

Please cite the Published Version

Dobbin, Nick, Gardner, Adrian, Daniels, Matt and Twist, Craig (2018) The influence of preseason training phase and training load on body composition and its relationship with physical qualities in professional junior rugby league players. *Journal of Sports Sciences*, 36 (24). pp. 2778-2786. ISSN 0264-0414

DOI: <https://doi.org/10.1080/02640414.2018.1473993>

Publisher: Taylor & Francis

Version: Accepted Version

Downloaded from: <https://e-space.mmu.ac.uk/621558/>

Usage rights: © In Copyright

Additional Information: This is an Author Accepted Manuscript of a paper accepted for publication in *Journal of Sports Sciences*, published by and copyright Taylor & Francis.

Enquiries:

If you have questions about this document, contact openresearch@mmu.ac.uk. Please include the URL of the record in e-space. If you believe that your, or a third party's rights have been compromised through this document please see our Take Down policy (available from <https://www.mmu.ac.uk/library/using-the-library/policies-and-guidelines>)

1 **Title:** The influence of preseason training phase and training load on body composition and
2 its relationship with physical qualities in professional junior rugby league players.

3

4 **Submission Type:** Original Investigation

5

6 **Authors:** Nick Dobbin^{1,2}, Adrian Gardner³, Matt Daniels³, Craig Twist¹

7

8 **Affiliation:** ¹Department of Sport and Exercise Sciences, University of Chester, Chester, UK

9 ² Rugby Football League, Red Hall, Leeds, UK

10 ³ Saint Helens Rugby Football Club, Cowley Training Complex, Saint Helens, UK

11

12 **Corresponding Authors:** Nick Dobbin, University of Chester, Parkgate Road, Chester, CH1

13 4BJ, England.

14 **Work Tel:** 01244 513465

15 **Work Email:** n.dobbin@chester.ac.uk

16

17 Name: Adrian Gardner

18 Email: ade192@hotmail.com

19 Name: Matt Daniels

20 Email: mattdaniels@saintsrlfc.com

21 Name: Craig Twist

22 Email: c.twist@chester.ac.uk

23

24 **Preferred Running Head:** Preseason changes in body composition

25

26 **Abstract Word Count: 200**

27 **Manuscript Word Count: 3996**

28 **Table: 4**

29 **Figures: 2**

30

31

32

33

34

35

36

37

38

39

40

41

42

43

44

45

46

47

48

49

50

51 **Abstract**

52

53 This study investigated changes in body composition in relation to training load determined
54 using RPE and duration (sRPE), and its relationship with physical qualities over a preseason
55 period. Sixteen professional academy players (age = 17.2 ± 0.7 years; stature = 179.9 ± 4.9 cm;
56 body mass = 88.5 ± 10.1 kg) participated in the study. Body composition was assessed before
57 and after each training phase and physical qualities assessed at the start and end of preseason.
58 Across the whole preseason period, skinfold thickness, body fat percentage and fat mass were
59 *most likely* lower (ES = -0.73 to -1.00), and fat free mass and lean mass were *likely to most*
60 *likely* higher (ES = 0.31 to 0.40). Results indicated that the magnitude of change appeared
61 phase-dependent (ES = -0.05 to -0.85) and demonstrated large individual variability. Changes
62 in physical qualities ranged from *unclear* to *most likely* (ES = -0.50 to 0.64). Small to moderate
63 correlations were observed between changes in body composition, and TL with changes in
64 physical qualities. This study suggests training phase and TL can influence a player's body
65 composition; that large inter-participant variability exists; and that body composition and TL
66 are related to the change in physical qualities.

67

68

69

70

71

72

73

74

75 **Key Words:** Collision sport, performance, skinfolds, nutrition.

76 **Introduction**

77 Rugby league is a high-intensity intermittent collision sport, requiring players to possess well-
78 developed speed, strength, power and intermittent running capacity to cope with the demands
79 of training and match-play (Johnston, Gabbett & Jenkins, 2014). Such physical qualities are
80 routinely measured and used to ensure players are conditioned appropriately to perform rugby-
81 specific skills (Gabbett, Jenkins & Abernethy, 2010), evaluate adaptation to training
82 programmes (Morgan & Callister, 2011), talent identification (Johnston et al., 2014) and
83 monitoring the development of players (Waldron, Worsfold, Twist & Lamb, 2014). Whilst we
84 recognise that performance and success in rugby league might be influenced by the complex
85 interaction of an individual's and team's technical and tactical characteristics, much focus has
86 been given to the anthropometric, body composition and physical qualities of players (Johnston
87 et al., 2014).

