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7 **Faster, higher, stronger, older: Relative age effects are most influential during the youngest**8 **age grade of track and field athletics in the United Kingdom**9 PHILIP E. KEARNEY^{1*}, PHILIP R. HAYES², & ALAN NEVILL³10 ¹*Physical Education & Sports Sciences Department, University of Limerick;* ²*Department of*11 *Sport, Exercise and Rehabilitation, Northumbria University, UK; and* ³*Institute of Sport & Human*12 *Sciences, University of Wolverhampton, UK.*

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Abstract

28 The relative age effect (RAE) is a common phenomenon in youth sport, whereby children born
29 early in the selection year are more likely to experience success and to sustain participation.
30 There is a lack of research investigating variables which influence RAEs within track and field
31 athletics. Such information is vital to guide policies in relation to competition structure, youth
32 development squads and coach education. A database of competition results was analysed to
33 determine the extent to which RAEs were present in track and field athletics in the United
34 Kingdom. Subsequent analyses examined whether age, sex, event and skill level influenced the
35 RAE. Examination of 77,075 records revealed that RAEs were widespread, but most
36 pronounced during Under 13 (U13) competitions; that is, during athletes' first exposure to
37 formal track and field competition. Sex, event and skill level further influenced the existence
38 and magnitude of RAEs at different age grades. Relative age is a key influencing factor within
39 track and field athletics, especially at the youngest age category. Consequently, national
40 governing bodies need to consider what administrative and stakeholder initiatives are
41 necessary to minimise the effects of RAEs on young athletes' early experiences of competition.

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Keywords: youth sport, talent, coaching

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Introduction

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Within youth sport, children and adolescents are often assigned to categories based upon chronological age with the intention of ensuring appropriate competition experiences (Cobley, Baker, Wattie, & McKenna, 2009). However, children of the same chronological age may show wide variation in biological development (Jones, Hitchen, & Stratton, 2000; Malina, 2011). This problem is compounded by the use of broad age categories in many sports, typically one or two years in span. Within such categories, the average child born shortly after the cut-off date is thought to possess a considerable physical and cognitive advantage relative to the average child born shortly before the cut-off date for that age group (Buchheit & Mendez-Villanueva, 2014; Nutton et al., 2012; Roberts, Boddy, Fairclough, & Stratton, 2012). This initial advantage is thought to be compounded as coaches may confuse this developmental advantage for a difference in potential and provide additional opportunities to relatively early born children in the form of supplementary coaching (e.g., selection to development squads) or access to higher levels of competition (Barnsley, Thompson, & Barnsley, 1985; Hancock, Adler, & Côté, 2013; Sherar, Bruner, Munroe-Chandler, & Baxter-Jones, 2007). As a result, relative age effects (RAEs) emerge, whereby an individual's age relative to their peers during youth sport exerts an influence on their progress and participation in later years (for a review see Cobley et al., 2009).

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Pronounced RAEs have been identified in a number of track and field contexts (Brazo-Sayavera et al., 2016; Hollings et al., 2014; Romann & Cobley, 2015). This finding is unsurprising given that there is a well-established relationship between chronological age and performance on tests of basic motor capabilities which underpin track and field events such as sprinting speed, endurance running, and jumping distance (Haubenstricker & Seefeldt, 1986; Ross, Dotson, Gilbert, & Katz, 1985; Veldhuizen, Wade, Cairney, Hay, & Faught, 2014), hence the use

70 of age groups for competitions. However, at the end of adolescence and during adult
71 competition, by which point maturation-related differences have largely dissipated (Malina,
72 Rogol, Cumming, Coelho-e-Silva, & Figueirido, 2015), examinations of a number of track and
73 field contexts have revealed persisting RAEs (Morris & Nevill, 2006; Saavedra-García et al.,
74 2016); that is, the sample of top performers still contains a disproportionately high number of
75 individuals born in the first quarter of the year. Furthermore, while research in other sports has
76 investigated how RAEs are influenced by factors such as age, event, and skill level (Delorme,
77 Boiché, & Raspaud, 2010a; Stenling & Hölmstrom, 2014; Till et al., 2010), limited research has
78 investigated the effect of such factors on RAEs in track and field athletics. It is critically
79 important for administrators and coach educators to understand the factors influencing RAEs
80 so that they can deliver appropriate organizational and educational initiatives in response.

