International Female Rugby Union Players' Anthropometric and Physical Performance Characteristics: A Five-Year Longitudinal Analysis by Individual Positional Groups

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Abstract

Longitudinal changes in anthropometric and physical performance characteristics of International female rugby union players were evaluated across 5-seasons, according to field position. Sixty-eight international female rugby union players from a top 2 ranked international team, undertook anthropometric and physical performance measurements across five seasons. Anthropometric and physical performance changes occurred, with skinfolds decreasing between 2015 and 2017 and body mass increasing between 2017 and 2019. Single-leg isometric squat (SL ISO), 0-10 m momentum (0-10Mom) and 20-30 m momentum (20-30Mom) were higher in 2018 and 2019 than all years. Front-row players were characterised by greater SL ISO and 1-RM bench press than inside and outside backs, with higher skinfolds and lower endurance levels than all positions. Between 2017 and 2019, front-row players had larger decreases and increases in endurance and one repetition maximum (1-RM) bench press respectively, compared to all other positions. Forwards had the highest 0-10Mom and 20-30Mom, and scrum-half the lowest, while outside backs had faster 0-10, 30-40, and 40 m (TT40 m) times, and greater peak velocity (V_{max}) compared to forward positions. These longitudinal findings show that physical performance has increased, with anthropometric and performance characteristics becoming more distinctive between positions, among elite female rugby union players.

Introduction

Elite rugby union is a stochastic, intermittent field-based team sport, combining skilled actions with forceful physical contact and varying locomotion intensities, ranging from walking to sprinting (Beard et al., 2019; Cuniffe et al., 2009). The volume of intensive linear high-speed running, accelerating and decelerating appears to be greater at International standard compared to club standard (Beard et al., 2019). Accordingly, the diverse range of physical abilities required to meet the demands of the elite rugby environment, are also superior amongst elite performers compared to lesser standards of play (Argus et al., 2012; Quarrie et al., 1995; Smart et al., 2013). The advent of professionalism in the male game has resulted in longitudinal position-specific changes in physical characteristics, such as greater height and body mass and lower fat mass (Fuller et al., 2012; Hill et al., 2018). Based on findings from male rugby union, physical performance characteristics, such as strength, power, sprint speed and momentum, and endurance capacity (Argus et al., 2012; Smart et al., 2013) are also greater among professionals compared to lower-standard players. However, such physical performance determinants have not yet been reported in female rugby union. Whilst professionalism was introduced in female rugby union in 2017, with many nations currently supporting part-, and full-time training programmes, there is no longitudinal evidence of either the magnitude or type of physical adaptations among elite female players.

Differences in physical characteristics between female forwards and backs are less pronounced compared to the male game (Quarrie et al., 1995; Smart et al., 2013), and are limited to greater jump and sprint performance amongst backs, and greater total

83 mass and fat mass amongst forwards (Hene et al., 2011; Nyberg et al., 2016). These

84 positional differences are also less clear at lower standards, suggesting that physical

85 performance and anthropometric characteristics in female rugby are less pronounced.

86 This is, perhaps, due to the specialised training and selection processes at

87 international standard (Hene et al., 2011; Nyberg et al., 2016). However, the

88 rudimentary categorisation of players into forwards and backs positional groups may

89 limit the current understanding of specific positional characteristics in the female

90 game, as differences in anthropometric and physical performance characteristics

91 between more discrete positions are evident in male rugby (Smart et al., 2011). A

92 recent study by Posthumus et al. (2020) reported that front row and locks were heavier

93 and had greater body fat than back row forwards within a top two World-ranked female

94 rugby union cohort. This is presumably because of the greater demand for intensive

95 static force production of the front five in set piece events, such as scrummaging, and

96 suggests that more discrete positional differences are apparent at the elite-standard

97 of female rugby. However, there have been no reports of elite female physical

98 performance characteristics using more refined positional categorisation, which could

99 limit both the specificity of training programmes delivered to these athletes and the

100 early identification of developmental athletes with the innate physical potential required

101 for elite-standard performance. Furthermore, the absence of longitudinal data,

102 spanning the transition from amateur to professional status in elite female players,

103 limits understanding of the impact of professionalism on physical and performance

104 characteristics.

105

106 The aim of this study was to conduct the first longitudinal analysis of anthropometric

107 and physical performance characteristics in elite international female rugby union

108 players. The differences in physical characteristics were evaluated between: i) discrete

109 field positions ii) five consecutive years of an elite female rugby program (2015-2019).

110

111

112 **Materials & Methods**

113 *Participants*

114 To evaluate changes in physical characteristics across time, a five-year longitudinal

115 analysis of anthropometric and physical performance assessment scores was

116 conducted between 2015 and 2019, using samples from an international team ranked

117 in the top 2 nations across the study period. The team achieved world cup finalist

118 status in 2014 and 2017. A total of 68 international female rugby union players took

119 part across the five seasons (players observed per season; 38 ± 3), with a minimum

120 of five international caps per player set as the inclusion criteria for an established

121 international player (age 25 ± 4 years, stature 170.6 ± 7.0 cm, body mass 76.9 ± 9.8

122 kg). Due to variation in the squad personnel throughout the study, players were

123 involved in five (*n* = 14), four (*n* = 13), three (*n* = 19), two (*n* = 14) and one (*n* = 8)

124 seasons of data collection. Players undertook an extensive annual periodised physical

125 training programme during the study period, which was prescribed by the same

126 national Strength & Conditioning coach and delivered in collaboration with each

127 player's domestic club practitioner. During off-season holiday periods, which

128 accounted for approximately three-weeks of the year; players were not prescribed any

129 formal training and did not play matches. For the remainder of the year, the

130 approximate weekly programme consisted of strength sessions (two during

131 international competitions, up to six during pre-season training, and approximately

132 during domestic competition periods); conditioning sessions (zero during international

133 competitions, approximately four during pre-season, and up to three during domestic

134 competition depending on individual requirements); skill-based sessions (two during

135 international competitions, five during pre-season, and approximately three during

136 domestic competition); and rugby matches (up to two during international

137 competitions, zero during pre-season, and one during domestic competition). During

138 each season, a standardised battery of anthropometric and physical performance

139 assessments was carried out three times with a total of 567 individual observations for

140 the standardised battery of assessments (observations per season; 113 ± 7). For

141 comparative purposes, players were grouped into six positional roles, comprising

142 front-row forwards (FR) (n = 15), locks (L) (n = 7), back-row forwards (BR) (n = 11),

143 scrum-halves (SH) (n = 6), inside backs (IB) (n = 13) and outside backs (OB) (n = 16).

144 Players provided informed consent to allow data to be used for analysis purposes

145 through their contractual agreement with the national governing body. Institutional

146 ethics approval was granted for the study (SMEC_2018-19_057).

147

148 *General procedures*

149 Assessments were conducted at three specific points during each season, which

150 corresponded with the 'late physical development' stage before major competitions

151 (early-September, early-January, late-June). Assessments were conducted at a

152 standardised International athletics training facility, which were consistent throughout

153 the five seasons and were delivered by the same practitioners. The overall score for

154 each year used in the analysis was calculated as a participant's mean score for the

155 assessments completed in that year.

