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1 Dynamic balance performance varies by position but not by age group
2 in elite Rugby Union players – a normative study

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18

19 ABSTRACT

20 This cohort study aimed to provide normative Y Balance Test scores for an elite Rugby
21 Union population, while investigating the effect player age groups (senior/under-20),
22 playing positions (forwards/backs) and anthropometrics (height and body mass) had on
23 performance. 261 elite male under-20 ($n = 50$) and senior ($n = 211$) players completed
24 baseline Y Balance Test during the 2015/2016 season. One-way ANCOVA and post-hoc t-
25 tests were used to investigate the effect playing position, player group, height and weight
26 had on performance. The cohort was then stratified into groups (age group and/or playing
27 position), and normative percentiles were presented. There was a statistically significant
28 difference ($p < 0.05$) in Y Balance Test performance between playing positions, when
29 controlling for age group. This difference did not remain when controlling for player body
30 mass. Post-hoc analysis demonstrated that backs had a longer normalised reach distance,
31 with medium-large and small-medium effect sizes for the under-20 and senior cohorts
32 respectively. The one-way ANCOVA analysis suggests that this difference is likely due to the
33 larger differences in player body mass between forward and back playing positions. The
34 normative values presented in this paper may be used by clinicians and researchers to aid
35 injury prevention and rehabilitation strategies.

36

37 **Key Words**

38 Dynamic Balance

39 Dynamic Postural Control

40 Y Balance Test

41 Elite Rugby Union

42 Normative

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44 Rugby Union is a field based contact sport eliciting a variety of physiological responses due
45 to the demands of high-intensity linear and multi-directional movements and frequent
46 contact (Duthie, Pyne, & Hooper, 2003). Key physical attributes required for success in
47 Rugby Union include cardiovascular fitness, strength, power, range of motion, agility and
48 balance (Duthie, et al., 2003). Players are broadly categorised into two positional units;
49 forwards (ball-winners) and backs (ball-carriers), with key anthropometric profiles
50 (forwards have a greater height and body mass) differentiating the positional units (Darrall-
51 Jones, Jones, & Till, 2016; Zemski, Slater, & Broad, 2015). Additionally, previous research
52 has established that as adolescent elite Rugby Union players progress to meet the
53 requirements of competing in their respective positions at an elite senior level, the nature
54 of their body composition, and their performance in sport specific tasks changes to reflect
55 their specialisation (Darrall-Jones, Jones, & Till, 2015; Darrall-Jones, et al., 2016).

56 The maintenance of dynamic balance is central to Rugby Union performance, with
57 individuals required to complete complex multi-directional movements at high velocity,
58 while sustaining constant pressure and contact from the opposition. The Star Excursion
59 Balance Test (SEBT) is a commonly utilised clinical dynamic balance assessment, capable of
60 providing a valid and reliable measure of dynamic balance performance (Gribble, Hertel, &
61 Plisky, 2012). It requires an individual to move from a position of bilateral to unilateral
62 stance, perform a maximal reach excursion, and return to the starting position in a
63 controlled manner, in eight defined directions (Gribble, et al., 2012). Previous research has
64 established the redundancy of five of the eight reach directions (Hertel, Braham, Hale, &
65 Olmsted-Kramer, 2006), resulting in the development of a commercially available
66 instrumented dynamic balance assessment tool (functionalmovement.com, Danville, VA),
67 the Y Balance Test (YBT) (Plisky et al., 2009). Such assessments demand a combination of

68 many of the domains required for optimal rugby performance, such as strength, range of
69 motion, proprioception and balance, thus challenging the sensorimotor subsystems
70 (Gribble, et al., 2012). Previous research has demonstrated the role these assessments play
71 in identifying those at risk of sustaining a lower extremity injury (Gribble et al., 2015; C. A.
72 Smith, Chimera, & Warren, 2015; Stiffler et al., 2017a), differentiating lower limb
73 musculoskeletal injuries (Aminaka and Gribble, 2008; Doherty et al., 2015; Gribble, Hertel,
74 Denegar, & Buckley, 2004; Herrington, Hatcher, Hatcher, & McNicholas, 2009; Hertel, et al.,
75 2006), and as an objective outcome measure, capable of tracking recovery following an
76 injury (Clagg, Paterno, Hewett, & Schmitt, 2015; Doherty et al., 2016; Hale, 2007) in a range
77 of American collegiate sports. As such, both medical teams and strength and conditioning
78 personnel are frequently interested in the quantification of dynamic balance performance.