88

89 Body composition is of particular interest for both practitioners and researchers, as changes in
90 criterion (e.g. DXA) or predictive (e.g. skinfolds) measures of body fat percentage (%BF), fat
91 mass (FM), fat free mass (FFM) and lean mass (LM) can be indicative of adaptation to training
92 (Gabbett et al., 2010; Bradley, Cavanagh, Douglas, Morton, & Close, 2015), physical
93 development (Waldron et al., 2014; Jones et al., 2017) and a player's dietary intake (Smith,
94 Jones, Sutton, King, & Duckworth, 2016). Studies examining body composition of rugby
95 league players have reported differences between playing positions (Morehen, Routledge,
96 Twist, Morton, & Close, 2015), performance standards (Jones et al., 2015) and phase of the
97 competitive season (Harley, Hind, & O'Hara, 2011; Georgeson, Weeks, McLellan, & Beck,
98 2012). Hit-up forwards are heavier, have greater LM, FM and %BF compared to outside backs
99 and adjustable, with small differences between the latter positions (Morehen et al., 2015). Super
100 League players typically have lower %BF and FM, with greater total, leg and trunk LM

101 compared to Championship players (Jones et al., 2015). Seasonal variation also indicates that
102 FM increases and LM decreases during the latter stages of the season (Harley et al., 2011).
103 These findings highlight the importance of body composition in rugby league and support the
104 notion that it should be regularly monitored across the season whilst considering playing
105 position and training status.

106

107 To develop anthropometric and physical qualities, strength and conditioning (S&C) practices
108 are a key component in rugby league, particularly during the preseason period, where S&C
109 coaches have 12-13 weeks to prepare players for competition. Once competition commences,
110 the focus is largely placed on recovery, technical performance and tactical awareness, resulting
111 in a decrease in training volume (Gabbett & Domrow, 2007). To date, several studies have
112 explored the preseason changes in anthropometric and physical qualities in rugby league
113 (Comfort, Haigh, & Matthews, 2012; Morgan & Callister, 2011; Gabbett & Domrow, 2007),
114 suggesting this period is effective for reducing fat mass (-0.6 kg) and percentage body fat (-
115 1.0%), and promoting muscle mass (0.7 kg) in rugby league players (Morgan & Callister,
116 2011). Furthermore, Comfort et al. (2012) observed improvements in sprint times across 5, 10
117 and 20 m as well as greater relative strength (1.78 ± 0.27 *cf.* 2.05 ± 0.21 kg·kg⁻¹). These results
118 concur with those of Argus et al. (2010) who observed reductions in skinfold thickness and
119 FM, and a small increase in FFM after only 6 weeks of rugby union preseason training, which
120 coincided with increases in bench press and box squat. Whilst comparisons between codes
121 should be made with caution, these findings suggest that preseason training ranging from 6 to
122 13 weeks is effective for promoting changes in body composition.

123

124 Typically, the preseason comprises 3-4 periodised phases of varying length (Morgan &
125 Callister, 2011). Each phase will vary depending on the coach, though typically focus on

126 aerobic and anaerobic conditioning, sprinting mechanics, muscular strength and power,
127 flexibility, and rugby-specific skills (Morgan & Callister, 2011; Weakley et al., 2017). Whilst
128 previous research has reported the pre- to post-preseason change in body composition, to our
129 knowledge no one has reported the change in relation to the training phase and training load
130 within each periodised block. How these changes in body composition and training load relate
131 to changes in physical qualities is of interest to support future programming and enable sports
132 nutritionist and players to periodise energy and macronutrient intake (Close, Hamilton, Philp,
133 Burke, & Morton, 2016). Therefore, the aims of this study were threefold: 1). To determine the
134 effects of training phase and training load on group and individual changes in body
135 composition, 2). To explore the individual variability of the change in body composition, and
136 3). To assess the relationship between the overall changes in body composition, total training
137 load and measures of physical qualities.

138

139 **Methods**

140 *Participants*

141 With institutional ethics approval, 16 academy rugby league players (forwards = 8; backs = 8)
142 from a single professional club playing in the Under-19s Super League competition (age, 17.2
143 \pm 0.7 years; stature = 179.9 \pm 4.9 cm; body mass 88.5 \pm 10.1 kg) participated in this study.
144 Players were familiar with all testing procedures and were informed of the benefits and risks
145 associated with this study before providing written informed consent and completing a pre-test
146 health questionnaire. Parental assent was obtained for participants <18 years old. Only players
147 free of injury during the whole preseason period, as confirmed by the club's medical team,
148 were included.

149

150 *Study design*

151 A repeated measures design was used to investigate the changes in body mass, skinfold
152 thickness, %BF, FM, FFM and LM as well as measures of physical qualities. Training load
153 (TL) was recorded for every session and used to assess the relationship between TL and
154 changes in body composition with the change in physical qualities. The preseason training was
155 prescribed by the club's strength and conditioning coach and was divided into three phases
156 (phase 1 = 5 weeks, phase 2 = 4 weeks, phase 3 = 4 weeks + 1-week taper), with the end of
157 phase 1 and start of phase 2 interspersed by a 10-day rest period. A 'typical' week is presented
158 in Table 1. Assessments of body composition were taken before and after each training phase
159 and physical qualities assessed the week before preseason training started and one week before
160 their first competitive fixture. All physical qualities were measured on the club's own artificial
161 pitch by the same researcher.

