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1 ***Reference values for performance test outcomes relevant to English female***
2 ***soccer players***

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52 **Reference values for performance test outcomes relevant to English female soccer players**

53

54 **Abstract**

55 *The purpose of this study was to present reference standards for physical performance test*
56 *outcomes relevant to elite female soccer players. We analysed mixed-longitudinal data (n =*
57 *1715 observations) from a sample of 479 elite youth and senior players as part of the English*
58 *Football Association's national development programme (age range: 12.7 to 36.0 years).*
59 *Semi-parametric generalized additive models for location, scale and shape (GAMLSS)*
60 *estimated age-related reference centiles for 5-m sprinting, 30-m sprinting, countermovement*
61 *jump (CMJ) height, and Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IRI) performance.*
62 *The estimated reference centiles indicated that the median of the distribution of physical*
63 *performance test scores varied non-linearly with advancing chronological age, improving until*
64 *around 25 years for each performance variable. These are the first reference ranges for*
65 *performance test outcomes in elite English female soccer players. These data can assist*
66 *practitioners when interpreting physical test performance outcomes to track an individual's*
67 *progress over time and support decision making regarding player recruitment and*
68 *development.*

69

70 **Keywords:** Fitness testing; football; player tracking; physical performance; age-related
71 reference ranges; GAMLSS

72

73 **Introduction**

74 Physical performance testing provides an opportunity to evaluate a player's physical qualities
75 (1) and represents an integral component of an elite soccer player's development programme
76 (2). Information derived from physical performance testing can support the decision-making
77 processes of coaches and practitioners involved in talent identification, player selection and
78 development (3). A wide range of physical performance tests are available (1,4,5) with
79 measurement of linear speed, lower limb body power (i.e., jumping based tests) and high-
80 intensity intermittent endurance (6) considered important by coaches and practitioners (e.g.,
81 face and content validity) (3,7–11).

82

83 Despite women's soccer research being comparatively under-researched relative to male soccer
84 (12), the area of physical performance testing has received moderate attention (13), with a focus
85 on exploring age group differences (2,14). Previous research has shown high-intensity
86 endurance capacity to differentiate between age groups with national team senior players
87 achieving higher scores than their U15, U17 and U20 counterparts (2,14,15). Similarly, a
88 general improvement in linear speed performance has been demonstrated through adolescence
89 to the age of 23 years in national team players (16), with senior players also exhibiting faster
90 20 m linear speed times compared to U15, U17 and U20 national team players (14). However,
91 40 m linear speed was consistent in elite players from U18 to > 25 years (17). Jumping
92 performance has also been shown to increase through adolescence in high-level (18) and elite
93 (19) female players with higher values reported in senior national team players compared to
94 youth (U15 and U17) players (2,14). However, these observations are not consistent as
95 countermovement jump (CMJ) performance did not differ in elite players from U18 to > 25
96 years (17) and U19 national team players jumped higher than senior players (19).

97

98 Previous literature has largely focused on relatively small samples of sub-elite (20,21), elite
99 youth (22,23) or players competing in governing body age categories, i.e., U17, U20 and
100 seniors (2,14,19) with the majority of studies being cross-sectional in nature. Cross sectional

101 studies lack temporality and therefore the information provided across these broad age
102 categories does not allow for specific year by year progressions to be considered (16). While
103 recent research (16) explored trends in physical test performance at different ages in female
104 soccer players from Canada (age range: 12 – 34 years), there are no reference centiles values
105 available for benchmarking physical test performance of the elite female soccer player.
106 Reference centiles are commonly used in clinical settings as a tool to understand changes in
107 function and relative standing (24,25). In elite sport, information from reference values can
108 assist practitioners when interpreting physical test performance data by indicating the player
109 performance level at a given chronological age (24). The purpose of this study, therefore, was
110 to develop age-related reference centiles for physical performance variables relevant to elite
111 female soccer players.