79 The evaluation of an individual's dynamic balance performance using the YBT and SEBT is
80 typically completed in one of two ways: (1) reach distances and asymmetries (dominant leg
81 vs non-dominant leg) are compared to a population normative reference value; (2) reach
82 distances are compared to an individual's previous baseline score, allowing for direct
83 inference of an individual's improvement or deterioration in performance. As an example,
84 clinicians often evaluate athletes during pre-season to establish if they may be at an
85 increased risk of sustaining a lower extremity injury (Gribble, et al., 2015; J. L. Smith,
86 Hutton, & Eldred, 1974), with limb asymmetry and poor performance being associated with
87 an increased likelihood of sustaining a lower limb injury across a range of populations
88 (Gribble, et al., 2015; C. A. Smith, et al., 2015; Stiffler, et al., 2017a). However, due to time
89 commitments and the burdens of high-level sport, clinicians frequently do not have access
90 to an individual's own healthy baseline score. As such, if an athlete sustains an injury,
91 clinicians must rely on population reference norms to inform their decision regarding when
92 the individual may have returned to pre-injury levels of dynamic balance performance.

93 While clinical thresholds and normative values can provide guidance relating to an athlete's
94 injury risk, there is evidence that differences in dynamic balance performance may be
95 influenced by factors such as player height and weight (Gribble and Hertel, 2003; Ozunlu,
96 Basari, & Baltaci, 2010), and that differences may exist between sports, sexes and age
97 groups (McCann et al., 2015; Stiffler, Sanfilippo, Brooks, & Heiderscheit, 2015; Teyhen et
98 al., 2014). Thus, Stiffler and colleagues (2015) recommended that normalised reach
99 distance cut-off scores should only be used within the context of the sport, and level of
100 participation in which they were developed. Additionally, Gribble and colleagues (2012)
101 called for the collection of normative data using sport specific populations to be leveraged
102 by clinicians and researchers.

103 To date no normative values have been presented in the literature for an elite Rugby Union
104 population, or investigated what factors (playing position; age group; anthropometrics)
105 may influence balance performance. Establishing population specific normative values for
106 the YBT assessment will augment clinical practice in two key ways. Firstly, such information
107 may aid clinicians in determining when a player has returned to pre-injury levels of dynamic
108 balance performance, providing an objective outcome measure to ensure that the athlete
109 has met key performance indicators prior to return to sport. Secondly, such information
110 allows clinicians and strength and conditioning personnel to implement neuromuscular
111 control training interventions to improve an individual's dynamic balance, in an attempt to
112 mitigate a potential risk factor for lower limb injury (Gribble, et al., 2015; C. A. Smith, et al.,
113 2015; Stiffler et al., 2017b).

114 Therefore, the aim of this study was to provide accurate normative YBT reference scores
115 for an elite Rugby Union population. In doing so, we investigated the differences in YBT
116 performance between player age groups (senior/under-20), and positional units
117 (forwards/backs) to establish the most appropriate stratification. A concurrent aim was to

118 establish what key anthropometric factors may contribute to any differences in
119 performance observed. It was hypothesised that senior players would possess superior
120 dynamic balance performance when compared with under-20 players, while backs would
121 possess superior dynamic balance performance when compared with forwards. The
122 differences in performance between groups may be explained by differences in
123 anthropometric profiles.

124

125 METHODOLOGY

126 PARTICIPANTS

127 Two hundred and sixty-one male elite Rugby Union players, consisting of 50 under-20
128 players, aged 19-20 years, and 211 senior players, aged 21-37 years were recruited from
129 the Irish National under-20 squad and the four Irish professional Rugby Union clubs.
130 Participants were excluded from this study if they had sustained a lower limb injury in the
131 last 6 months, had vestibular, visual or balance impairment and any neurological disease.
132 Ethical approval was obtained from the University Research Ethics board and all
133 participants read the information leaflet and provided informed consent prior to testing. All
134 participants rights were protected, and participants were advised that they had the right to
135 withdraw from the study at any point.