162

163 **** INSERT TABLE 1 HERE ****

164

165 ***Methodology***

166 *Body Composition*

167 An International Society for the Advancement of Kinanthropometry (ISAK) protocol was used
168 and the same assessor conducted all measurements (intra-rater reliability CV = 0.3-1.3%).
169 Stretch stature was measured using a portable stadiometer (Seca, Leicester Height Measure,
170 Hamburg, Germany) to the nearest 0.1 cm, and body mass (Seca, 813, Hamburg, Germany) to
171 the nearest 0.1 kg. Skinfold thickness was assessed using Harpenden calipers (Harpenden,
172 Burgess Hill, UK) on the right side of the body and included seven sites (triceps, subscapular,
173 biceps, supraspinale, abdominal, thigh, calf). All measures were taken in duplicate with the
174 mean value used, unless the differences exceeded 5%, whereby a third measurement was taken
175 and the median value used. Body density was calculated (Withers et al., 1985) before the

176 following equation was applied to covert body density to %BF: $\%BF = (495/\text{body density}) -$
177 450 (Siri 1956). Fat free mass (body mass – FM) was then calculated using the equation: FFM
178 $= \text{body mass} - (\text{body mass} * \%BF)/100$. Lean mass index was also used to quantify proportional
179 changes in LM using the equation M/S^x ; where M is the log transformed body mass in
180 kilograms, S is log transformed skinfold thickness in millimetres and x represents an exponent
181 for rugby union backs (0.14) (Slater, Duthie, Pyne & Hopkins, 2006).

182

183 *Sprint performance and momentum*

184 Sprint performance was measured using electronic timing gates (Brower, Speedtrap 2, Brower,
185 Utah, USA) positioned at 0, 10 and 20 m. Participants began each sprint from a two-point
186 athletic stance with their driving foot placed 30 cm behind the start line. Participants performed
187 two maximal 20 m sprints recorded to the nearest 0.01 s with two minutes recovery. The best
188 10 and 20 m sprint times were used for analysis (CV = 4.2 and 3.6%, respectively). Momentum
189 was calculated by multiplying body mass by mean velocity (distance / time) over the best 10
190 and 20 m times (Darrall-Jones, Jones, & Till, 2015). Sprint performance and momentum over
191 these distances are reported to be reliable (Dobbin, Hunwicks, Highton, & Twist, 2017).

192

193 *Change of direction*

194 Change of direction (CoD) performance was measured using electronic timing gates (Brower,
195 speedtrap 2, Brower, Utah, USA) placed 150 cm apart and at a height of 90 cm, and required
196 participants to complete two trials (left and right) consisting of different cutting manoeuvres
197 over a 20 x 5 m course with markers position at 0, 5, 15 and 20 m (see Dobbin et al. 2017).
198 Participants started when ready from a two-point athletic stance with their driving foot placed
199 30 cm behind the start line and the times from the left and right were combined and used for
200 analysis (CV = 2.5%) (Dobbin et al., 2017).

201

202 *Countermovement Jump*

203 Participants completed two countermovement jumps (CMJ) with their hands placed on the hips
204 and two minutes recovery between jumps. Participants started upright before flexing at the
205 knee to a self-selected depth and then extending into the jump striving for maximal height
206 keeping their legs straight throughout. Jump height was recorded using a jump mat (Just Jump
207 System, Probotics, Huntsville, Alabama, USA) and corrected (Dobbin, Hunwicks, Highton, &
208 Twist, 2016) before peak height was used for analysis (CV = 5.9%) (Dobbin et al., 2017).

209

210 *Medicine ball throw*

211 To measure whole-body power, participants began standing upright with a medicine ball
212 (dimensions: 4 kg, 21.5 cm diameter) above their head before lowering the ball towards their
213 chest, squatting down to a self-selected depth and extending up onto their toes pushing the ball
214 as far as possible. Feet remained shoulder width apart, stationary and behind a line that
215 determined the start of the measurement. The distance was measured to the nearest centimetre
216 using a tape measure from the start line to the rear of the ball's initial impression on the 3G
217 surface. A trial was not recorded if the participant stepped into the pass, jumped or if the ball
218 landed outside of the measuring area and, in such cases, an additional trial was completed.
219 Participants completed two trials separated by 2-minutes recovery with the furthest distance
220 used for analysis (CV = 9.0%; Dobbin et al., 2017).