112

113 **Methods**

114

115 **Design**

116 Mixed-longitudinal field-based physical performance testing data were collected from elite
117 youth and senior soccer players as part of the English Football Association's national
118 development programme. Players from this development programme were selected to
119 represent England at all age groups (seniors and youth squads). Data were collected from 479
120 female soccer players covering the youth-to-senior spectrum (age range: 12.7 to 36.0 years)
121 and analysed retrospectively. With some players measured once and others more than once
122 (range: 1 to 12 assessments), the present study sample included goalkeepers and outfield
123 players tested at multiple time points across four seasons for a total of 1715 individual
124 observations. Performance tests were conducted at three time points (start (September), middle
125 (January) and end of season April)) throughout the year. Performance data were collected as a
126 condition of employment in which player physical performance is routinely assessed (26). All
127 data were anonymised prior to analysis to ensure player confidentiality and appropriate
128 institutional ethics committee approval was granted. At the time of testing, an average training
129 week for the senior players consisted of 4-6 pitch-based training sessions, 2-3 strength sessions
130 and 1-2 competitive matches, whereas U15 players completed 2-3 pitch-based training
131 sessions, 1 strength session and 1 match per week.

132

133 **Procedures**

134 A standardised warm-up was completed, consisting of generic warm-up activity prior to
135 commencing the physical performance tests. Specific warm-ups were also completed prior to
136 each of the performance tests. To ensure consistency between testing occasions, National
137 federation staff coached the warm-up activity. Prior to assessment, all players had previously
138 completed each test on at least one occasion. All performance tests were performed on third
139 generation turf (indoor arena). Tests were completed in a single session and in the same order
140 on each test occasion. Countermovement jump (CMJ) was completed first, followed by linear
141 speed and finally the Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1). Reliability
142 assessments were undertaken, with 140 players completing physical performance testing on
143 two separate occasions separated by seven days (27).

144

145

146 **Countermovement jump**

147 Estimations of player's lower limb muscular power were assessed via a CMJ on a jump mat
148 (KMS Innervations, Australia). The jump mat was placed on a firm, concrete surface at the
149 edge of the third-generation turf (indoor arena). Following the generic and jump-specific
150 warm-up activity, the player was permitted an additional practice jump on the mat before

151 performing three recorded trials. The player was instructed to step on to the mat and place their
152 feet in the middle of the mat (a comfortable distance apart) with their hands on their hips. The
153 player started from an upright position and was instructed to jump as high as possible while
154 keeping their hands on their hips. Players self-selected the depth of flexion prior to take off and
155 were instructed to keep their legs straight whilst in the air and refrain from bringing their legs
156 into a pike position or flicking their heels. The highest jump height recorded to the nearest 0.1
157 cm was used as the criterion measure of performance. The estimated standard error of the
158 measurement (SEM) for this test was 1.1 cm (95%CI, 0.9 cm to 1.2 cm) and the coefficient of
159 variation (CV) was 3.9% (95%CI, 3.4% to 4.3%) (27).

160

161 **Linear speed**

162 Player's linear speed times were evaluated using electronic timing gates (Brower TC Timing
163 System, USA) over distances of 5-m and 30-m. A 50 m steel tape measure (Stanley, UK) was
164 used to measure the 30 m distance and markers were placed at 0, 5 m and 30 m, in addition, a
165 marker was placed 1 m behind the zero line. Tripods were placed directly over each marker at
166 a height of 0.87 m above ground level and a timing gate (transmitter) was fitted to each tripod.
167 Opposite each tripod, at a distance of 2 m, another tripod and timing gate (receiver) was
168 positioned. Following the generic and speed-specific warm-up activity, the player was
169 permitted an additional practice sprint through the course before performing three recorded
170 trials. Each sprint was separated by a 3-min recovery period. The player commenced each
171 sprint with their preferred foot on a line 1 m behind the first timing gate. The fastest time at
172 each distance to the nearest 0.01 s was used as the criterion measure of performance. The
173 estimated SEM was 0.024 s (95%CI, 0.021 s to 0.027 s) and 0.057 s (95%CI, 0.051 to 0.064 s)
174 for 5 m and 30 m linear sprinting respectively (27). The CV was 1.2% (95%CI, 1.1% to 1.4%)
175 and 3.9% (95%CI, 3.4% to 4.3% for 5-m and 30-m sprinting respectively (27).

176

177 **Yo-Yo Intermittent Recovery Test Level 1**

178 Estimations of player's high-intensity endurance capacity were assessed using the Yo-Yo IR1.
179 During the test, participants completed a series of repeated 20 m shuttle runs with a
180 progressively increasing running speed (10-19 km·h⁻¹) interspersed with 10 s rest intervals (28).
181 The SEM for this test was 74 m (95%CI, 67 m to 84 m) and the CV was 7.2% (95%CI, 6.3%
182 to 8.1%) (27).

