4.6 \pm 2.4 ¹	10.5 \pm 10.0 [*]	33.6 \pm 15.2 ^{a1,b2}	37.8 \pm 20.6 ^{a1,b2}
Passes·min ⁻¹	0.03 \pm 0.02	0.10 \pm 0.08	0.05 \pm 0.02	0.12 \pm 0.11	0.39 \pm 0.17	0.44 \pm 0.23

* Significant difference and large effect size compared to the match ($P < 0.05$; $d > 0.80$).

^a Significant difference compared with outside backs ($P < 0.05$).

^b Significant difference compared with centres ($P < 0.05$).

¹ Large effect size compared with outside backs ($d > 0.80$).

² Large effect size compared with centres ($d > 0.80$).

Table 3. Notational Analysis (Mean \pm SD) displayed in absolute and relative values during competitive matches and training sessions for forwards.

Position	Loose Forwards		Locks Forwards		Front Row Forwards	
Variable	Match	Training	Match	Training	Match	Training
Tackles	7.2 \pm 3.2 ^{a1,b2}	2.4 \pm 2.6 ^{*1}	6.0 \pm 2.9 ^{a1,3}	2.4 \pm 2.6 ^{*1}	5.6 \pm 3.0 ^{a1}	1.7 \pm 1.8 [*]
Tackles·min ⁻¹	0.08 \pm 0.03	0.02 \pm 0.04	0.07 \pm 0.04	0.02 \pm 0.02	0.07 \pm 0.05	0.02 \pm 0.02
Rucks	12.9 \pm 4.2	1.3 \pm 3.8 [*]	15.0 \pm 6.4	1.0 \pm 4.1 [*]	10.9 \pm 4.5	1.2 \pm 3.6 [*]
Rucks·min ⁻¹	0.14 \pm 0.04	0.01 \pm 0.04 [*]	0.20 \pm 0.12	0.01 \pm 0.04 [*]	0.15 \pm 0.13	0.01 \pm 0.03 [*]
Mauls	3.1 \pm 2.7	1.5 \pm 3.0 [*]	3.3 \pm 3.0	1.9 \pm 3.3	2.9 \pm 2.6	1.8 \pm 3.4
Mauls·min ⁻¹	0.03 \pm 0.03	0.01 \pm 0.03	0.03 \pm 0.03	0.02 \pm 0.03	0.04 \pm 0.04	0.02 \pm 0.04
Scrum	23.4 \pm 3.9	1.8 \pm 3.4 [*]	21.4 \pm 7.2	1.6 \pm 3.2 [*]	21.7 \pm 5.5	1.6 \pm 3.2 [*]
Scrum·min ⁻¹	0.27 \pm 0.06	0.02 \pm 0.06 [*]	0.28 \pm 0.13	0.01 \pm 0.03 [*]	0.31 \pm 0.21	0.01 \pm 0.03 [*]
Lineout Attack	12.7 \pm 4.8	4.3 \pm 5.9 [*]	13.0 \pm 5.1	4.1 \pm 5.4 [*]	12.2 \pm 5.3	3.7 \pm 5.3 [*]
Lineout Attack·min ⁻¹	0.14 \pm 0.05	0.05 \pm 0.08 [*]	0.16 \pm 0.06	0.04 \pm 0.06 [*]	0.17 \pm 0.13	0.04 \pm 0.06 [*]
Lineout Defence	11.6 \pm 2.7	4.1 \pm 6.2 [*]	10.2 \pm 4.3	3.9 \pm 5.6 [*]	10.7 \pm 3.6	3.5 \pm 5.7 [*]
Lineout Defence·min ⁻¹	0.13 \pm 0.03	0.05 \pm 0.08 [*]	0.14 \pm 0.09	0.04 \pm 0.06	0.145 \pm 0.07	0.04 \pm 0.07 [*]

* Significant difference and large effect size compared to the match ($P < 0.05$; $d > 0.80$).

^a Significant difference compared with outside backs ($P < 0.05$).

^b Significant difference compared with centres ($P < 0.05$).

^c Significant difference compared with halves ($P < 0.05$).