136 TESTING PROCEDURE

137 Baseline YBT testing was conducted as part of a wider study protocol, with participants
138 completing the YBT protocol in the morning prior to training to reduce the residual effects
139 of fatigue on YBT performance (Johnston, Dolan, Reid, Coughlan, & Caulfield, 2017).
140 Baseline evaluation was conducted by two Chartered Physiotherapists (WJ and CD) with
141 extensive experience in administering the YBT. Furthermore, previous research has

142 demonstrated the excellent (0.99-1.00) inter-rater reliability of the instrumented YBT
 143 (Plisky, et al., 2009). As per previously published guidelines, the YBT requires the individual
 144 to complete four practice trials followed by three recorded reach excursions in three
 145 defined directions; anterior (ANT), posteromedial (PM) and posterolateral (PL), on
 146 dominant (DM) and non-dominant (ND) stance legs (Gribble, et al., 2012). Players were
 147 required to repeat the reach excursion if they applied support to the sliding block, raised
 148 the heel of the stance foot from the centre plate, placed the reaching foot on the ground,
 149 kicked the plate to gain more distance, removed their hands from their hips, or were
 150 unable to maintain their balance during the task. YBT testing took place on a hard surface,
 151 with athletes required to complete the protocol in bare feet.

152 Players' leg lengths were obtained by measuring the distance between the anterior-
 153 superior iliac spine and the most distal part of the medial malleolus on the same limb.
 154 Reach distances were normalised to the length of the players stance leg as per previously
 155 published guidelines using the following formula (Gribble, et al., 2012):

$$156 \quad \text{Normalised Reach Distance} = \frac{\text{Reach distance (cm)}}{\text{Leg Length (cm)}} \times \frac{100}{1}$$

157 The average of the three recorded trials was used for analysis, to ensure a reliable measure
 158 of dynamic balance (Gribble, et al., 2012).

159 STATISTICAL ANALYSIS

160 Descriptive statistics for age, height, weight, BMI and leg length are presented through
 161 means $\pm$ standard deviations (SD) (table 1). Paired-samples t-tests indicated no significant
 162 differences between individuals' dominant and non-dominant limbs (ANT p = 0.74; PM p =
 163 0.12; PL p = 0.21), as such the average of both stance legs was used for the analysis. To
 164 investigate if normalised YBT reach distances differed when comparing player groups (age
 165 groups/playing position groups), one-way analysis of covariance (ANCOVA) was used

166 individually for each reach direction. If there was a statistically significant effect, post-hoc
167 independent sample t-tests were used to investigate the effects of age group
168 (senior/under-20) and playing position (forward/back) on YBT reach distances. To
169 investigate the effect key anthropometric factors (height and weight) had on YBT
170 performance, one-way ANCOVA analyses were conducted to determine if there was a
171 statistically significant difference in normalised reach distances between groups when
172 controlling for height and/or weight. The level of significance was adjusted for the number
173 of reach directions using a Bonferonni correction. Cohens D effect sizes (d) were calculated
174 for each independent t-test comparison using the method proposed by Cohen, with small,
175 medium and large effect sizes ranging from 0.02 - 0.049, 0.05 - 0.079 and ≥ 0.08
176 respectively (Cohen, 2013). Partial eta squared (ηp^2) was used as an estimate of effect size
177 for the one-way ANCOVA, with a small, medium and large effect sizes ranging from 0.01 -
178 0.089, 0.09 - 0.24 and ≥ 0.25 respectively. Based on the findings of this analysis, the cohort
179 was then stratified into groups (age group and/or playing position), and percentiles were
180 calculated to present normative reference values.

181 RESULTS

182 Descriptive information related to player age, height, weight, BMI and leg length, stratified
183 by playing position and age group, is presented in table 1.