183

184 **Statistical analysis**

185 Semi-parametric generalized additive models for location, scale and shape (GAMLSS)
186 estimated physical performance age-related reference centiles (29). The *lms* function
187 determined the smoothing degrees of freedom and the distribution of physical performance
188 data based on the model minimising the global deviance score (29). Models estimated nine
189 reference centiles at 0.38th, 2.27th, 9.12th, 25.25th, 50th, 74.75th, 90.88th, 97.72th, and 99.62th
190 values spaced $\frac{2}{3}$ of a standard deviation score apart (30). Postestimation diagnostics were
191 performed to identify outliers from the fitted model with values greater than +3.5 or lower than
192 -3.5 residuals based on the visual inspection of the worm plot prior to final analysis (31).
193 Reference standards analyses were performed using the *gamlss* package (27).

194

195 **Results**

196 Predicted reference centiles for 5-m sprinting, 30-m sprinting, CMJ height, and Yo-Yo IR1
197 mixed-longitudinal data are illustrated in Tables 1-4, respectively. The functions for the models
198 estimating predicted reference centiles for the 5-m sprinting and CMJ variables with Box-Cox
199 Cole-Green distribution, whereas models for the 30-m sprinting and Yo-Yo IR1 variables used
200 Box-Cox *t* and Box-Cox power exponential distributions, respectively. In general, physical test

201 performance improved non-linearly with chronological age for each physical test performance
202 measure until approximately 25 years (Figures 1-4). Residuals diagnostics revealed the
203 presence of 1 outlier in the 5-m sprinting, 30-m sprinting, and Yo-Yo IR1 datasets. Following
204 the exclusion of the identified outliers, visual inspection of the worm plots suggested adequate
205 model fit (Fig. 5).

206

207 **Discussion**

208 This is the first study to present reference values for physical performance outcomes based on
209 a large-scale sample of elite English female soccer players. The estimated reference centiles
210 indicated that the median of the distribution of physical performance test scores varied non-
211 linearly with advancing chronological age, improving up to around 25 years. These data are
212 novel and provide practitioners with information relevant to different processes from practical
213 and medical standpoints, with a particular reference to inform decisions regarding talent
214 identification, player selection and development, and return to play of individual female soccer
215 players. Specifically, the construction of age-related reference centiles facilitates the
216 interpretation of real-world performance data for tracking the individual player over different
217 career stages (32).

218

219 Importantly, estimation of reference centiles that may be informative for coaches and
220 practitioners depends on the study design (33,34). In clinical research, the construction of
221 growth references generally entail the adoption of a cross-sectional study design using one-off
222 measurements only (32). However, centile values determined from cross-sectional data might
223 be uninformative for individual tracking purposes (32,35,36). Also, the construction of age-
224 related reference centiles using cross-sectional data requires relatively larger sample sizes than
225 mixed- or longitudinal designs where some or all of the athletes are measured at least twice
226 (37,38). With our study framework informed by methodological guidelines for the construction
227 of reference values (32,37–39), our investigation is the first to use a mixed-longitudinal design
228 for the development of age-related reference centiles that may support the screening of the
229 individual elite female soccer player throughout their professional career.

230

231 To demonstrate how the reference centiles illustrated in the present study can serve as a tool
232 for practitioners to track an individual player's progress over time, consider an individual
233 player who registers a CMJ of 27 cm at 17 years of age and then 35 cm at 21 years of age.
234 Using the predicted reference centiles for CMJ (Table 3), it can be shown that the player has
235 moved from the 25th centile at 17 years of age to the 75th centile at 21 years of age, thus
236 highlighting the simplicity and practicality of tracking the individual player's relative
237 performance standing over time. Additionally, the predicted reference centiles provide a
238 framework which permits simple comparisons between equivalent datasets. However, the
239 present lack of data from other countries similar to that illustrated in our study precluded formal
240 comparisons with other populations of elite female soccer players. What our illustration aimed
241 to address was the need for translating empirical findings into performance-based solutions for
242 the creation of an operational framework in clubs and federations that may support the
243 development of the elite female soccer player (40).