81 One framework which may be useful to stakeholders attempting to understand and
82 address RAEs is Hancock, Adler, & Côté's (2013) Social Agent Model. The central point of the
83 model is that social agents, such as parents, coaches or athletes, may all amplify RAEs by falsely
84 conflating physical maturity with actual skill differences. Specifically, parents are proposed to
85 initially influence RAEs by preferentially enrolling relatively older children in sport (Delorme,
86 Boiché, & Raspaud, 2010b; Hancock, Ste-Marie, & Young, 2013). Subsequently, coaches are
87 proposed to influence RAEs due to their greater expectations of relatively older athletes
88 translating into changes in behaviour (e.g., more frequent feedback or praise; Solomon,
89 DiMarco, Ohlson, & Reece, 1998). Athletes themselves are proposed to influence RAEs by
90 acting congruently with the expectations placed upon them (e.g., increased diligence in
91 training). Thus, interventions to address RAEs need to target multiple social agents. An in-
92 depth assessment of the factors that influence RAEs (e.g., age grade, skill level) should be
93 valuable in guiding such interventions. For example, such information could aid administrators

94 in the design of competitions (e.g., individual versus team contests; at what age group to
95 introduce national competitions) and national ranking systems (e.g., at what age group should
96 rankings begin to be published; should athletes be ranked by year or by month). Furthermore,
97 increased knowledge of factors influencing RAEs could guide regional development officers in
98 recruitment to development squads (e.g., at what age to begin squads) and consideration of
99 the curriculum offered (e.g., single or multi-event focus at different age grades), and for coach
100 educators to design more relevant courses/guidance (e.g., including information on the
101 influence of relative age on performance).

102 Copley et al.'s (2009) meta-analysis suggested that RAEs are most prominent during
103 late adolescence, however, the majority of sports included in this review were team sports. It is
104 plausible that advantages due to physical development may peak earlier in track and field
105 athletics due to the emphasis that these events place on a single attribute (e.g., speed in
106 sprinting). There is a dearth of research investigating RAEs at younger ages of track and field
107 competition, with the majority of previous research focusing on athletes who are Under 15 or
108 older (Brazo-Sayavera et al., 2016; Hollings et al., 2014; Morris & Nevill, 2006; Saavedra-García
109 et al., 2016). Within track and field athletics, performances are judged on objective data (e.g.,
110 distance jumped), rather than on the subjective evaluation of an individual's contribution to a
111 team performance. Athlete rankings, and selection to development squads is similarly based
112 upon such performances. Understanding when RAEs are strongest would allow coaches,
113 parents and administrators to interpret such performances more appropriately; that is, as
114 indicative of short-term advantage rather than long-term potential (Güllich & Emrich, 2006;
115 Moesch, Elbe, Hauge, & Wikman, 2011).

116 In addition to age, a number of factors have been demonstrated to influence RAEs in
117 track and field athletics. Two studies have investigated the effect of skill level on RAEs in track

118 and field; Brazo-Sayavera et al. (2016) examined athletes selected to Spanish national
119 federation training camps, while Romann & Cobley (2015) divided athletes who had competed
120 in the 60m sprint into groups on the basis of their seasonal best performance. In both cases,
121 RAEs were higher when examining higher skill level athletes. Investigations of the influence of
122 event on the existence or strength of RAEs have produced mixed results (Hollings et al., 2014;
123 Saavedra-García et al., 2016). For example, Hollings et al. (2014) identified a smaller RAE in
124 boys competing in middle distance events at the 2009 World Youth Championships (Under 18).
125 For girls, the smallest RAE was observed in the jumping events. The authors suggested that as
126 the various events rely on different gross motor abilities (i.e., strength, speed), it was likely that
127 events would show RAEs at different points. Finally, and in contrast to the majority of research
128 on RAEs (Cobley et al., 2009), mixed results have been reported in relation to the effect of sex
129 on RAEs in track and field. Specifically, investigations of various female populations have found
130 no effect (Romann & Fuchslocher, 2014), or else have identified an effect for female athletes
131 competing in certain events or age groups, but not for others (Brazo-Sayavera et al., 2016;
132 Hollings et al., 2014; Saavedra-García et al., 2016). Thus, within track and field, it appears that
133 sex might interact with age and event in determining where RAEs are most prominent.

134 It is clear from the above review that a more comprehensive analysis of RAEs within
135 track and field athletics is warranted. Such an analysis should provide valuable information to
136 coaches and administrators in relation to athlete selection and development policies. Based
137 upon the findings of previous research, we hypothesised that RAEs would be stronger within
138 male populations and in higher skill level populations. As the evidence relating to the effect of
139 event is equivocal, no predictions were made as to how event might moderate RAEs. While we
140 hypothesised that RAEs should be stronger at Under 15 than at subsequent age grades, given

141 the absence of prior investigations no prediction could be made in relation to the Under 13 age
142 grade.

143 **Method**

144 Data were acquired from a publicly-available website, www.powerof10.info, which
145 hosts information on athlete track and field performances and rankings within the United
146 Kingdom. All data used in this study are reported anonymously. Institutional ethical approval
147 was obtained for the project.