156

157 *Assessments*

158 Players undertook anthropometric and strength and power assessment protocols in

159 the morning between 09:30 and 12:00 and completed sprint and endurance running

160 assessment in the afternoon between 14:30 and 16:00, with a standardised break of

161 approximately 2.5 h between sessions. Peer and assessor verbal encouragement was

162 given throughout all the physical performance assessments.

163

164 *Body mass and skinfolds*

165 Participants recorded their body mass before breakfast in an overnight fasted state

166 during which only water was consumed. Participants wore shorts, vests and

167 undergarments only, using calibrated electronic scales (Seca, London, UK). The mass

168 of clothing was uncorrected in the final measurement. The sum of eight skinfolds

169 (bicep, tricep, subscapular, supraspinale, suprailiac, abdomen, mid-thigh, medial calf)

170 was measured due to this method's relative ease of delivery, low cost and consistent

171 evidence of high reliability (Kasper et al., 2021). Skinfold thickness was taken using

172 Harpenden calipers (British Indicators, Hertfordshire, United Kingdom) and

173 standardised protocols according to the International Society for the Advancement of

174 Kinanthropometry (ISAK) were implemented by the same level 3 ISAK practitioner with

175 sampling experience of over 500 athletes, and a technical error of measurement of

176 <2% within this elite female cohort.

177

178 *Single leg isometric squat*

179   Participants completed a general warm-up, consisting of dynamic mobility exercises,

180   bodyweight lunges, squats and good mornings, followed by three progressive

181   submaximal single-leg isometric pushes against a pre-loaded barbell, suspended on

182   fixed pins in a power rack. All participants were familiarised with the assessment

183   protocol two days before the test. Participants then performed a maximum of 3 trials

184   of the single leg isometric squat (Hart et al., 2012), with 5 min rest between trials. The

185   reliability of the protocol has been previously established for elite rugby players (CV

186   <4.7% and ICC >0.96) (Hart et al., 2012). A customised power rack with integrated

187   isometric rig and a force platform installed at floor height was used. The force platform

188   and analysis software used between 2015 and 2016 (400-series, Ballistic

189   Measurement System, Fitness Technology, Adelaide, Australia) differed to that used

190   between 2017 and 2019 (FD4000, Force Decks, Vald Performance, Brisbane,

191   Australia). Whilst the former had a lower sampling frequency (600 and 1000 Hz

192   respectively), the variation in peak force between systems with such sampling

193   frequency differences has been reported (CV <3.7% and ICC >0.96) (Dos Santos et

194   al., 2016). Absolute peak force (SL ISO) and force relative to body mass (SL

195   ISO/kgBM) were used for analysis.

196

197   *Single leg drop jump*

198   Single-leg drop jumps (SL DJ) were used to indirectly assess reactive stiffness under

199   fast stretch-shortening cycle (SSC) conditions (Schmidtbleicher., 2002), which is

200   associated with sprint speed and change of direction (Maloney et al., 2017).

201   Participants hopped from a 20 cm box, with hands fixed on their hips, onto a jump mat

202   (Kinematic Measurement Systems, Innervations, Australia), landing on the same leg

from which they hopped. Upon landing participants rebounded as high as possible with minimal ground contact time (Maloney et al., 2017) and instructions were given to jump 'high and fast'. Participants carried out 6 jumps per leg, alternating between left and right with 30 s separating each trial. The initial 3 jumps per leg was used for task familiarisation (Maloney et al., 2017) and the average of the final 3 jumps used for analysis. Trials were discarded and repeated if ground contact time was greater than 250 ms (Schmidtbleicher., 2002). The reactive strength index (RSI) was quantified by the software package automatically (Kinematic Measurement Systems, Innervations, Australia) through the division of flight (ms) time by contact time (ms) and the maximum RSI was recorded for analysis (Bishop et al., 2019). Levels of reliability for RSI have been previously reported (CV ~5%, ICC ~0.95; Beattie & Flanagan, 2015).

Counter-movement jump

Counter-movement jump peak power output (CMJ PPO) and relative power output (CMJ PPO/kg BM) were derived from jumps on a force platform (Joffe & Tallent., 2020), the reliability of which has been demonstrated (CV < 2.9% and ICC > 0.97; Markovic et al., 2004). Participants stood on a force platform (Fitness Technology, Adelaide, Australia between 2015 and 2017, and Vald Performance, Brisbane, Australia, between 2017 and 2019) with a self-selected stance width, and hands on hips to reduce contribution of the upper-body to jump outcomes (Mosier et al., 2019). Participants performed a counter-movement to a self-selected depth and jumped as high as possible, with the legs remaining straight during the flight phase, before landing with straight knees to ensure consistency of measurement (Markovic et al.,

227 2004). A maximum of five trials, separated by 1-min rest between trials, were

228 performed until participants achieved their highest score, which was taken for analysis.

229

230 *One-repetition maximum bench press*

231 Participant's maximum upper-body strength was assessed using a one-repetition

232 maximum (1-RM) bench press protocol (Appleby et al., 2012, Hene et al., 2011) which

233 has demonstrated sufficient reliability (CV ~5%, ICC ~0.94; Ritti-Dias et al., 2011;

234 Dong-il et al., 2012). Before maximal attempts, participants carried out a progressive

235 warm up of 10 repetitions at 60% maximum, five repetitions at 80%, three repetitions

236 at 80% and one repetition at 90%, with a 3-min rest period between warm-up sets. A

237 maximum of five progressive 1-RM attempts were then permitted with a minimum of

238 five minutes rest between attempts until a 1-RM was achieved. Grip width was

239 standardised between 150 and 200% of bi-acromial breadth for optimal performance

240 (Wagner et al., 1992). Participants were required to maintain contact between their

241 hips and the bench, and their feet and the floor, and to touch the barbell on their chest

242 for each attempt to be counted. The absolute and relative weight lifted in kg (Bench 1-

243 RM & Bench 1-RM/kg BM) was recorded for analysis.

244

245 *Acceleration and peak speed*

246 Participants performed three trials of a maximal 40 m sprint on a 110 m indoor sprint

247 track in trainers with a minimum of 5-min rest between trials. 40m was chosen in line

248 with previous reports for female rugby union players (Nyberg & Penpraze., 2016; Hene

249 et al 2011) and to represent the peak sprint distances experienced in female rugby

250 union (Suarrezz-Arrones et al., 2016). Timing gates (Brower timing systems, Utah,

251 USA) were positioned at 0, 10, 20, 30 and 40 m, with the first gate lowered to 50 cm

252 and the start line positioned 50 cm behind the first gate to minimise the risk of false

253 signals (Haugen & Bucheit., 2016). Subsequent gates were set at 85 cm, or

254 approximately hip height for this population (Cronin & Templeton., 2008; Yeadon et

255 al., 1999). Participants initiated the sprints from a two-point stance with the front foot

256 placed 0.5 m behind the start line. The best 40 m sprint (TT40 m) was recorded and

257 splits for 0-10 m and 30-40 m were used to represent acceleration and maximum

258 running ability respectively. Such split measurements are shown to be reliable (CV

259 ~5%, Darrall-Jones et al., 2016). Before the sprints, participants performed a

260 standardised warm-up consisting of general dynamic mobility and jogging, and

261 progressive intensity running.