221

222 *Prone Yo-Yo Intermittent Recovery Test Level 1*

223 The prone Yo-Yo IR1 was used to measure rugby-specific high-intensity intermittent running
224 ability and required participants to complete as many 40 m (2 x 20 m) shuttles as possible with
225 a 10 s active recovery (walking) between shuttles. Running speed for the test commenced at

226 10 km·h⁻¹ and increased 0.5 km·h⁻¹ approximately every 60 s to the point at which the
227 participants could no longer maintain the required running speed. Unlike the traditional Yo-Yo
228 IR1, participants were required to start each 40 m shuttle in a prone position with their head
229 behind the start line and legs straight, and were allowed two practice shuttles before starting
230 the test. The final distance achieved was recorded after the second failed attempt to meet the
231 start/finish line in the allocated time (CV = 9.9%; Dobbin et al., 2017).

232

233 *Training Load*

234 Thirty minutes after training, away from teammates and coaches, participants were asked to
235 provide a rating of perceived exertion (RPE) for each activity (i.e. gym, skills, conditioning)
236 using 10-point scale, which was subsequently multiplied by duration in minutes to provide a
237 measure of training load (sRPE; Foster et al., 2001).

238

239 *Statistical Analysis*

240 Data are presented as mean ± standard deviation (SD). Magnitude-based inferences (MBI) and
241 effect sizes with 90% confidence limits were used, with effect sizes calculated as the difference
242 between trials divided by the pooled SD for all assessments. This approach was applied to the
243 body composition data to assess the pre-to-post change within each training phase and overall
244 changes (pre-phase 1 to post-phase 3) in body composition measures and physical qualities.
245 Threshold values for effect sizes were: 0.0-0.2, *trivial*; 0.2-0.6, *small*; 0.6-1.2, *moderate*; 1.2-
246 2.0, *large*; >2.0, *very large*. Threshold probabilities for a mechanistic effect based on the 90%
247 confidence limits were: 25-75% *possibly*, 75-95% *likely*, 95-99% *very likely* and > 99.5 *most*
248 *likely* (Batterham & Hopkins, 2006). Effects with confidence limits spanning a likely small
249 positive or negative change were classified as *unclear*. To determine if a change in body
250 composition was practically meaningful when considering the researcher's reliability, the

251 smallest worthwhile changes ($0.2 * \text{pooled SD}$) was added to the coefficient of variations [(TE
252 / grand mean) x 100] to give 75% confidence likely change. To ascertain the relationship
253 between the overall (i.e. pre-phase 1 to post-phase 3) change in body composition measures,
254 TL and changes in physical qualities, Pearson's correlation (r) was used with the following
255 criteria applied: < 0.1 , *trivial*; $>0.1-0.3$, *small*; $>0.3-0.5$, *moderate*; $>0.5-0.7$, *large*; $>0.7-0.9$,
256 *very large*; and $>0.9-1.0$, *almost perfect* and the coefficient of determination included.
257 Statistical analysis was conducted using a predesigned spreadsheet for comparing means
258 (Hopkins, 2006) and correlations coefficient and coefficient of determination (Hopkins 2015).

259

260 **Results**

261 Players' completed $90 \pm 7\%$ of total sessions during the preseason period. Phase 1 consisted of
262 37 ± 1 sessions (14 ± 1 resistance, 12 ± 2 conditioning and 11 ± 1 rugby) and an accumulated
263 TL of 11018 ± 1130 AU (4288 ± 517 resistance, 4206 ± 513 conditioning and 2525 ± 490 AU
264 rugby). Phase 2 included 26 ± 6 sessions (11 ± 2 resistance, 7 ± 2 conditioning and 8 ± 2 rugby)
265 and resulted in a total TL of 7493 ± 1322 AU (3126 ± 658 resistance, 1926 ± 332 conditioning,
266 2441 ± 521 AU rugby). The final phase consisted of 25 ± 2 sessions (10 ± 2 resistance, 4 ± 1
267 conditioning and 11 ± 2 rugby) and an accumulated TL of 4159 ± 839 AU (1788 ± 373
268 resistance, 331 ± 111 conditioning, 2051 ± 482 AU rugby).

269

270 ***INSERT TABLE 2 ABOUT HERE***

271

272 Mean body composition before and after each training phase as well as the whole period are
273 presented in Table 2. Individual changes in body mass, skinfold thickness, %BF, FM, FFM
274 and LM are presented for each training phase in Figure 1 and 2.

275

276 ***INSERT FIGURE 1 ABOUT HERE***

277 *** INSERT FIGURE 2 ABOUT HERE***

278

279 Changes in 10- and 20 m sprint time over the preseason period were *unclear*. Ten and twenty-
280 metre momentum were *possibly* lower and of trivial and small magnitude, respectively. A small
281 to moderate effect was observed for countermovement jump, power pass and prone Yo-Yo IR1
282 scores, which were considered *very to most likely* higher after the preseason period. Change of
283 direction time was *very likely* lower and of a small magnitude after the preseason period (Table
284 3).