184

		Mean (SD)		Effect Size (<i>d</i>)	
		Forwards	Backs	Senior v Under-20	Forwards v Backs
Age (years)	Senior	26.5 (4.2)	25.5 (5.5)	1.8*	0.3*
	Under-20	19.7 (0.5)	18.9 (3.9)		
Height (cm)	Senior	189.0 (7.2)	182.9 (5.5)	0.2*	0.6*
	Under-20	188.0 (6.8)	174.5 (36.0)		
Body Mass (kg)	Senior	111.5 (7.8)	93.6 (8.2)	0.5*	1.8*
	Under-20	106.1 (7.4)	86.5 (20.3)		
BMI (kg/m ²)	Senior	31.3 (2.8)	27.9 (1.7)	0.4*	1.4*
	Under-20	30.1 (2.4)	27.3 (2.8)		
DM Leg Length (cm)	Senior	101.6 (5.5)	97.4 (4.2)	0.2	0.9*
	Under-20	102.3 (5.7)	97.9 (4.4)		
ND Leg Length (cm)	Senior	101.6 (5.5)	97.2 (4.2)	0.1	0.9*
	Under-20	102.6 (5.5)	97.9 (4.1)		

185 **Table 1:** Presents the demographic information for each group. Additionally, Independent
186 sample t-test comparison between age-group and position groups are presented using
187 Cohens D effect size, with statistically significant differences ($P < 0.05$) denoted in **bold** with
188 an *.

190 One-way ANCOVAs were used to investigate the effect of playing position on normalised
191 reach distance, when controlling for age group. Statistically significant differences ($\eta p^2 =$
192 0.05 ANT; $\eta p^2 = 0.06$ PM; $\eta p^2 = 0.05$ PL) were observed between positional units when
193 controlling for age group, but not between age groups ($\eta p^2 = 0.01$ ANT; $\eta p^2 = 0.01$ PM; ηp^2
194 < 0.01 PL) when controlling for positional units. Post-hoc analysis demonstrated that backs
195 reached further than forwards across both age groups, with a medium-large effect size for
196 the under-20 group ($d = 0.7$ ANT; $d = 0.9$ PM; $d = 0.7$ PL), and small-medium effect size for
197 the senior group ($d = 0.4$ ANT; $d = 0.5$ PM; $d = 0.4$ PL) (table 2). When the under-20 and
198 senior cohorts were considered together, backs demonstrated a statistically significantly

199 longer ($d = 0.5$ ANT; $d = 0.5$ PM; $d = 0.5$ PL) normalised reach distance across all three
200 directions.

201 Table 3 demonstrates that when controlling for player height, the significant difference
202 between positional unit reach distance was maintained. However, when controlling for
203 player weight, no significant differences ($p > 0.05$) between forwards and backs were
204 observed. Furthermore, there were no statistically significant ($p > 0.05$) differences
205 between age groups when controlling for player height or weight across all three reach
206 directions.

		Normalised Reach (%) Mean (SD)		Forward v Back		
		Forwards	Backs	Mean Difference	95% CI	Effect Size
ANT	Senior	56.1 (6.3)	58.4 (4.9)	2.32*	0.83 - 3.81	0.4
	Under-20	57.2 (5.1)	60.5 (4.3)	3.34	0.20 – 6.48	0.7
PM	Senior	100.2 (9.1)	104.0 (7.2)	3.91*	1.72 – 6.12	0.5
	Under-20	101.0 (6.6)	106.3 (5.2)	5.38*	1.87 – 8.89	0.9
PL	Senior	97.0 (8.8)	100.4 (6.7)	3.50*	1.41 – 5.58	0.4
	Under-20	97.9 (6.7)	102.1 (5.5)	3.92	0.10 – 7.74	0.7

207 **Table 2:** Presents the post-hoc normalised reach distance (%) comparison of the positional
208 units for the Senior and under-20 cohorts. Independent sample t-test comparison between
209 age-group and position groups are presented using Cohens D effect size, with statistically
210 significant differences ($P < 0.05$) denoted in **bold** with an *.