262

263 *Momentum and Force-Velocity variables*

264 Momentum was calculated for both 0-10 m (0-10 Mom) and 20-30 m (20-30 Mom)

265 splits due to the decisive role of this variable for winning collisions (Cunningham et al.,

266 2018; Baker & Newton., 2008). For the calculation of mechanical sprint variables, 0.5

267 s was added to the initial split to correct for initial triggering (Haugen et al., 2019) due

268 to the athlete's start position being 0.5 m behind the first speed cell. This mitigated for

269 any additional momentum that may have been built before the triggering of the sprint

270 start as the initiation of force in propulsion and the triggering of the initial speed cell

271 must be closely aligned as a condition for accurate F-V profiling (Morin & Samozino,

272 2016).

273

274 The following variables were derived from the modelling of the entire power-force-

275 velocity relationship using a purpose-built spreadsheet (Morin & Samozino, 2016)

276 which integrated body mass, split times and atmospheric pressure and ambient

277 temperature set at 760 mm Hg and 17 ^{0}C, respectively. These conditions were

278 consistent for each testing session according to the typical training and competition

279 conditions set by the International athletics training facility. The maximum theoretical

280 horizontal force (F_0) per unit of body mass, corresponding to the initial push off in sprint

281 acceleration, and computed as the y-intercept of the linear F-V relationship. The

282 maximum mechanical power output in the horizontal direction (P_{max}), referring to the

283 apex of the Power-Velocity 2nd degree polynomial relationship. The maximum ratio of

284 force (RF_{max}), calculated as the maximum ratio of the step averaged horizontal

285 component of the ground reaction force to the corresponding resultant force. The rate

286 of decline in the ratio of force with increasing speed (DRF) computed as the slope of

287 the RF-V relationship. These variables are shown to be higher in elite sprinters due to

288 a superior ability to efficiently apply propulsive force and have been shown to be

289 sensitive to specific training interventions (Cahill et al., 2020; Haugen et al., 2019).

290

291 *Endurance Testing*

292 Participant's aerobic running fitness was assessed using a 1200 m continuous run on

293 a 100 m indoor running track (12 x 100 m shuttles). This test was chosen for ease of

294 delivery with large participant numbers, to control for adverse weather conditions and

295 to minimise protocol time. 1200m continuous time trials, and shuttle based derivates,

296 are demonstrated to be valid and reliable measures of aerobic running performance

297 (CV ~10%, ICC ~0.9), (Brew & Kelly., 2014; Swaby et al., 2016). Mean aerobic speed

298 was calculated by dividing total distance by the time to completion in seconds (m/s).

299

300 Statistical Analysis

301 Linear mixed-modelling was conducted (SPSS v.22.NY.IBM Corporation) to evaluate

302 the fixed effects of season (2015-2019) and position, consisting of front-row forwards

303 (FR), locks (L), back-row forwards (BR), scrum-halves (SH), inside backs (IB), and

304 outside backs (OB). The random effects were individual players for all analyses. All 24

305 dependant variables were analysed using separate models. Where fixed factors were

306 significant ($p < 0.05$), *post-hoc* Bonferroni comparisons were conducted to determine

307 differences between standards. Significance was accepted as $p < 0.05$ for all null

308 hypothesis testing.

309

310 **Results**

311 Linear mixed modelling revealed significant effects of season for body mass ($p <$

312 0.001), skinfolds ($p < 0.001$), SL ISO ($p < 0.001$), SL ISO/BM ($p < 0.001$), CMJ height

313 ($p < 0.001$) CMJ PPO ($p < 0.001$), bench press 1 RM ($p < 0.001$), 0-10 m ($p < 0.001$),

314 30-40 m ($p < 0.05$), TT40 m ($p < 0.001$), 0-10 Mom ($p < 0.001$), 20-30 Mom ($p < 0.001$),

315 P_{max} ($p < 0.001$), F_0 ($p < 0.001$), RF_{max} ($p < 0.001$) and DRF ($p < 0.05$). Pairwise effects

316 are shown in Table 1 and descriptive data is shown in tables 2 (anthropometry and

317 strength variables), 3 (jumping and force-velocity derived variables) and 4 (sprint and

318 endurance variables).

319

320   Effects of position were shown for body mass ($p < 0.001$), skinfolds ($p < 0.001$), SL

321   ISO ($p < 0.001$), SL DJ ($p < 0.001$), CMJ height ($p < 0.001$), CMJ PPO/BM ($p < 0.001$),

322   0-10 m ($p < 0.001$), 30-40 m ($p < 0.001$) and TT40 m ($p < 0.001$), V_{max} ($p < 0.001$), 0-

323   10 Mom ($p < 0.001$), 20-30 Mom ($p < 0.001$), F_0 ($p < 0.001$), P_{max} ($p < 0.001$), RF_{max}

324   ($p < 0.001$) and endurance ($p < 0.001$). Pairwise effects are shown in Table 1 and

325   descriptive data is shown in tables 2 (anthropometry and strength variables), 3

326   (jumping and force-velocity derived variables) and 4 (sprint and endurance variables).

327

328   There were season x position interactions for CMJ height ($p < 0.001$), bench press 1-

329   RM/BM ($p < 0.05$), 0-10 m ($p < 0.05$), 30-40 m ($p < 0.05$), RF_{max} ($p < 0.05$), DRF ($p <$

330   0.05) and endurance ($p < 0.05$). Pairwise differences are shown in Tables 2

331   (anthropometry and strength variables), 3 (jumping and force-velocity derived

332   variables) and 4 (sprint and endurance variables).

333   ***Insert Table 1 near here***

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337   ***Insert Table 2 near here***

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341   ***Insert Table 3 near here***

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349 **Discussion**

350 The aim of the current study was to assess, for the first time, the physical

351 characteristics of elite female rugby union players i) across time (seasons 2015-2019),

352 and ii) between positions. The main findings of the study were that body mass,

353 strength, power and sprint momentum increased across time, while body fat

354 decreased. Anthropometric and physical performance characteristics were, in many

355 cases, specific to position, and for FR and OB, positional characteristics became more

356 distinct across time.

357

358 We show that body mass increased across time among elite female players, despite

359 no change in stature, which agrees with previous longitudinal observations of senior

360 international male players, transitioning between amateur and professional

361 generations (1955 – 2015; Hill et al., 2017). However, the rate of increase across a 5-

362 year period (~ 6.5%) amongst this elite female cohort is descriptively greater than the

363 first 10 years following professionalism in male rugby (~ 3.8%; Hill et al., 2017).

364   Despite no significant position x time interactions, we also show similar trends to male

365   rugby, whereby the rate of mass gain is descriptively fastest amongst FR and IB (11.8

366   and 9.1% respectively). Furthermore, skinfolds were reduced in 2016 compared to

367   2015 followed by a further drop in 2019. When accompanied by the overall increase

368   in body mass, this suggests that total lean mass has increased amongst elite female

369   players across consecutive seasons. Presumably, this is accounted for by progressive

370   volume and specificity of training with professionalism, alongside more specific

371   selection practices (Fuller et al., 2012; Hill et al., 2017).