244

245 Within the settings of modern academies and national federations, reference values for
246 measures used to support decisions on the individual player would enable coaches, managers,
247 and executives more objective value judgments (41). In practice, the need for benchmarking
248 player physical performance demands the development of reference standards for establishing
249 minimum criteria for the individual player to pursue a career at a professional level. While
250 useful for appraising the degree to which needs for physical performance development are

251 being met during the academy stages (42), reference values might also provide valuable
252 insights regarding the expected time before a player may reach peak performance. For example,
253 our results suggest that physical performance test scores improve until around 25 years. This
254 finding aligns with previous explorations in elite female soccer players suggesting players
255 reach peak physical performance between ~22 and ~25.5 years across a range of physical
256 performance tests (e.g., 30-15 intermittent fitness test, CMJ, squat jump, broad jump, 10-m and
257 40-m sprinting) (16).

258
259 The present study is not without limitations. We used data gathered from players selected for
260 a national development programme and, therefore, our findings may be deemed prone to biases
261 in player selection and training programme design, thereby limiting the generalisability of our
262 results in other contexts. Players were selected to the development programme based on a
263 combination of physical and technical criteria and consequently the reference values presented
264 in this study may be influenced by the physical profile of players selected to the programme.
265 Secondly, while in line with the clinical literature, we presented reference centiles by
266 chronological age only, and not by biological age. Researchers in this field suggested that the
267 assessment of biological age via reference methods (i.e., skeletal age; secondary sex
268 characteristics) can be important to support player development strategies (43). However, this
269 data was not available in the current study, and, notably, gathering consistent biological age
270 measurements may not be feasible throughout an individual player's career. Thirdly, the sample
271 size in the current study was not sufficient to permit splitting the available dataset for the
272 estimation of reference centiles by playing position (38). Likewise, our sample composition,
273 involving subjects measured once and others more than once, precluded a formal estimation of
274 unbiased pointwise confidence bands for individual centile curves. In our study context,
275 estimating the uncertainty for a given centile curve represented a design issue (39). The use of
276 mixed-longitudinal data is a valuable compromise to address ethical and study cost issues
277 typical of other study designs (37). Specifically, adopting a cross-sectional design requires a
278 relatively larger number of study participants yet providing information about distance that
279 may be comparable to estimations conducted in smaller-scale study settings (44). While
280 bootstrapping procedures are currently available for our modelling methods, inappropriate
281 treatment of mixed-longitudinal data can result in deriving misleadingly inflated standard
282 errors yielding overly precise confidence bands (39). In conventional cross-sectional study
283 designs with normally distributed data, confidence bands approximate ± 2 standard errors (45).
284 However, in the context of our study, clear procedures for estimating confidence bands for
285 reference centiles based on mixed-longitudinal data remains unexplored and warrants future
286 methodological work in this field of research. Finally, the menstrual cycle phase was not
287 recorded during physical performance testing and is acknowledged that this may have
288 influenced performance. However, existing research on this particular aspect remains
289 inconsistent (46).

290 291 **Conclusions**

292 The present study provided, for the first time in female soccer, reference centiles for
293 performance test outcomes relevant to English female soccer players. The reference centiles
294 provide novel data for coaches and practitioners involved in player recruitment and
295 development by enabling the tracking of the individual players progress over time against
296 benchmark values derived from the reference population. The development of reference
297 centiles for performance test outcomes in players from other countries deserves consideration
298 for longitudinal tracking purposes and to allow comparison of estimations between different
299 contexts.

300

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305 size and composition relevant to reference centiles development studies.

306
307 **Disclosure of Interest**

308 The authors report no conflict of interest.

309
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Table 1. Predicted reference centiles for 5-m sprinting time by chronological age (N=416, n=1191)

Age	0.4 th	2 nd	9 th	25 th	50 th	75 th	91 st	98 th	99.6 th
13	0.91	0.95	0.99	1.03	1.07	1.12	1.17	1.23	1.28
15	0.94	0.97	1.01	1.04	1.08	1.12	1.16	1.21	1.25
17	0.95	0.97	1.00	1.03	1.06	1.10	1.13	1.18	1.21
19	0.94	0.96	0.99	1.02	1.05	1.09	1.12	1.16	1.20
21	0.93	0.95	0.99	1.02	1.05	1.09	1.13	1.18	1.22
23	0.93	0.95	0.98	1.02	1.05	1.09	1.13	1.18	1.23
25	0.93	0.95	0.98	1.01	1.05	1.08	1.12	1.17	1.21
27	0.94	0.96	0.99	1.02	1.05	1.08	1.12	1.16	1.21
29	0.95	0.98	1.00	1.03	1.06	1.10	1.13	1.18	1.21