285

286 ***INSERT TABLE 3 ABOUT HERE***

287

288 The correlation coefficient and coefficient of determinations between changes in body
289 composition and TL with changes in physical qualities are presented in Table 4.

290

291 ***INSERT TABLE 4 ABOUT HERE***

292

293 **Discussion**

294 This study sought to determine the changes in body composition in relation to training phase
295 and TL, and establish if a relationship existed between body composition and TL with changes
296 in physical qualities over the preseason period. The principle findings were that preseason
297 training phase influenced the change in body composition, with greater changes observed
298 during phase 1 when training load was highest. Results also indicated large individual
299 variability in changes of body composition and that these changes were correlated with the
300 change in physical qualities.

301

302 Mean data revealed that changes in total body mass across each phase and the entire preseason
303 were *most likely trivial*, which might be explained by the contrasting changes in FM and FFM
304 and the inclusion of forward and backs. For example, Morgan & Callister (2011) observed a
305 0.9 kg increase in body mass for rugby league backs, whereas forwards reported a reduction of
306 0.3 kg during a 14-week preseason period. However, it is important to acknowledge the
307 ‘individual’ when interpreting such data as demonstrated in phase one where the percentage
308 change in body mass ranged from -3.8% to 4.1%. Interestingly, the results show that the
309 direction of change for body mass was, for the most part, consistent for each participant (i.e. if
310 they increased in body mass during phase 1, they did for all phases). This possibly indicates
311 that the participants’ nutritional intake remained stable across the preseason period regardless
312 of TL and has important implications for those players who need to adjust their energy intake
313 to increase/decrease body mass to optimize performance and reduce injury risk (Smith et al.,
314 2016).

315

316 A reduction in skinfold thickness was observed after phase 1 and 2 but not phase 3. Over the
317 entire preseason, a moderate change was observed in skinfold thickness reaffirming work of
318 Bradley et al. (2015) and Morgan and Callister (2011) in rugby union and rugby league,
319 respectively. At the individual level, our results indicate that phase 1 and 2, both of which had
320 the highest TL, elicited *most likely* reductions in skinfold thickness, though during phase 3 the
321 changes was somewhat more variable with some individuals increasing their skinfold thickness
322 by 1.3 to 18.3%. Furthermore, the mean absolute and relative body fat were comparable to that
323 reported for Super League players (Morehen et al., 2015; Jones et al., 2015), though it is
324 important to recognise the methodological differences between studies. The overall change in
325 %BF (-3.4%) and FM (-3.3 kg) were larger than that previously observed in rugby union

326 (Bradley et al., 2015; Argus et al., 2010; Smart & Gill, 2013) and rugby league (Morgan &
327 Callister, 2011) players, and might reflect the longer preseason period and large emphasis on
328 conditioning during phase 1. This finding might also be explained by the training age of the
329 participants as it is known that chronological age, biological maturity and training experience
330 can influence the magnitude of adaptation observed in youth rugby league players (Till,
331 Darrall-Jones, Weakley, Roe & Jones, 2017). Almost all players continued to reduce their body
332 fat during phase 2 potentially owing to the higher TL, though changes during phase 3 were
333 considered trivial. Over a competitive season it has been reported that %BF and FM increases
334 towards the end of the season due to a reduced TL (Harley et al., 2011; Georgeson et al., 2012).
335 Our results suggest that some individuals increased body fat when TL was reduced towards the
336 end of preseason. In these situations, it is essential players and staff are aware of the energy
337 requirements for each individual to ensure optimum performance during different stages of the
338 preseason period as an increase in %BF and FM is likely to be detrimental to rugby
339 performance (Jones et al., 2017; Harley et al., 2011; Georgeson et al., 2012).

340

341 Given the physicality of rugby league and the requirements to dominate an opponent during a
342 tackle, increasing lean mass is a key focus during the preseason period (Harley et al., 2011).
343 The assessment of whole body or regional LM is impractical given it requires access to
344 expensive and sophisticated equipment (i.e. DXA) that is not readily available in the applied
345 setting. As such, the use of skinfold measurements and predictive equations for fat free mass
346 and lean mass index has been used and relate ($r = 0.97$ and $r = 0.97$, respectively) to criterion
347 measures of FFM (Delaney et al., 2016). Our results indicate a greater FFM compared to
348 adolescent rugby union players (Smart & Gill, 2013) and semi-professional rugby league
349 players (Morgan & Callister, 2011) but lower than professional rugby union players (Bradley
350 et al., 2015; Argus et al., 2010). Over the preseason period, FFM increased by 2.3 kg on