372

373   Greater lean body mass can differentiate between elite and sub-elite male rugby

374   athletes (Fontana et al., 2015; Jones et al., 2015) and is associated with the ability to

375   win collisions due to greater momentum and perform repeated high-intensity efforts

376   (Baker & Newton., 2008; Cunningham et al., 2018). Indeed, we also report greater 0-

377   10 m momentum and upper-body strength, particularly amongst FR and L, in 2019

378   compared to any other year. This finding suggests the evolution of physical

379   characteristics observed are highly specific to the typically high collision and contact

380   demands of FR and L (Beard et al., 2019). The increase in momentum may be

381   underpinned by the greater absolute leg force and power in 2019 compared to all years

382   except 2018, whilst players maintained relative leg power and reactive leg stiffness

383   over the five seasons. Therefore, the increase in body mass was not to the detriment

384   of 40 m sprint performance and maximal velocity, which remained unchanged. Despite

385   this longitudinal trend in sprint performance, a decline in initial acceleration (0-10 m),

386   particularly among FR, L and IB, occurred between 2017 and 2018 but improved in

387   2019. This improvement in acceleration could be partly explained by increases in the

388   mechanical sprint characteristics of RF_{max}, and P_{max}, suggesting that players optimised

389   their power application during the initial sprint start, perhaps due to greater training

390   emphasis on acceleration development during 2019.

391

392   The decline in endurance ability of FR, L and IB in the final two years of testing

393   occurred alongside increased mass, strength and momentum profiles, particularly for

394   FR, who's bench press performance had increased disproportionately compared to all

395   other positions by 2019. Such specific longitudinal adaptations may represent more

396   intensive positional demands in static contact and collision events. Furthermore, the

397   magnitude of difference in endurance performance between positions also increased

398   in 2018 and 2019. For example, unlike any other years, in 2019 FR showed poorer

399   endurance performance than all positions except L, and OB were superior to all

400   forwards positions in this regard. The IB also had greater endurance than L in 2016

401   and 2017, but not in 2018 or 2019. Our finding that the endurance capacity of OB was

402   maintained and was comparable with SH is consistent with previous reports among

403   international female players (Kirby & Riley, 1993), as well as being similar to trends

404   reported in male rugby (Quarrie et al.,1996; Smart et al., 2013). The OB also had

405   greater relative leg power, acceleration, peak velocity, P_{max} and RF_{max} and lower DRF

406   values compared to all forward positions, which highlights the varied qualities required

407   to perform as an OB in the modern female International game.

408

409   Other positional groups displayed distinctive characteristics, which would support their

410   ability to perform specific match actions. For example, FR were stronger than all

411   backline positions and had greater body mass, skinfolds and momentum over 10 m

412   than all other positions, except for L, reflecting the forceful demands of the set piece,

413   mauling and tackling actions (Duthie et al., 2003). Similar trends of greater strength

414   and lower endurance capacity among forwards have been reported for female players

415   (Kirby & Riley 1993). The higher body mass among FR is also consistent with male

416   rugby players (Quarrie et al., 1996; Smart et al., 2013) and supports the high

417   scrummaging forces necessary for this positional group (Quarrie et al., 2000).

418

419   Consistent with observations in male rugby players (Quarrie et al., 1996), SH had

420   lower acceleration momentum than all other positions, but jumped higher than L and

421   BR. This suggests the requirement for explosive agility to move quickly between rucks

422   and distribute the ball effectively (Quarrie et al., 1996). Differences between L, BR and

423   IB were less pronounced, with IB showing greater peak velocity and RF_{max} compared

424   to L and BR, and greater SL DJ, compared to BR, whilst L had greater acceleration

425   momentum than IB. These positional characteristics are consistent with trends in male

426   rugby, where IB were faster than forwards (Smart et al., 2013). However, in contrast

427   to our findings, male BR have been reported to have lower body mass and body fat

428   composition than L (Fontana et al., 2015), whilst SH are also lighter than centres

429   (Durandt et al., 2006). Although we show identical inter-positional trends, statistical

430   significance was not reached, suggesting that body mass is a more homogenous

431   physical characteristic amongst elite female players, with the exception of FR, who

432   were heavier than all positions except L. The female game is less mature in its

433   professional status and, subsequently, player stature may be less specialised than the

434   male game according to positional demand (Fuller et al., 2013; Hill et al., 2017). This

435   is noteworthy, since stature will partly determine these body mass differences (Hill et

436   al., 2017). Furthermore, the female game is historically associated with lower kicking

437   outputs and a tendency to attack more with the ball in hand (Hughes et al., 2017),

438 perhaps resulting in a more continuous style of play. If this is the case, a more

439 homogenous body shape might be expected, as reported among Seven's players,

440 which is a rugby code characterised by a greater density of play and minimal

441 requirement for specialised body shapes for the set-piece (Agar-Newman et al., 2015;

442 Ross et al., 2015).

443

444 Higher relative strength and power levels among male players are associated with

445 critical match performance indicators at elite-standard (Cunningham et al., 2019)

446 suggesting that these physical characteristics are vital. Elite male strength athletes

447 typically have ~25% greater relative strength and power outputs than elite females

448 (Owens., 2011; Zupan et al., 2009). We show relative upper-body strength amongst

449 elite females to be ~20% lower than reported for elite male rugby players (Smart et al.,

450 2013; Appleby et al., 2016), whilst relative lower-limb force and power was ~15% lower

451 than elite male rugby league players (Speranza et al., 2016) using similar testing

452 methods. The larger sex discrepancy between upper-limb capabilities might have

453 been anticipated, since female athletes have a smaller volume of their total lean tissue

454 distributed in the upper-body compared to males (Marcovic & Sekulic, 2006). On the

455 assumption that strength and power characteristics have similar importance among

456 female players, we suggest that further development of relative upper-limb strength

457 and power may provide a good return on training investment. Further research is

458 required to understand the role of these physical characteristics on match

459 performance.

460

461 In conclusion, we provide rugby practitioners, for the first time, with normative data of

462 physical characteristics among international female rugby players at a positional level,

463 and how these have changed across seasons. Changes in body composition, strength

464 and power occurred, across the last five years, particularly amongst FR players, while

465 endurance declined for FR, L and IB. These changes likely underpin the progression

466 in sprint momentum and could be associated with performance during contact events

467 and set-piece (Baker et al., 2008; Cunningham et al., 2018), and rapid speed and

468 directional changes, which are commonplace in modern female rugby. These findings

469 can be used to develop future normative data on some of the World's most elite female

470 players, provide training guidance for players of different positional groups, and inform

471 physical criteria for talent identification.

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477 **Declaration of Interest Statement**

478 The authors report no conflict of interest. No funding was provided in support of this

479 research.

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Table 1. Fixed effect pairwise comparisons for season and position among elite female rugby union players across five seasons.