211

Independent	Covariate	Dependent	P Value	Partial Eta Squared (ηp^2)
Position	Height (cm)	ANT	<0.01	0.04
		PM	<0.01	0.04
		PL	<0.01	0.03
	Body Mass (kg/m ²)	ANT	>0.05	0.01
		PM	>0.05	0.01
		PL	>0.05	0.01

Table 3: presents the one-way ANCOVA results investigating the differences in YBT reach distances (dependent variable) between positional units (independent variable), when controlling for height and body mass (covariates). Statistically significant effects are highlighted in **bold** and with an *. Partial Eta Squared presents a measure of effect size.

Based on the one-way ANCOVA and post-hoc analysis results, the cohort was stratified into playing position groups when determining the normative reference percentiles for the elite rugby union cohort (table 2).

Reach Direction	Position	Normalised Reach (%) Percentiles						
		5 th	10 th	25 th	50 th	75 th	90 th	95 th
ANT	Back	50.8	52.9	54.9	59.1	61.9	65.4	67.2
	Forward	47.0	48.5	52.2	56.4	60.3	64.2	66.3
PM	Back	91.5	94.9	100.5	105.1	109.6	112.6	115.3
	Forward	89.2	90.9	94.6	100.4	105.9	110.6	114.5
PL	Back	88.3	93.3	97.1	100.7	105.4	108.9	110.0
	Forward	84.5	88.0	91.8	97.2	102.2	107.3	110.1

Table 4: Presents the normalised reach distance (%) percentiles for the entire cohort, stratified by playing position.

223 DISCUSSION

224 This study set out to present normative reference values for an elite Rugby Union
225 population, providing clinicians and researchers with accurate and representative
226 population normative scores for the YBT. In doing so, this study has identified differences in
227 dynamic balance performance between key positional units (forwards vs backs), while
228 establishing that there is no difference between senior and under-20 age groups.
229 Furthermore, we have identified that the increased body mass possessed by the forward
230 players likely contributes to decreased YBT performance, when compared to the back
231 players.

232 The one-way ANCOVA analyses demonstrate that there are differences in normalised reach
233 distances between forwards and backs, when controlling for the player age group.

234 Conversely, no difference was observed between age-groups when controlling for playing
235 position. Backs had a significantly longer normalised reach distance than forwards, for the
236 senior age-group across all reach directions, with the senior backs on average having a
237 normalised reach distance 2.3% (ANT), 3.9% (PM) and 3.5% (PL) greater than the forwards.

238 There was only a difference between playing positions for the under-20 cohort in the PM
239 reach direction (table 3), with the under-20 backs having a normalised reach distance 5.4%
240 (PM) greater than the forwards in the PM direction. While there was no significant

241 difference between under-20 positional units in the ANT and PL reach directions, the
242 Cohens D analysis demonstrates that playing position has a medium effect on normalised
243 reach distance, with forwards on average having a normalised reach distance 3.3% and
244 3.9% less than backs for the ANT and PL reach directions, respectively. A potential

245 explanation for the non-significant result despite the medium effect size may be the
246 smaller sample size recruited for the under-20 comparison (n = 24 forwards; n = 26 backs)

247 and the implementation of a Bonferroni correction, potentially increasing the chance of a
248 type 2 error (Freiman, Chalmers, Smith Jr, & Kuebler, 1978; Perneger, 1998).

249 An important aspect to consider when comparing dynamic balance performance are the
250 anthropometric characteristics of the respective groups, and the impact this may have on
251 performance. The results from this study demonstrate that forwards had a statistically
252 significantly greater height, weight, BMI and leg length when compared to the backs
253 (medium-large effect size). On average, forwards were 7.7cm taller, 18.5kg heavier, had a
254 BMI of 3.3 kg/m² greater and had longer DM (4.2cm) and ND (4.4cm) leg lengths than
255 backs. These clear anthropometric differences between positional units are expected due
256 to the diverse physical needs required by the different playing positions. These differences
257 are likely because forwards are typically involved in the close contact strength based
258 physical aspects of rugby, requiring a greater body mass and height. Conversely, backs are
259 typically engaged in more multi-directional and high speed running tasks, requiring a
260 smaller, more mobile athlete (Kaplan, Goodwillie, Strauss, & Rosen, 2008). The findings of
261 this analysis are consistent with previous research published in the area demonstrating
262 anthropometric differences between forwards and backs at senior and academy elite
263 Rugby Union levels (Darrall-Jones, et al., 2015, 2016; Zemski, et al., 2015). When the cohort
264 was stratified by age-group, senior players demonstrated a statistically significantly greater
265 weight, height and BMI than the under-20 cohort, with a small effect size. The larger
266 anthropometric profile of the senior cohort may be expected due to the specialisation and
267 physical maturation that occurs as the athlete's progress from under-20 to senior elite
268 levels.