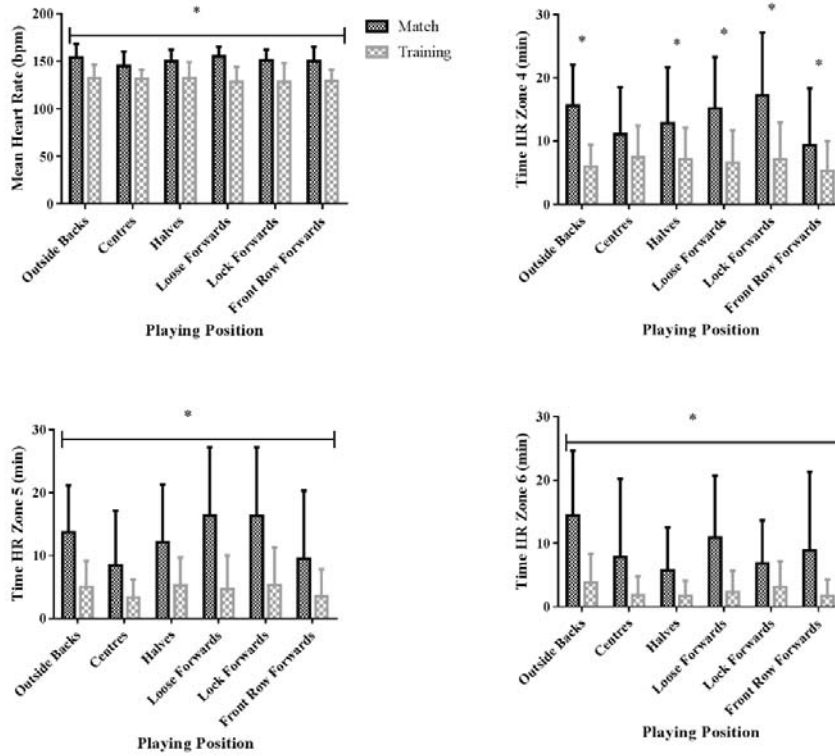
¹ Large effect size compared with outside backs ($d > 0.80$).

² Large effect size compared with centres ($d > 0.80$).

³ Large effect size compared with halves ($d > 0.80$).

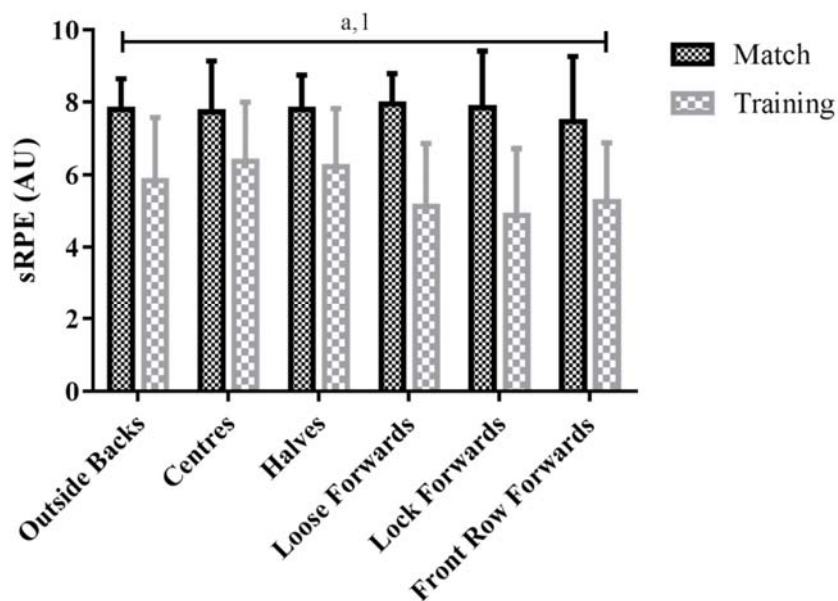
⁴ Large effect size compared with loose forwards ($d > 0.80$).

Figure 1. A comparison of competitive match and training session heart rate values.



* Significant difference and large effect size compared to the match ($P < 0.05$; $d > 0.80$).

Figure 2. A comparison of competitive match and training session sRPE values.



^a Significant difference between matches and training ($P < 0.05$).

¹ Large effect size between positions ($d > 0.80$).