	Season effect	Position effect
Stature (cm)	-	-
Body mass (kg)	[2017,2018,2019 > 2015] [2016, 2019 > 2017]	[FR,L,BR > SH,IB,OB] [FR > BR]
Skinfolds (mm)	[2016,2017,2018,2019 > 2015] [2019 > 2016]	[FR > L,BR,SH,IB,OB]
Endurance (m/s)	-	[L,BR,SH,IB,OB > FR] [OB > L]
Single leg drop jump (ft/ct)	-	[IB,OB > FR] [IB > BR]
Counter movement jump height (cm)	[2019 > 2015,2016,2017]	[OB > L,BR,IB] [SH > L,BR]
Counter movement jump peak power output (W)	[2019 > 2015,2016,2017] [2018 > 2015]	-
Counter movement jump relative peak power output (W/kg)	-	[OB > FR,L,BR]
Single leg isometric squat peak force (N)	[2016,2017,2018,2019 > 2015] [2018,2019 > 2016,2017]	[FR > SH,IB,OB] [L > SH,OB]
Single leg isometric squat relative peak force (kg/kgBM)	[2017,2018,2019 > 2015] [2018,2019 > 2016]	-
Bench press 1 repetition maximum (kg)	[2019 > 2015,2016,2017,2018]	[FR > IB,OB]
Relative bench press 1 repetition maximum (kg/kgBM)	-	[SH > L]
0-10 m sprint (s)	[2018 > 2015,2017,2019] [2016 > 2015]	[FR,L,BR > OB], [FR > IB]
30-40 m sprint (s)	[2018 > 2015]	[FR,L,BR > IB,OB] [SH > OB]
40 m sprint (s)	[2016,2017,2018 > 2015] [2018 > 2019]	[FR,L,BR > IB,OB]
Theoretical maximum velocity (m/s)	-	[OB > FR,L,BR,IB] [IB > FR,L]
0-10 momentum (kg/m/s)	[2019 > 2015,2016,2017,2018]	[FR,L,BR,IB,OB > SH] [FR,L >IB,OB] [FR > BR]
20-30 momentum (kg/m/s)	[2019 > 2015,2016,2017]	[FR,L,BR,IB,OB > SH] [FR,L > IB,OB]
Theoretical maximum force (N)	[2019 > 2016, 2018, 2017 > 2018]	[FR,L > SH,IB,OB] [BR > SH]
Theoretical maximum power (W/kg)	[2015,2017,2019 > 2018] [2015 > 2016]	[FR,L,BR > IB,OB]
Maximum ratio of force (%)	[2015,2017,2019 > 2018]	[OB > FR,L,BR] [IB > FR]
Rate of decline in the maximum ratio of force (%)	[2018 > 2017]	[OB > FR]

FR, L, SH, IB, OB denote Front row, Lock, Scrum half, Inside back, Outside back, respectively. – denotes no fixed effect found, > denotes greater than

Table 2: Interactions between season and position for anthropometry and strength variables among elite female rugby players. Pairwise comparisons show within and between-season differences for position.

		FR	L	BR	SH	IB	OB
2015	Stature (cm)	169.0 ± 4.4	180.8 ± 1.1	172.8 ± 5.4	163.8 ± 6.2	171.3 ± 5.0	167.7 ± 3.2
	Body mass (kg)	80.9 ± 5.8	84.9 ± 7.8	78.5 ± 4.5	62.5 ± 1.8	71.3 ± 7.6	66.4 ± 3.2
	Skinfolds (mm)	107.0 ± 19.5	110.9 ± 61.1	88.2 ± 18.8	84.9 ± 10.3	93.6 ± 18.3	83.0 ± 13.4
	SL ISO (N)	1830.7 ± 364.6	1885.0 ± 423.6	1737.8 ± 236.1	1616.6 ± 365.6	1761.7 ± 318.6	1688.1 ± 244.3
	SL ISO/BM (kg/kgBM)	2.39 ± 0.5	2.41 ± 0.6	2.39 ± 0.4	2.62 ± 0.6	2.58 ± 0.6	2.81 ± 0.3
	Bench 1-RM (kg)	74.7 ± 12.6·$_{*\$}$	66.3 ± 10.3$_{\$}$	69.5 ± 9.4	72.7 ± 3.5	66.5 ± 6.5	66.0 ± 9.6