269 One-way ANCOVA analysis were conducted to investigate if the differences in normalised
270 reach distances (dependent variable) observed between playing position (independent
271 variables) is maintained when controlling for player weight or height (covariate). Table 3

272 demonstrates that when controlling for player height, the significant difference in YBT
273 performance between positions is maintained; however, when controlling for player
274 weight, there is no statistically significant difference between forwards and backs. The
275 findings from this analysis suggest that while there is a significant difference between
276 forwards and backs YBT performance, the significantly greater body mass (table 1)
277 possessed by the forwards likely contributes to their reduced YBT reach distances, when
278 compared to the backs. The results demonstrated in this study are supported by previous
279 reports in the literature which demonstrated reduced dynamic balance performance during
280 the SEBT when individuals' completed the task while carrying extra weight (Ozunlu, et al.,
281 2010). However, it is important to note that the findings demonstrated in these two studies
282 must be compared with caution due to the vastly different methodologies employed.
283 Ozunlu and colleagues (2010) utilised the SEBT protocol, recruited adolescent basketball
284 players and added additional body weight, while our study leveraged the YBT, recruited a
285 cohort of rugby union players and investigated the effect of differences in body mass on
286 dynamic balance performance.

287 Previous research carried out by Coughlan and colleagues (2014) investigating dynamic
288 balance performance in elite junior Rugby Union players (under-19 and under-18)
289 established that there are no significant differences in SEBT reach distances between
290 forwards and backs. The results of our study have demonstrated that there are significant
291 differences between positional units across both senior and under-20 cohorts. The differing
292 results observed are likely due to the increased positional specialisation which occurs as
293 players progress towards under-20 and senior levels of elite Rugby Union. At junior-level,
294 players have yet to fully complete their physical and technical development as Rugby Union
295 players. Thus, it is hypothesised that as the players specialise in their respective positions,
296 undergo increased levels of strength, conditioning and pre-habilitation specific to their
297 position (Darrall-Jones, et al., 2015, 2016), individuals dynamic balance performance may

change to mirror the demands of that position. Alternatively, it must be considered that players may progress from underage to elite under-20 and senior level because of their superior dynamic balance performance capability. An important consideration when comparing the results obtained in this study and those with previously published studies leveraging the SEBT, is the use of different reach distance testing methods. Previous research has demonstrated significant differences between the normalised reach distances obtained using the YBT and SEBT for the ANT reach direction. However, there are no significant differences between the two testing methods when considering the PM and PL reach directions (Coughlan, Fullam, Delahunt, Gissane, & Caulfield, 2012). As such, direct comparison between studies using the SEBT and our study can be conducted for the PM and PL reach directions only, when hands are positioned on hips.

One of the key hypotheses from this study was that dynamic balance performance would differ between senior and under-20 elite Professional Rugby Union players. Interestingly, the findings of this study contradict the original hypothesis, as the one-way ANCOVA analyses demonstrated that there was no significant difference ($p > 0.05$) in normalised YBT reach distance between senior and under-20 players. One potential explanation for this is highlighted by the significant confounding effect which player body mass (covariate) had on dynamic balance performance; conversely, there was no significant effect of player height on YBT performance (table 3). While there was a significant difference in body mass between both groups (age groups and positional units), there is a much larger magnitude effect of player position ($d = 1.8$) on body mass than player age group ($d = 0.5$). When considering the one-way ANCOVA and post-hoc analysis together, the smaller difference in body mass observed between senior and under-20s (mean difference 7.3kg) than between forwards and backs (mean difference 18.5kg) may help to explain why no significant difference was observed between the two age groups.