351 average, with *most likely* increases occurring during phase 1. However, assessing the individual
352 responses, one participant decreased FFM by approximately 2%, suggesting further training or
353 nutritional support (i.e. protein consumption) might be required. This is particularly pertinent
354 in light of the poor nutritional knowledge amongst rugby players (Walsh, Cartwright, Corish,
355 Sugrue, & Wood-Martin, 2011). Responses during phase 2 and 3 were considered *most likely*
356 *trivial* and demonstrated large inter-participant variability. Lean mass index represents the
357 changes in body mass adjusted for changes in skinfold thickness and provides some insight
358 into an individual's LM status. Our results indicate that mean LM increased by 0.8 kg over the
359 preseason period, reaffirming existing observations of 0.8 and 0.7 kg increases in lean mass in
360 rugby league forwards and backs, respectively, over a similar period (Morgan and Callister,
361 2011). Furthermore, the percentage change observed in this study (~2.4%) is consistent with
362 that recommended by Jones et al. (2017) to stay in positive balance after consideration for the
363 1-2% loss over a competitive season (Harley et al., 2011; Georgeson et al., 2012). However,
364 our results suggest that some players might be approaching the season sub-optimally given the
365 association LM has with several physical qualities; and therefore, nutrition, TL and the contents
366 of each training phase requires consideration in order to maximise performance and reduce
367 injury risk.

368

369 Changes in 10- and 20 m sprint times were considered *unclear* between the two assessments
370 and agree with Weakley et al. (2017), who observed trivial changes in rugby union players
371 sprint time after a 12-week preseason period. That body mass was lower after preseason likely
372 explains the *possibly* lower 10- and 20 m momentum scores, though the magnitude of change
373 was considered trivial and small, respectively. Trivial to small correlations existed between
374 changes in body composition and sprint time whereas, small to large correlations were
375 observed with TL and changes in sprint time. Countermovement jump height was *very likely*

376 higher after the preseason period, which is agreement with previous research (Weakley et al.,
377 2017; Smart & Gill, 2013). Further, moderate correlations were observed between resistance,
378 skills and total TL with changes in CMJ height. Similarly, Weakley et al. (2017) reported *very*
379 *large* correlations between the percentage change in CMJ height and total TL, supporting the
380 notion that practitioners should ensure sufficient TL is provided through resistance training and
381 rugby-specific skills (i.e. wrestling) to develop lower-body power. Medicine ball throw
382 performance was *most likely* higher after preseason and was positively correlated with
383 resistance TL, which agrees with Weakley et al. (2017). Change of direction times were *very*
384 *likely* lower after the preseason period with small to moderate positive correlations between
385 changes in some measures of body composition. A *most likely* improvement in prone Yo-Yo
386 IR1 performance was elicited over the preseason period and was higher than the required
387 change for 75% confidence previously reported (Dobbin et al., 2017). Small negative
388 correlations were observed for changes in body mass, skinfold thickness, FM and %BF with
389 the change in prone Yo-Yo IR1 distance, indicating that body mass and excessive body fat
390 might be detrimental for high-intensity intermittent running. These results concur previous
391 work in soccer where a relationship between sRPE-TL and time to exhaustion during the
392 Montreal Track test, lower-body power and sprint performance was observed in junior soccer
393 players (Gill-Rey, Leun, Los Arcos, 2015). In all, the result indicated that changes in body
394 composition over the entire preseason period as well as training load accumulated can influence
395 the anthropometric and physical qualities of youth rugby league players.

396

397 Our results support the notion that TL and the change in body composition can influence
398 physical qualities in rugby league players, though there are some limitations. Dietary intake
399 was not monitored in this study and a single club was used. Therefore, future research might
400 determine the nutritional intake of rugby league players across the preseason period using

401 multiple clubs and explore how this influences measures of body composition. Whilst we have
402 provided the coefficient of determination between variables, future analysis might use a larger
403 sample size and consider step-wise regression to understand the extent to which the change in
404 measures of physical qualities can be explained by changes in body composition and TL.
405 Finally, this study used sRPE to determine training load, which might not fully reflect the
406 psychophysiological construct associated with certain activities and therefore more detailed
407 analyses combining microtechnology and differential RPE to quantify training load (McLaren,
408 Smith, Spears & Weston, 2017) might be considered in the future.

409

410 **Conclusion**

411 For the first time, we provide evidence that training phase and TL is important to consider
412 when assessing body composition during the preseason period in rugby league players. These
413 findings have practical implications for strength and conditioning staff working to develop the
414 physical attributes of rugby league players, and suggest that coaches should provide sufficient
415 TL to optimise body composition and monitor player's dietary intake during the preseason
416 period, particularly during the latter stages. These results support previous work and show large
417 inter-participant variability and therefore suggest that practitioners within rugby league should
418 consider the 'individual' rather than group means. Finally, given the influence changes in body
419 composition and TL can have on improvements in physical qualities over a specified training
420 phase, optimising body composition and providing sufficient TL should be a priority for
421 practitioners.