	Bench 1-RM/BM (kg/kgBM)	0.92 ± 0.1	0.78 ± 0.1	0.91 ± 0.2	1.15 ± 0.1	0.90 ± 0.1	0.99 ± 0.2
2016	Stature (cm)	168.7 ± 4.1	181.2 ± 0.5	172.7 ± 4.6	163.8 ± 6.2	171.8 ± 5.4	168.0 ± 3.1
	Body mass (kg)	83.7 ± 6.0	86.5 ± 4.5	79.0 ± 3.2	63.8 ± 2.3	71.7 ± 6.7	65.0 ± 2.7
	Skinfolds (mm)	114.6 ± 28.6	98.1 ± 27.9	83.6 ± 8.3	74.8 ± 9.2	82.2 ± 18.0	67.2 ± 4.3
	SL ISO (N)	2189.0 ± 256.3	2025.1 ± 337.3	2117.7 ± 249.2	1450.3 ± 120.7	1782.5 ± 210.8	1834.5 ± 295.8
	SL ISO/BM (kg/kgBM)	2.77 ± 0.4	2.37 ± 0.5	2.74 ± 0.3	2.58 ± 0.4	2.65 ± 0.4	2.88 ± 0.5
	Bench 1-RM (kg)	77.6 ± 13.2$^{ef}_{\wedge\$}$	68.5 ± 5.5$_{\wedge\$}$	72.2 ± 9.4	71.7 ± 8.0	63.0 ± 10.5^{a}	67.6 ± 9.6^{a}
	Bench 1-RM/BM (kg/kgBM)	0.92 ± 0.1	0.80 ± 0.1	0.91 ± 0.12	1.10 ± 0.1	0.84 ± 0.1	1.04 ± 0.1
2017	Stature (cm)	169.1 ± 4.1	180.4 ± 1.4	170.5 ± 4.4	166.3 ± 4.2	171.5 ± 5.5	169.5 ± 4.5
	Body mass (kg)	84.7 ± 7.1	86.5 ± 3.9	79.3 ± 2.0	64.6 ± 1.0	73.6 ± 6.1	68.3 ± 4.7
	Skinfolds (mm)	95.7 ± 19.4	93.2 ± 14.1	93.5 ± 24.3	80.0 ± 8.6	76.7 ± 13.4	72.4 ± 10.7
	SL ISO (N)	2286.3 ± 352.2	2206.3 ± 340.9	2033.3 ± 440.3	1622.8 ± 125.1	1961.8 ± 307.6	1904.7 ± 296.1
	SL ISO/BM (kg/kgBM)	2.87 ± 0.4	2.59 ± 0.4	2.60 ± 0.6	2.80 ± 0.4	2.73 ± 0.5	2.88 ± 0.6
	Bench 1-RM (kg)	85.6 ± 11.1$^{ef}_{\#\$}$	71.6 ± 5.5	70.9 ± 13.3	65.8 ± 10.1	64.0 ± 7.3^{a}	63.0 ± 9.0^{a}
	Bench 1-RM/BM (kg/kgBM)	1.01 ± 0.1	0.83 ± 0.1	0.89 ± 0.2	1.03 ± 0.2	0.88 ± 0.1	0.95 ± 0.2
2018	Stature (cm)	170.1 ± 4.4	180.7 ± 0.8	169.8 ± 5.3	161.7 ± 8.6	170.7 ± 5.6	172.1 ± 4.4
	Body mass (kg)	89.7 ± 6.1	86.6 ± 2.7	79.4 ± 2.2	64.7 ± 2.4	75.0 ± 4.9	70.3 ± 4.0
	Skinfolds (mm)	95.9 ± 13.8	92.3 ± 11.5	90.2 ± 17.5	70.7 ± 15.1	84.7 ± 7.6	77.4 ± 7.7
	SL ISO (N)	2499.3 ± 253.6	2439.5 ± 235.0	2085.5 ± 199.0	1976.1 ± 146.2	2154.0 ± 180.3	1983.5 ± 209.3
	SL ISO/BM (kg/kgBM)	2.82 ± 0.4	2.09 ± 0.2	2.55 ± 0.4	3.11 ± 0.1	2.97 ± 0.1	2.86 ± 0.4
	Bench 1-RM (kg)	85.4 ± 12.3$^{cdef}_{\#¥}$	69.9 ± 6.0	63.6 ± 5.2^{a}	69.2 ± 7.6^{a}	70.0 ± 6.1^{a}	65.4 ± 9.6^{a}
	Bench 1-RM/BM (kg/kgBM)	0.96 ± 0.1	0.81 ± 0.1	0.80 ± 0.1	1.07 ± 0.1	0.93 ± 0.0	0.93 ± 0.2
2019	Stature (cm)	170.3 ± 5.3	180.6 ± 1.0	170.3 ± 5.9	165.3 ± 5.5	172.6 ± 7.0	170.1 ± 3.1
	Body mass (kg)	91.7 ± 7.3	87.7 ± 4.7	80.8 ± 7.6	65.8 ± 1.1	78.2 ± 5.6	70.7 ± 5.0
	Skinfolds (mm)	97.1 ± 14.0	86.9 ± 10.0	83.6 ± 19.5	61.7 ± 9.8	79.1 ± 5.7	70.4 ± 6.4
	SL ISO (N)	2534.5 ± 328.1	2394.3 ± 279.2	2175.1 ± 181.0	1905.4 ± 247.0	2222.4 ± 183.5	2128.6 ± 170.9
	SL ISO/BM (kg/kgBM)	2.81 ± 0.4	2.79 ± 0.3	2.65 ± 0.5	2.98 ± 0.4	2.97 ± 0.1	3.08 ± 0.4
	Bench 1-RM (kg)	86.3 ± 11.3$^{cdef}_{\#¥*}$	73.9 ± 4.8$_{\#¥}$	71.5 ± 8.4^{a}	69.2 ± 8.3^{a}	69.4 ± 9.2^{a}	61.1 ± 6.2^{a}
	Bench 1-RM/BM (kg/kgBM)	0.94 ± 0.2	0.86 ± 0.1	0.89 ± 0.1	1.05 ± 0.1	0.89 ± 0.1	0.86 ± 0.1