323 Although other studies have found adaptations that progress with age, such as sprint speed
324 (Gabbett, 2002), vertical jump, agility, and maximal aerobic power (Barr, Sheppard,
325 Gabbett, & Newton, 2014), our results suggest that balance capacity may be developed
326 earlier in Rugby players' careers. As such, when our results are viewed in conjunction with
327 those presented by Barr (2014) and Gabbett (2002), it may indicate that a players' balance
328 capacity develops early in their career, whilst their power, speed and strength continue to
329 improve towards senior level.

330 The primary aim of this study was to present YBT performance reference scores for elite
331 Rugby Union, based on the appropriate stratifications determined from the playing position
332 and age group comparisons. Based on the above comparisons, the cohort was divided by
333 playing position for the normative data presentation. No previous studies have presented
334 YBT reference scores for an elite Rugby Union population, thus the findings of this study are
335 significant as they provide clinicians and researchers with accurate normative scores. This
336 has the potential to augment clinical practice by providing accurate population specific
337 reference values which can help clinicians and strength and conditioning coaches
338 determine when an athlete may be ready to return to play, and identify suboptimal
339 performance, allowing for the implementation of balance training interventions to mitigate
340 potential risk factors for lower limb injury (Gribble, et al., 2015; C. A. Smith, et al., 2015;
341 Stiffler, et al., 2017b).

342 While no previous studies have investigated YBT performance in under-20 and senior elite
343 Rugby Union populations, previous research has investigated SEBT performance across a
344 range of sporting populations (Coughlan, et al., 2014; Gribble, et al., 2015; C. A. Smith, et
345 al., 2015). Coughlan and colleagues (2014) previously reported SEBT results, stratified by
346 forward and back position, for a cohort of elite junior Rugby Union players. For both the
347 PM and PL reach directions, the cohort presented in our study demonstrated a greater

348 normalised reach distance than the junior Rugby Union cohort. This may be expected due
349 to increased specialisation and the effect of training which occurs as players progress
350 towards senior Rugby Union. Additionally, when comparing the results obtained in this
351 study with those of elite division 1 collegiate athletes (basketball, golf, ice hockey, soccer,
352 American football and wrestling) we see the Rugby Union cohort has superior PL reach
353 direction performance, while the collegiate cohort demonstrated superior performance in
354 the PM reach direction (Stiffler, et al., 2015). However, due to the different testing
355 methods used in these studies, comparisons should be made with caution.

356 There are two key contextual factors that need to be acknowledged surrounding this study.
357 Firstly, while this study investigated the effect of player body mass and height on YBT
358 performance, it is possible that other key anthropometric characteristics such as body fat
359 percentage and muscle mass may influence performance. However, as this was outside the
360 scope of the present study further research is required to investigate the effects of various
361 anthropometric profiles on dynamic balance performance. Secondly, all players who
362 participated in this study were affiliated with the Irish Rugby Football Union. While the
363 players affiliated with the Irish Rugby Football Union represent many different nations,
364 most are Irish males, progressing through a unified academy system. As a result, these
365 results may not be representative of players who progressed through the academy system
366 of other Rugby Union nations.

367 CONCLUSION

368 This study is the first to present normative reference scores for the YBT in an elite rugby
369 union population and investigate the effect playing position (forward/back), age group
370 (senior/under-20) and key anthropometric characteristics have on dynamic balance
371 performance. The findings of this study demonstrate that there is no significant difference
372 in YBT performance between senior and under-20 cohorts. However, backs have a

373 significantly greater normalised reach distance when compared to forwards which may be
374 explained by the forwards greater body mass. As such, the normative reach distances
375 presented in this paper were stratified by playing position. These findings are of note as
376 they suggest that when assessing dynamic balance performance, clinicians and strength
377 and conditioning professionals should consider forwards and backs separately. These
378 findings are significant as they provide clinicians working in elite Rugby Union with
379 accurate, population specific normative YBT reference values. This has the potential to
380 impact clinical practice as it allows clinicians to compare an athletes scores with the
381 appropriate normative reference. This will allow clinicians to determine what percentile of
382 performance the player falls into, potentially helping to inform when a player is ready to
383 progress to the next level of rehabilitation following an injury, or inform when the
384 implementation of injury prevention interventions may be appropriate.

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