148 **Participants**

149 All participants listed on www.powerof10.info in one of nine events (100m, 800m,
150 1500m, sprint hurdles, long jump, high jump, shot put, discus, javelin) between 2005 and 2015,
151 and for whom a date of birth was available, were identified. These events were chosen as they
152 represent the core athletic disciplines. More specialist events (e.g., pole vault, hammer) were
153 not considered due to the lower number of participating athletes. Birthdates were available for
154 67% of athletes in the Under 13 (U13) category, 69% of U15s, 79% of U17s, 89% of U20s, and
155 99% of senior athletes. Senior athletes were defined as those aged between 20 and 35 (the
156 entry point for masters competition) years. Within the United Kingdom, youth athletes are
157 organized within two- (U13, U15, U17) or three-year (U20) age bands. So that each athlete was
158 only counted once per age category, the analysis was restricted to those athletes who were in
159 the senior year of each age category. To enable statistical comparisons across events, athletes
160 who were ranked in multiple events were only counted within the event in which they were
161 ranked most highly. Consequently, the final sample involved 77,985 records. These records
162 were sorted into categories based on age grade (i.e., U13, U15, U17, U20, Senior), skill level
163 (see data analysis section for details), event, and sex.

164 **Procedure**

165 The cut-off date for the majority of youth age grades in the United Kingdom is 31st
166 August. However, for U20 athletes, the cut-off date changes to the international cut-off date
167 for track and field of December 31st. On visual inspection of the data, it was apparent that the
168 31st August cut-off date experienced during their initial years in the sport exerted the dominant
169 influence on the U20 populations, rather than the December 31st cut-off date which the
170 athletes had only lately experienced. Consequently, all athletes were classified into birth
171 quartiles such that quartile one ranged from September 1st to November30th, quartile two
172 ranged from December 1st to February 28th/29th, quartile three ranged from March 1st to May
173 31st, and quartile four from June 1st to the August 31st.

174 **Data Analysis**

175 To analyse the data set for RAEs, the 77,985 records were processed using customised
176 Microsoft Excel spreadsheets and IBM SPSS Version 24. For each combination of age grade,
177 event, and sex, χ^2 Goodness of Fit tests were used to examine whether the distribution of
178 births present within the sample differed from that of the general UK population for the
179 relevant years, retrieved from <http://data.un.org> (Table 1). To examine whether RAEs were
180 more pronounced for top ranked athletes, the analysis was repeated for the athletes ranked in
181 the top 20 in each category. The top 20 was chosen as these athletes represented those who
182 could reasonably be expected to make national semi-finals. Furthermore, as the top 20 has
183 previously been used in analyses of athlete progression and retention within UK athletics
184 populations (Morris & Nevill, 2006; Shibli & Barrett, 2011), using this category facilitated
185 comparison with previous research. Due to the smaller sample size available for top 20
186 athletes, event groups (Sprints/Hurdles: 100m, hurdles; Middle Distance: 800m, 1500m;
187 Jumps: high jump, long jump, Throws: shot, discus, javelin) were analysed rather than
188 individual events. Cohen's w provided a measure of effect size, with values of 0.1, 0.3 and 0.5

189 indicating small, medium and large effect sizes, respectively (Cohen, 1992). Ninety-five percent
190 confidence intervals for w were calculated following the procedure of Smithson (2003). Where
191 significant chi-square results and at least a small effect size were found, standardized residuals
192 (SR) provided a post-hoc test to identify where there were significant deviations from the
193 expected frequencies (Hancock, Young, & Ste-Marie, 2011). SRs $\geq \pm 1.96$ were deemed
194 noteworthy.

195 *[Insert Table 1 about here]*

196 Consistent with Cobley et al. (2009), odds ratios (ORs) and 95% confidence intervals
197 (95% CIs) were calculated for relative age quartile distributions using the observed number of
198 athletes available from the website in quartile one, using quartile four as the reference
199 quartile. This procedure allows an estimation of the odds or risk size of RAEs (Cobley et al.,
200 2009; Till et al., 2010), and to evaluate the influence of sex, event, and skill level on RAEs
201 (Cumming, 2012).

202 In order to interpret differences in ORs and 95% CIs, independent samples are required
203 (Cumming, 2012). A comparison across age grades for the entire sample was not appropriate
204 due to participants appearing at multiple age grades. To investigate how age grade moderated
205 the strength of the RAE, a sample was formed from the years 2005-2006 and 2014-2015, in
206 which independent samples existed across age grades (i.e., performers from 2005/06 would be
207 too old for the U20 category in 2014). This reduced sample consisted of 27,855 records, and
208 was analysed in the manner described above. Event groups (as described previously in relation
209 to skill level) were analysed rather than individual events, due to the smaller sample sizes
210 which existed for some events.