FR, L, SH, IB, OB denote Front row, Lock, Scrum half, Inside back, Outside back, respectively. SL ISO = single leg isometric squat peak force, SL ISO/BM = single leg isometric squat relative peak force, Bench 1-RM = bench press 1 repetition maximum. a, b, c, d, e, f = significantly different to front row, lock, back row, scrum half, inside back, outside back respectively, within the tabulated year. #, ¥, *, ^, $ = significantly different to 2015, 2016, 2017, 2018, 2019 respectively, within the tabulated position.

Table 3: Interactions between season and position for jumping and force-velocity derived variables among elite female rugby players. Pairwise comparisons show within and between-season differences for position.

Year		FR	L	BR	SH	IB	OB
2015	SL DJ (ft/ct)	1.2 ± 0.3	1.1 ± 0.2	1.1 ± 0.1	1.3 ± 0.2	1.5 ± 0.3	1.4 ± 0.2
	CMJ height (cm)	30.8 ± 4.7[f,$]	29.0 ± 3.1[f]	29.8 ± 1.9[f]	35.1 ± 1.1	34.4 ± 4.6	37.9 ± 4.1[abc]
	CMJ PPO (W)	3287.3 ± 515.4	3789.3 ± 848.5	3456.9 ± 429.2	3140.5 ± 477.3	3286.3 ± 313.1	3325.3 ± 358.3
	CMJ PPO/BM (W/kgBM)	40.8 ± 7.8	44.3 ± 7.4	44.2 ± 3.8	49.4 ± 7.7	46.4 ± 5.6	49.9 ± 6.0
	F_0 (N)	457.4 ± 34.4	461.5 ± 65.1	429.4 ± 25.1	343.1 ± 18.0	427.8 ± 47.0	385.3 ± 34.7
	P_{max} (W/kg)	11.0 ± 1.3	11.0 ± 0.4	11.8 ± 1.0	12.3 ± 0.9	13.2 ± 1.1	13.4 ± 0.9
	RF_{max} (%)	37.0 ± 2.0[ef,∧]	36.0 ± 1.0	37.0 ± 2.0	38.0 ± 1.0	40.0 ± 2.0[a,¥]	39.0 ± 2.0[a]
	DRF (%)	-7.0 ± 0.8[f,∧]	-6.6 ± 0.9	-6.1 ± 1.0	-5.8 ± 0.8	-6.4 ± 0.5	-5.9 ± 0.5[a]
2016	SL DJ (ft/ct)	1.2 ± 0.1	1.3 ± 0.3	1.1 ± 0.2	1.3 ± 0.0	1.3 ± 0.3	1.6 ± 0.2
	CMJ height (cm)	29.4 ± 3.0[f]	28.1 ± 4.4[df,*∧$]	29.5 ± 4.0[f]	35.0 ± 5.5[b]	31.5 ± 6.0	37.9 ± 5.0[abc]
	CMJ PPO (W)	3692.6 ± 410.1	3800.2 ± 543.7	3500.9 ± 380.9	3252.8 ± 290.0	3261.6 ± 382.1	3353.7 ± 478.4
	CMJ PPO/BM (W/kgBM)	44.1 ± 4.1	44.1 ± 5.5	44.0 ± 3.8	51.0 ± 4.7	46.7 ± 6.2	51.3 ± 6.0
	F_0 (N)	466.4 ± 34.2	471.0 ± 25.0	435.1 ± 18.1	350.1 ± 14.6	386.9 ± 47.0	378.9 ± 37.0
	P_{max} (W/kg)	10.8 ± 0.8	10.7 ± 1.1	11.5 ± 0.7	11.7 ± 0.7	11.4 ± 1.6	13.6 ± 1.0
	RF_{max} (%)	36.0 ± 1.0[f]	36.0 ± 2.0	37.0 ± 1.0	37.0 ± 1.0	36.0 ± 3.0[f,#]	40.0 ± 2.0[ae]
	DRF (%)	-7.0 ± 1.0[e,∧]	-6.4 ± 0.4	-6.2 ± 0.7	-6.1 ± 0.4	-5.7 ± 0.7[a]	-6.0 ± 0.4
2017	SL DJ (ft/ct)	1.3 ± 0.3	1.2 ± 0.2	1.3 ± 0.2	1.5 ± 0.2	1.5 ± 0.2	1.5 ± 0.2
	CMJ height (cm)	32.0 ± 3.8	30.8 ± 3.4[¥]	30.5 ± 3.8	33.4 ± 6.2	33.8 ± 3.2	34.2 ± 4.7[∧]
	CMJ PPO (W)	3632.3 ± 373.5	3801.1 ± 512.7	3407.8 ± 502.1	3148.3 ± 382.1	3583.0 ± 283.3	3430.4 ± 363.1
	CMJ PPO/BM (W/kgBM)	43.2 ± 3.5	44.0 ± 5.5	42.8 ± 6.1	48.9 ± 6.2	49.0 ± 4.9	50.6 ± 3.9
	F_0 (N)	451.3 ± 48.7	453.9 ± 77.9	445.8 ± 56.3	381.7 ± 19.3	386.9 ± 47.0	401.2 ± 42.2
	P_{max} (W/kg)	10.8 ± 1.0	10.6 ± 1.4	10.9 ± 1.7	12.8 ± 0.8	11.4 ± 1.6	13.2 ± 1.1
	RF_{max} (%)	36.0 ± 1.0[f]	35.0 ± 3.0	36.0 ± 3.0[f]	39.0 ± 1.0	36.0 ± 3.0[f,#]	39.0 ± 2.0[ac]
	DRF (%)	-6.5 ± 1.0	-6.2 ± 1.1	-7.0 ± 1.2	-6.5 ± 0.6	-5.7 ± 0.7[a]	-6.1 ± 0.6
2018	SL DJ (ft/ct)	1.2 ± 0.1	1.2 ± 0.2	1.3 ± 0.2	1.5 ± 0.1	1.4 ± 0.2	1.5 ± 0.2
	CMJ height (cm)	31.5 ± 2.9[df]	30.0 ± 4.1[df,¥]	26.9 ± 3.4[df]	43.5 ± 6.1[abce]	31.0 ± 2.2[df]	38.8 ± 5.1[abce,*$]
	CMJ PPO (W)	4094.0 ± 391.5	3663.9 ± 396.7	3379.8 ± 476.5	3438.0 ± 361.0	3328.7 ± 276.3	3781.3 ± 447.8
	CMJ PPO/BM (W/kgBM)	45.4 ± 3.3	42.7 ± 4.3	43.0 ± 6.6	51.6 ± 6.1	43.9 ± 2.6	53.7 ± 7.7
	F_0 (N)	460.6 ± 62.2	418.7 ± 33.0	390.6 ± 17.0	345.4 ± 34.6	401.5 ± 44.6	403.2 ± 36.8
	P_{max} (W/kg)	10.2 ± 1.0	9.9 ± 1.2	9.9 ± 0.8	11.4 ± 0.8	10.7 ± 1.1	13.3 ± 1.4
	RF_{max} (%)	35.0 ± 2.0[f,#]	34.0 ± 2.0[$]	34.0 ± 1.0[f]	37.0 ± 1.0	36.0 ± 2.0	39.0 ± 2.0[ac]
	DRF (%)	-6.2 ± 0.6[#¥]	-5.6 ± 0.3[$]	-5.9 ± 0.6	-5.9 ± 0.5	-6.2 ± 0.6	-5.8 ± 0.4
2019	SL DJ (ft/ct)	1.1 ± 0.2	1.2 ± 0.2	1.3 ± 0.3	1.5 ± 0.2	1.3 ± 0.2	1.5 ± 0.2
	CMJ height (cm)	32.9 ± 3.2[#]	32.1 ± 5.1[¥]	32.2 ± 4.9[f]	39.6 ± 2.9	35.2 ± 2.9	36.7 ± 3.8[c,*]
	CMJ PPO (W)	4045.3 ± 333.4	3786.2 ± 409.4	3463.3 ± 466.7	3569.0 ± 131.3	3597.2 ± 131.3	3538.9 ± 407.7
	CMJ PPO/BM (W/kgBM)	44.5 ± 3.8	43.3 ± 4.4	42.9 ± 4.8	54.1 ± 2.7	46.2 ± 2.66	50.1 ± 5.9
	F_0 (N)	480.8 ± 62.5	504.3 ± 73.5	427.5 ± 44.6	385.4 ± 46.2	450.1 ± 50.2	415.4 ± 52.6
	P_{max} (W/kg)	10.9 ± 0.7	11.4 ± 1.2	11.3 ± 1.5	13.6 ± 1.0	12.4 ± 1.7	13.7 ± 1.1
	RF_{max} (%)	36.0 ± 1.0[ef]	37.0 ± 2.0[∧]	37.0 ± 3.0	40.0 ± 1.0	38.0 ± 3.0[a]	39.0 ± 2.0[a]
	DRF (%)	-6.3 ± 0.6	-6.9 ± 0.9[f,∧]	-6.4 ± 1.0	-6.4 ± 0.6	-6.3 ± 0.7	-5.7 ± 0.6[b]

FR, L, SH, IB, OB denote Front row, Lock, Scrum half, Inside back, Outside back, respectively. SL DJ = single leg drop jump, CMJ height = counter movement jump height, CMJ PPO = counter movement jump peak power output, CMJ PPO/BM = counter movement jump relative power output, F_0 = theoretical maximal force, P_{max} = theoretical maximal power, RF_{max} = maximal ratio of force, DRF = ratio of decline in the ratio of horizontal force. a, b, c, d, e, f = significantly different to front row, lock, back row, scrum half, inside back, outside back respectively, within the tabulated year. #, ¥, *, ∧, $ = significantly different to 2015, 2016, 2017, 2018, 2019 respectively, within the tabulated position.

Table 4: Interactions between season and position for sprint, momentum and endurance variables among elite female rugby players. Pairwise comparisons show within and between-season differences for position.