Age range: 12.7 years to 36.0 years. Sparse data for chronological age > 25 years

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Table 2. Predicted reference centiles for 30-m sprinting time by chronological age (N=436, n=1327)

Age	0.4 th	2 nd	9 th	25 th	50 th	75 th	91 st	98 th	99.6 th
13	4.28	4.41	4.56	4.70	4.85	5.00	5.16	5.34	5.51
15	4.19	4.31	4.45	4.57	4.71	4.85	4.99	5.16	5.32
17	4.11	4.22	4.34	4.46	4.58	4.71	4.84	5.00	5.15
19	4.10	4.20	4.32	4.42	4.53	4.65	4.77	4.92	5.06
21	4.13	4.23	4.33	4.43	4.53	4.64	4.76	4.90	5.04
23	4.12	4.21	4.32	4.41	4.50	4.60	4.70	4.84	4.99
25	4.09	4.18	4.28	4.36	4.45	4.54	4.64	4.77	4.93
27	4.10	4.20	4.30	4.38	4.46	4.54	4.64	4.78	4.97
29	4.17	4.30	4.42	4.50	4.57	4.65	4.75	4.92	5.19

Age range: 12.7 years to 36.0 years. Sparse data for chronological age > 25 years

Table 3. Predicted reference centiles for CMJ height by chronological age (N=471, n=1629)

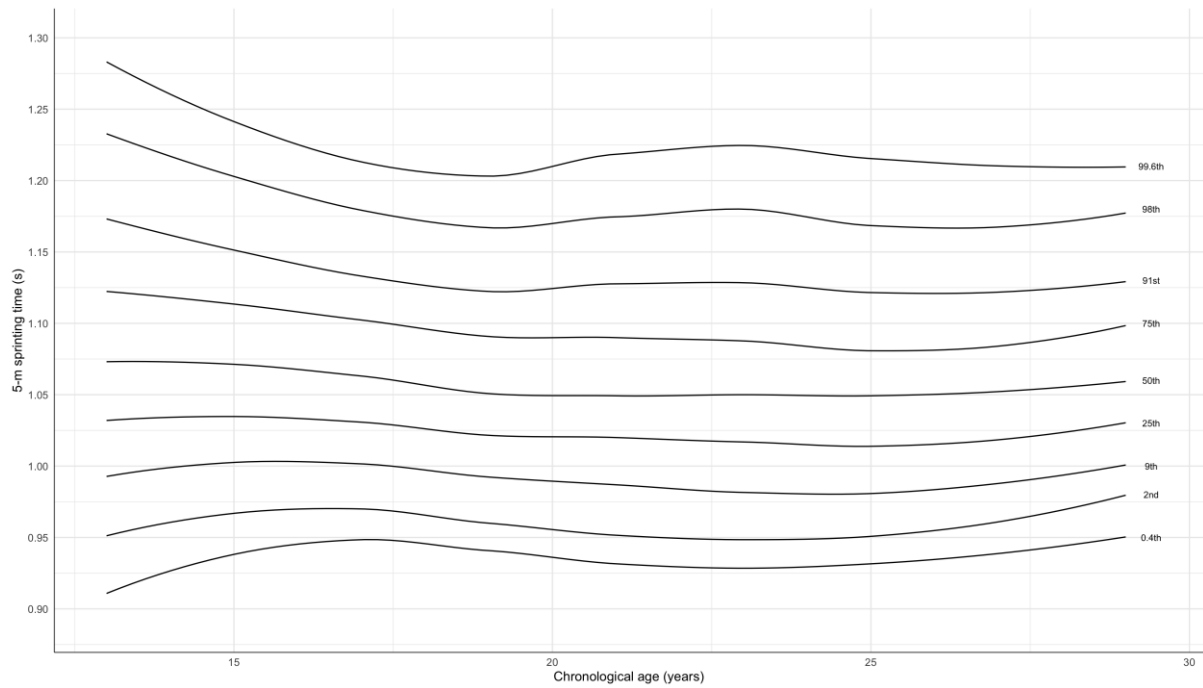
Age	0.4 th	2 nd	9 th	25 th	50 th	75 th	91 st	98 th	99.6 th
13	18.3	20.1	22.4	24.8	27.3	29.9	32.7	35.9	38.7
15	19.3	21.2	23.7	26.1	28.7	31.4	34.2	37.4	40.3
17	20.0	22.0	24.5	27.0	29.7	32.4	35.3	38.4	41.2
19	21.2	23.2	25.8	28.2	30.9	33.6	36.3	39.4	42.0
21	22.9	24.9	27.4	29.8	32.3	34.9	37.5	40.4	42.9
23	24.7	26.7	29.2	31.6	34.1	36.6	39.2	42.0	44.4
25	25.7	27.8	30.4	32.8	35.3	37.9	40.5	43.3	45.7
27	25.0	27.1	29.7	32.2	34.7	37.3	39.9	42.7	45.2
29	23.6	25.7	28.4	30.8	33.4	36.0	38.7	41.5	43.9