422

423

424

425

426 **References**

- 427 1. Argus, C. K., Gill, N., Keogh, J., Hopkins, W. G., & Beaven, C. M. (2010). Effects of
 428 a short-term pre-season training programmes on the body composition and anaerobic
 429 performance of professional rugby union players. *Journal of Sport Science*, 28(6), 679-
 430 686.
- 431 2. Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inference about
 432 magnitudes. *International Journal of Sports Physiology and Performance*, 1(1): 50-57.
- 433 3. Bradley, W. J., Cavanagh, B. P., Douglas, T. F., Morton, J. P., & Close G. L. (2015).
 434 Quantification of training load, energy intake, and physiological adaptation during a
 435 rugby preseason: a case study from an elite European rugby union squad. *Journal of*
 436 *Strength Conditioning Research*, 29(2), 534-544.
- 437 4. Close, G. L., Hamilton, D. L., Phil, A., Burke, L. M., Morton, J. P. (2016). New
 438 strategies in sport nutrition to increase exercise performance. *Free Radical Biology and*
 439 *Medicine*, 98, 144-158.
- 440 5. Comfort, P., Haigh, A., & Matthews, M. J. (2012). Are changes in maximal squad
 441 strength during preseason training reflected in changes in sprint performance in rugby
 442 league players? *Journal of Strength Conditioning Research*, 26(3), 772-776.
- 443 6. Darrall-Jones, J. D., Jones, B., (2015). Till, K. Anthropometric and physical profiles of
 444 English academy rugby union players. *Journal of Strength and Conditioning Research*,
 445 29(8), 2086-2096.
- 446 7. Delaney, J. A., Thornton, H. R., Scott, T. J., Ballard, D. A, Duthie, G. M., Wood, L.
 447 G., Dascombe, B. J. (2016). Validity of skinfold-based measures for tracking changes
 448 in body composition in professional rugby league players. *International Journal of*
 449 *Sports Physiology and Performance*, 11, 261-266.
- 450 8. Dobbin, N., Hunwicks, R., Highton, J., & Twist C. (2017). Reliable testing battery for
 451 assessing physical qualities of elite academy rugby league players. *Journal of Strength*
 452 *Conditioning Research*. Advanced online publication. doi:
 453 10.1519/JSC.0000000000002280.
- 454 9. Dobbin, N., Hunwicks, R., Highton, J., & Twist, C. (2016). Validity of a jump mat for
 455 assessing countermovement jump performance in elite rugby players. *International*
 456 *Journal of Sport Medicine*, 38(2), 99-104.
- 457 10. Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S.,
 458 Doeshal, P., & Dodge, C. (2001). A new approach to monitoring exercise training.
 459 *Journal of Strength Conditioning Research*, 15(1): 109-115.
- 460 11. Gabbett, T. J., & Domrow, N. (2007). Relationship between training load, injury, and
 461 fitness in sub-elite collision sports athletes. *Journal of Sport Sciences*, 23(13), 1507-
 462 1519.
- 463 12. Gabbett, T. J., Jenkins, D. G., & Abernethy, B. (2010). Physiological and
 464 anthropometric correlates of tackling ability in junior elite and subelite rugby league
 465 players. *Journal of Strength and Conditioning Research*, 24(11), 2989-2995.
- 466 13. Georgeson, E. C., Weeks, B. K., McLellan, C., Beck, B. R. (2012). Seasonal change in
 467 body, muscle and fat in professional rugby league players and its relationship to injury:
 468 a cohort study. *British Medical Journal Open*, 2(6): e001400.
- 469 14. Gill-Rey, E., Lezaun, A., & Los Arcos, A. (2015). Quantification of the perceived
 470 training load and its relationship with changes in physical fitness performance in junior
 471 soccer players. *Journal of Sport Science*, 33(20), 2125-2132.
- 472 15. Harley, J. A., Hind, K., & O'Hara, J. P. (2011). Three-compartment body composition
 473 changes in elite rugby league players during a super league season, measured by dual-