Year	Variable	FR	L	BR	SH	IB	OB
2015	0-10 m (s)	$1.93 \pm 0.07^{e}_{\wedge}$	$1.95 \pm 0.05_{\wedge}$	1.9 ± 0.08	1.87 ± 0.07	$1.81 \pm 0.07^{a}_{¥\wedge}$	1.81 ± 0.07
	30-40 m (s)	$1.34 \pm 0.12^{ef}_{\wedge}$	1.39 ± 0.05^{ef}	1.31 ± 0.07^{ef}	1.35 ± 0.10^{f}	$1.25 \pm 0.11^{abc}_{¥\$}$	1.22 ± 0.03^{abcd}
	TT40 m (s)	6.16 ± 0.39	6.18 ± 0.16	5.94 ± 0.24	5.91 ± 0.25	5.69 ± 0.24	5.60 ± 0.14
	V_{max} (m/s)	7.75 ± 0.68	8.02 ± 0.55	8.63 ± 0.89	8.97 ± 0.73	8.78 ± 0.36	9.26 ± 0.39
	0-10 mom (kg/m/s)	421.6 ± 25.4	423.9 ± 41.7	417.2 ± 19.9	334.1 ± 9.0	395.6 ± 38.9	367.6 ± 24.0
	20-30 mom (kg/m/s)	582.1 ± 38.6	588.1 ± 44.5	586.0 ± 41.5	492.2 ± 15.1	563.4 ± 56.2	541.2 ± 29.0
	Endurance (m/s)	3.8 ± 0.2^{f}	3.7 ± 0.3^{f}	4.0 ± 0.1	4.0 ± 0.2	4.0 ± 0.2	4.1 ± 0.2^{ab}
2016	0-10 m (s)	1.96 ± 0.06^{f}	1.97 ± 0.10^{f}	1.92 ± 0.04	1.92 ± 0.4	$1.95 \pm 0.13^{f}_{\#}$	1.81 ± 0.07^{abe}
	30-40 m (s)	$1.41 \pm 0.04^{f}_{\wedge}$	1.40 ± 0.03^{f}	1.32 ± 0.06^{f}	1.29 ± 0.10	$1.31 \pm 0.06_{\#}$	1.22 ± 0.03^{abc}
	TT40 m (s)	6.27 ± 0.22	6.22 ± 0.20	5.99 ± 0.27	5.93 ± 0.17	5.97 ± 0.26	5.57 ± 0.16
	V_{max} (m/s)	7.79 ± 0.69	7.97 ± 0.30	8.54 ± 0.71	8.56 ± 0.53	8.76 ± 0.42	9.41 ± 0.21
	0-10 mom (kg/m/s)	427.5 ± 24.8	441.9 ± 20.5	415.8 ± 21.0	337.2 ± 16.9	382.4 ± 27.5	378.8 ± 57.6
	20-30 mom (kg/m/s)	588.4 ± 73.9	624.7 ± 22.9	633.2 ± 90.2	484.1 ± 31.9	567.1 ± 32.1	534.0 ± 32.3
	Endurance (m/s)	$3.7 \pm 0.2^{cdef}_{\wedge}$	$3.9 \pm 0.4^{e}_{\wedge}$	4.0 ± 0.1^{a}	4.1 ± 0.3^{a}	$4.1 \pm 0.2^{ab}_{\#\$}$	4.1 ± 0.2^{a}
2017	0-10 m (s)	1.97 ± 0.07^{f}	2.00 ± 0.18^{e}	1.95 ± 0.11	1.84 ± 0.04	1.87 ± 0.05^{b}	1.83 ± 0.06^{a}
	30-40 m (s)	$1.34 \pm 0.09^{f}_{\wedge}$	1.39 ± 0.08^{ef}	1.38 ± 0.08	1.28 ± 0.09	1.28 ± 0.05^{bc}	1.25 ± 0.05^{abc}
	TT40 m (s)	6.15 ± 0.34	6.27 ± 0.26	6.25 ± 0.39	5.79 ± 0.24	5.81 ± 0.22	5.68 ± 0.18
	V_{max} (m/s)	8.08 ± 0.90	8.10 ± 0.41	7.75 ± 0.79	8.65 ± 0.61	8.75 ± 0.69	9.07 ± 0.51
	0-10 mom (kg/m/s)	429.1 ± 31.3	435.5 ± 44.0	408.5 ± 28.6	349.9 ± 11.5	396.1 ± 29.9	375.7 ± 28.2
	20-30 mom (kg/m/s)	608.5 ± 61.0	624.6 ± 34.2	559.6 ± 45.7	489.3 ± 20.6	573.2 ± 67.1	538.8 ± 37.0
	Endurance (m/s)	3.8 ± 0.2^{ef}	3.9 ± 0.2^{ef}	3.9 ± 0.1	4.1 ± 0.0	$4.0 \pm 02^{ab}_{¥}$	4.1 ± 0.2^{ab}
2018	0-10 m (s)	$2.02 \pm 0.08^{f}_{\#}$	$2.07 \pm 0.11^{f}_{\#\$}$	2.05 ± 0.06^{f}	1.95 ± 0.05	$1.98 \pm 0.08_{\#}$	1.83 ± 0.06^{abc}
	30-40 m (s)	$1.46 \pm 0.12^{df}_{\#¥*}$	1.43 ± 0.03^{f}	1.42 ± 0.06^{f}	1.32 ± 0.03^{a}	1.40 ± 0.04	1.24 ± 0.02^{abc}
	TT40 m (s)	6.44 ± 0.27	6.51 ± 0.18	6.36 ± 0.22	6.05 ± 0.09	6.29 ± 0.02	5.65 ± 0.12
	V_{max} (m/s)	7.96 ± 0.46	8.19 ± 0.49	8.03 ± 0.59	8.54 ± 0.19	8.13 ± 0.27	9.29 ± 0.56
	0-10 mom (kg/m/s)	443.8 ± 40.0	423.0 ± 25.5	387.5 ± 10.9	332.6 ± 19.9	383.8 ± 26.6	387.1 ± 27.2
	20-30 mom (kg/m/s)	632.9 ± 49.7	632.2 ± 31.5	571.1 ± 32.3	478.1 ± 9.3	552.8 ± 29.5	563.3 ± 22.0
	Endurance (m/s)	$3.6 \pm 0.2^{def}_{¥}$	$3.7 \pm 0.2^{df}_{¥}$	3.8 ± 0.2	4.2 ± 0.0^{ab}	4.0 ± 0.2^{a}	4.2 ± 0.2^{ab}
2019	0-10 m (s)	1.96 ± 0.06^{ef}	$1.91 \pm 0.12_{\wedge}$	1.93 ± 0.10	1.80 ± 0.04	1.87 ± 0.11^{a}	1.81 ± 0.07^{a}
	30-40 m (s)	1.36 ± 0.03^{f}	1.39 ± 0.05^{f}	1.35 ± 0.10^{f}	1.34 ± 0.03^{f}	$1.31 \pm 0.09^{f}_{\#}$	1.20 ± 0.04^{abcde}
	TT40 m (s)	6.12 ± 0.08	6.05 ± 0.18	6.03 ± 0.37	5.94 ± 0.10	5.82 ± 0.29	5.50 ± 0.16
	V_{max} (m/s)	8.16 ± 0.24	7.98 ± 0.38	8.27 ± 0.69	8.76 ± 0.62	8.58 ± 0.39	9.53 ± 0.39
	0-10 mom (kg/m/s)	459.3 ± 37.9	461.0 ± 40.2	404.5 ± 16.6	369.1 ± 16.7	419.6 ± 35.3	398.8 ± 33.2
	20-30 mom (kg/m/s)	653.6 ± 50.0	631.6 ± 34.6	579.6 ± 40.5	507.7 ± 36.7	588.82 ± 52.1	596.0 ± 20.0
	Endurance (m/s)	3.7 ± 0.2^{cdef}	3.7 ± 0.1^{f}	3.9 ± 0.2^{af}	4.1 ± 0.1^{a}	$3.9 \pm 0.2^{a}_{¥}$	4.2 ± 0.2^{abc}

FR, L, BR, SH, IB, OB, denote Front row, Lock, Scrum half, Inside back, Outside back, respectively. , 0-10 m = sprint time from 0 to 10 m, 30-40 m = sprint time from 30 to 40 m, TT40 m = total 40 m sprint time, V_{max} = theoretical maximal velocity, 0-10 mom = average momentum from 0 to 10 m, 20-30 mon = average momentum from 20 to 30 m. a, b, c, d, e, f = significantly different to front row, lock, back row, scrum half, inside back, outside back respectively, within the tabulated year. #, ¥, *, ^, $ = significantly different to 2015, 2016, 2017, 2018, 2019 respectively, within the tabulated position.