Age range: 12.7 years to 36.0 years. Sparse data for chronological age > 25 years

Table 4. Predicted reference centiles for Yo-Yo IR1 distance by chronological age (N=436, n=1308)

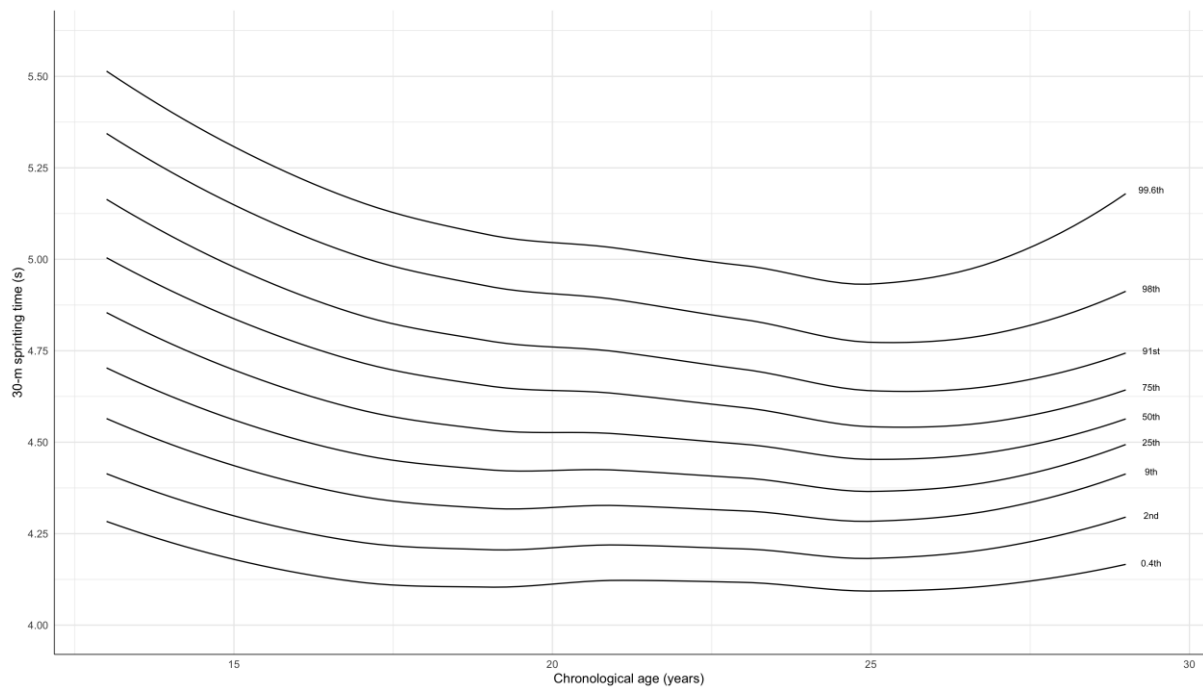
Age	0.4 th	2 nd	9 th	25 th	50 th	75 th	91 st	98 th	99.6 th
13	340	436	580	754	981	1249	1531	1850	2132
15	410	523	690	890	1153	1444	1713	1980	2193
17	462	596	788	1012	1297	1595	1850	2086	2264
19	482	637	849	1085	1372	1659	1893	2101	2254
21	518	705	945	1201	1500	1786	2011	2206	2346
23	575	812	1098	1386	1706	2004	2233	2430	2569
25	580	863	1181	1480	1795	2080	2300	2490	2626
27	535	849	1183	1470	1753	2003	2203	2381	2512
29	499	831	1175	1447	1691	1906	2088	2260	2391