- 474 energy X-ray absorptiometry. *Journal of Strength and Conditioning Research*, 25(4),
475 1024-1029.
- 476 16. Hopkins, W. G. (2006). Spreadsheets for analysis of controlled trials with adjustment
477 for a subject characteristic. *Sportscience*, 10, 46-50.
- 478 17. Hopkins, W. G. (2015). Spreadsheets for analysis of validity and reliability.
479 *Sportscience*, 19, 36-42.
- 480 18. Johnston, R. D., Gabbett, T. J., & Jenkins, D. G. (2014). Applied sport science of rugby
481 league. *Sports Medicine*, 44(8), 1087-1100.
- 482 19. Jones, B., Till, K., Barlow, M., Lees, M., O'Hara, J. P., & Hind, K. (2015).
483 Anthropometric and three-compartment body composition differences between super
484 league and championship rugby league players: considerations for the 2015 season and
485 beyond. *PLoS One*, 10(7): e0133188.
- 486 20. Jones, B., Till, K., Roe, G., O'Hara, J., Lees, M., Barlow, M. J., & Hind, K. (2017). Six-
487 year body composition change in male elite senior rugby league players. *Journal of*
488 *Sport Science*. Advanced online publication. doi: 10.1080/02640414.2017.
- 489 21. Jones, T. W., Smith, A., Macnaughton, L. S., & French, D. N. (2017). Strength and
490 conditioning and concurrent training practices in elite rugby union. *Journal of Strength*
491 *and Conditioning Research*, 30(12), 3354-3366.
- 492 22. McLaren, S. J., Smith, A., Spears, I. R., & Weston, M. (2017). A detailed quantification
493 of differential rating of perceived exertion during team-sport training. *Journal of*
494 *Science and Medicine in Sport*, 20(3), 290-295.
- 495 23. Morehen, J. C., Routledge, H. E., Twist, C., Morton, J. P., & Close, G. L. (2015).
496 Position specific difference in the anthropometric characteristics of elite European
497 super league rugby players. *European Journal of Sport Science*, 15(6), 523-529.
- 498 24. Morgan, P. J., & Callister, R. (2011). Effects of a preseason intervention on
499 anthropometric characteristics of semiprofessional rugby league players. *Journal of*
500 *Strength and Conditioning Research*, 25(2), 432-440.
- 501 25. Siri, W. E. (1956). Body composition from fluid spaces and density: analysis of
502 methods. *University of California Radiation Laboratory Report*, UCRL no. 3349.
- 503 26. Slater, G. J., Duthie, G. M., Pyne, D. B., Hopkins, W. G. (2006). Validation of a
504 skinfold based index for tracking proportional changes in lean mass. *British Journal of*
505 *Sports Medicine*, 40(3), 208-213.
- 506 27. Smart, D. J., & Gill, N. D. (2013). Effect of an off-season conditioning program on the
507 physical characteristics of adolescent rugby union players. *Journal of Strength and*
508 *Conditioning Research*, 27(3), 708-717.
- 509 28. Smith, D. R., Jones, B., Sutton, L., King, R. F., & Duckworth, L. C. (2016). Dietary
510 intakes of elite 14- to 19-year-old academy rugby league players during a pre-season
511 training period. *International Journal of Sport Nutrition and Exercise Metabolism*,
512 26(6), 506-515.
- 513 29. Till, K., Darrall-Jones, J., Weakley, J. J., Roe, G. A., & Jones, B. L. (2017). The
514 influence of training age on the annual development of physical qualities within
515 academy rugby league players. *Journal of Strength and Conditioning Research*, 31(8),
516 2110-2118.
- 517 30. Waldron, M., Worsfold, P., Twist, C., & Lamb, K. (2014). Changes in anthropometry
518 and performance, and their interrelationships, across three seasons in elite youth rugby
519 league players. *Journal of Strength and Conditioning Research*, 28(11), 3128-3136.
- 520 31. Walsh, M., Cartwright, L., Corish, C., Sugrue, S., & Wood-Martin, R. (2011). The body
521 composition, nutritional knowledge, attitudes, behaviours, and future education needs

- 522 of senior schoolboy rugby players in Ireland. *International Journal of Sport Nutrition*
523 *and Exercise Metabolism*, 21(5): 365-376.
- 524 32. Weakley, J. J., Till, K., Darrall-Jones, J., Roe, G. A., Phibbs, P. J., Read, D., & Jones,
525 B. L. (2017). Strength and conditioning practices in adolescent rugby players:
526 relationship with changes in physical qualities. *Journal of Strength Conditioning*
527 *Research*. Advanced online publication. doi: 10.1519/JCS.0000000000001828.
- 528 33. Withers, R. T., LaForgia, J., Phillans, R. K., Shipp, N. J., Chatterton, B. E., Schultz, C.
529 G., & Leaney, F. (1985). Comparisons of two-, three-, and four-compartment models
530 of body composition analysis in men and women. *Journal of Applied Physiology*, 85(1),
531 238-245.

Figure 1. Individual percentage change during training phase 1 (dark grey), 2 (grey) and 3 (light grey) body mass (A), skinfold thickness (B) and body fat percentage (C). The shaded area represents the SWC combined with TE (%) to provide a meaningful change with 75% confidence. Scores inside the shaded area are consider unclear.

Figure 2. Individual percentage change during training phase 1 (dark grey), 2 (grey) and 3 (light grey) fat mass (A), fat free mass (B) and lean mass index (C). The shaded area represents the SWC combined with TE (%) to provide a meaningful change with 75% confidence. Scores inside the shaded area are consider unclear.