Age range: 12.7 years to 36.0 years. Sparse data for chronological age > 25 years



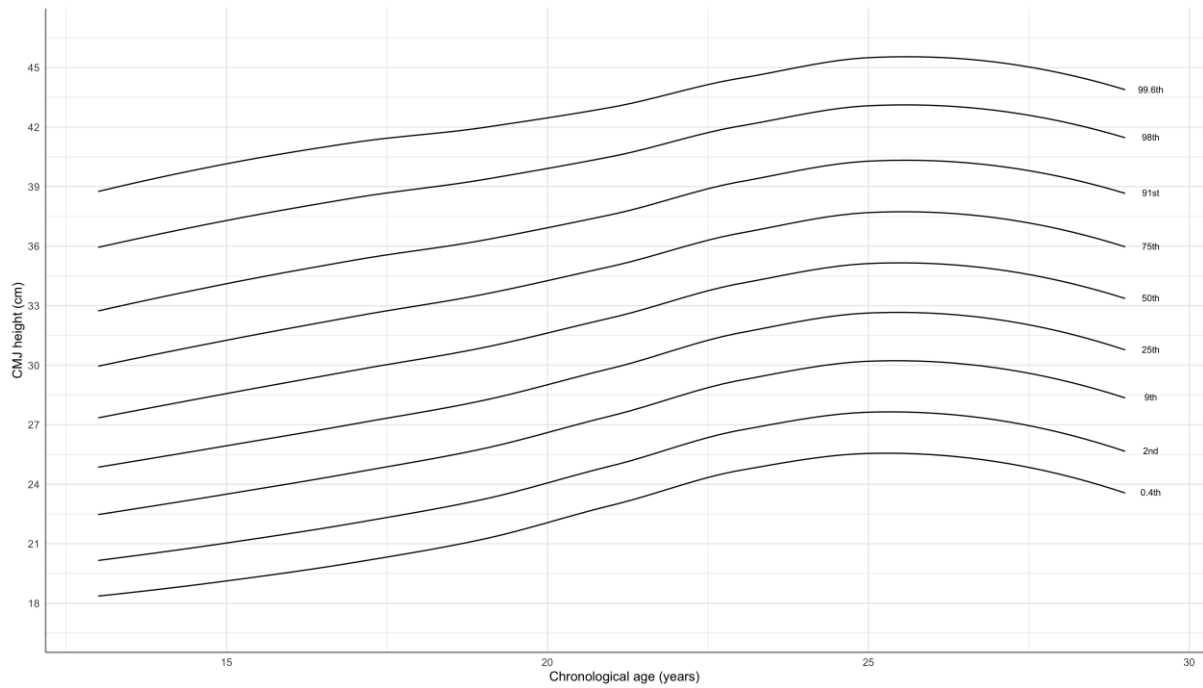
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Figure 1. Predicted reference centiles for 5-m sprinting time by chronological age (N=416, n=1191)



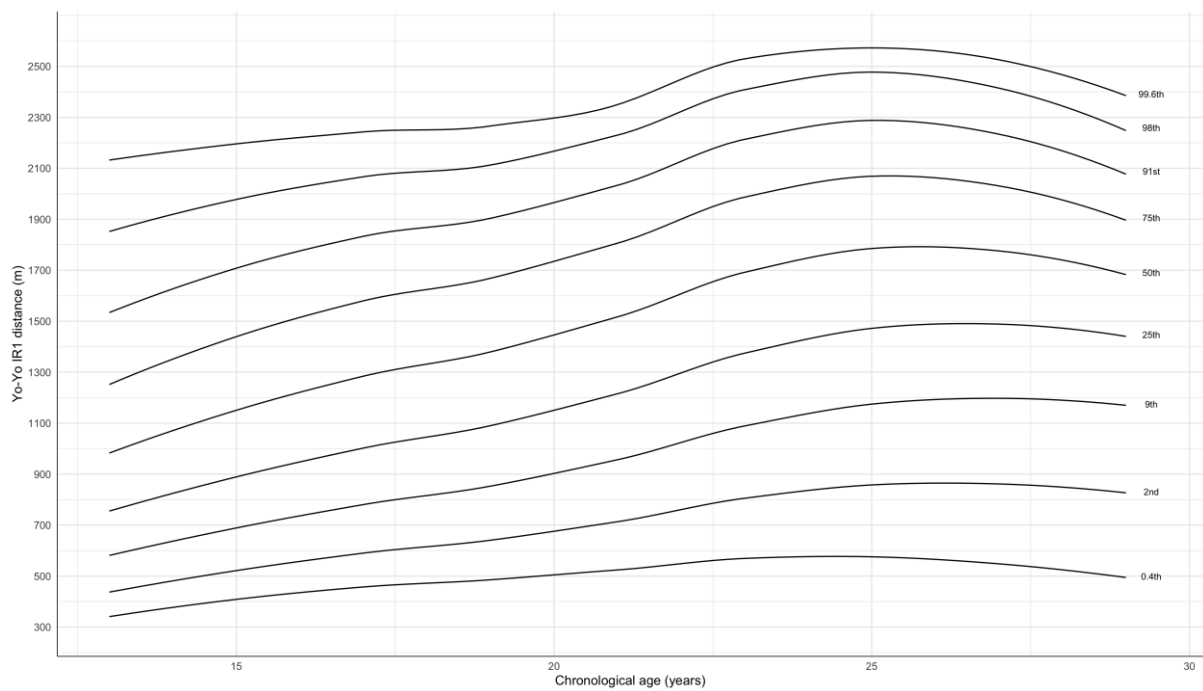
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Figure 2. Predicted reference centiles for 30-m sprinting time by chronological age (N=436, n=1327)



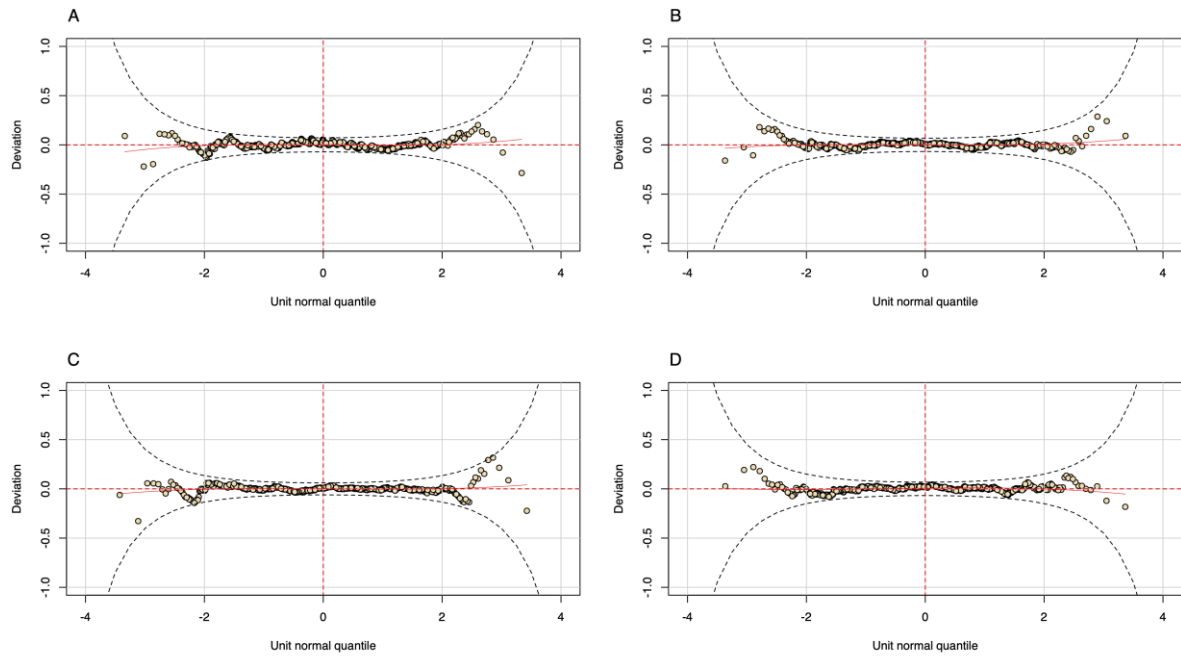
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Figure 3. Predicted reference centiles for CMJ height by chronological age (N=471, n=1629)



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Figure 4. Predicted reference centiles for Yo-Yo IR1 distance by chronological age (N=436, n=1308)



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Figure 5. Worm plots from the 5-m sprinting (A), 30-m sprinting (B), CMJ (C), and Yo-Yo IR1 (D) models