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Results

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A typical example of the RAEs observed is provided in Table 2 for women's high jump.

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A substantial bias in favour of the first quarter is evident within all age groups for this event.

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For efficiency, only the odds ratio (OR) calculations for the remaining RAE analyses are

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presented (Table 3). A detailed breakdown of RAEs within each event is available in

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supplementary file 1.

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[Insert Table 2 about here]

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The χ^2 tests revealed significant deviations from the pattern of births in the general

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population in all but four of the 90 samples examined (female U17 800m, 1500m and javelin;

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female U20 1500m). However, the 95% CIs around the ORs suggested caution in the

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interpretation of eight further cases (all female populations): 800m and 1500m at U15, shot at

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U17, 800m at U20, and 100m, 1500m, high jump and javelin at senior level (see Table 3).

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[Insert Table 3 about here]

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Inspection of 95% CIs in Table 3 suggested that at U13, U20 and Senior level, ORs were

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similar between males and females, but that RAEs are likely stronger in most male populations

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at U15 and U17. For example, U15 male 100m runners were 4.2 times more likely to be born in

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Q1 than Q4 (95% CI [3.5, 5.0]). While a RAE was still present in U15 female 100m runners,

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athletes were only 2.2 times more likely to be born in Q1 than Q4 (95% CI [1.8, 2.6]). Table 3

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illustrates that sex differences in the size of the RAE were likely in most events at U15, and in

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running events (100m, hurdles, 800m, 1500m) at U17.

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Further inspection of ORs and 95% CIs in Table 3 suggested that differences between

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events in the size of RAEs were relatively rare. However, analysis of the ORs suggested

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consistently smaller RAEs for the 1500m than for the other events for females at the U13, U15,

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U17 and U20 age categories, and for males at the U13, U15, U17 and Senior age categories.

235 The only other event-related differences appeared at U13, where for both males and females,
236 larger ORs were observed for the 100m (male OR 6.3, 95% CI [4.9, 8.2]; female OR 4.4, 95% CI
237 [3.7, 6.7]) and shot (male OR 5.5, 95% CI [3.9, 7.8]; female OR 5.0, 95% CI [3.7, 6.7]) relative to
238 other events.

239 Table 4 illustrates the RAEs for athletes ranked within the top 20 in their age grade. For
240 male athletes, it is clear from an inspection of the 95% CIs that ORs are likely substantially
241 larger for top 20 ranked athletes at the U13 and U15 age grades relative to their lower ranked
242 peers. For example, male U13 athletes competing in the 100m sprint or hurdles events who are
243 ranked in the top 20 are 14.8 times more likely to have been born in Q1 than Q4 (95% CI [7.4,
244 29.6]). While a pronounced RAE still exists for those athletes ranked outside the top 20 (OR 3.6,
245 95% CI [3.0, 4.3]), it is markedly lower than the effect for their top ranked peers. At U20 and
246 Senior level, there are no longer any skill level-related differences in RAEs for male athletes.
247 For female athletes, the only skill-related differences in the strength of RAEs appear at U13
248 level (all event groups), and for jumps at U15, where RAEs are stronger amongst top 20 ranked
249 athletes.

250 *[Insert Table 4 about here]*

251 Inspection of the ORs and 95% CIs in Table 5 reveals that, for both male and female
252 athletes, RAEs tended to be largest at the U13 age category. For both male and female
253 athletes, this difference was most pronounced in the sprints/hurdles event group. In contrast,
254 examining the ORs and 95% CIs for male middle distance runners revealed a relatively
255 consistent RAE across age grades. For female middle distance runners, ORs indicated that there
256 was no RAE from U15 through to Senior level.

257 *[Insert Table 5 about here]*

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Discussion

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The results of the current study provide valuable insight for administrators, regional development officers and coach educators into the factors which influence RAEs. It is clear that variations in relative age are a central factor contributing to success at different age grades of track and field competition in the United Kingdom. The existence of RAEs is consistent with most previous investigations of track and field athletics (Brazo-Sayavera et al., 2016; Hollings et al., 2014; Saavedra-García et al., 2016), however the larger sample size within the present study allowed for the investigation of individual events and a broader range of age categories within the same national system. In particular, by examining younger age groups than previous research, this study suggests that RAEs are most pronounced in early rather than late adolescence. The existence of RAEs is a serious problem for youth sport, due to the well-established connection between RAEs and dropout (Delorme, Boiché, & Raspaud, 2010b; Lemez, Baker, Horton, Wattie, & Weir, 2014).

In contrast to Cobley et al.'s (2009) meta-analysis, RAEs were generally largest in the youngest population examined (U13). Cobley et al.'s (2009) analysis focused predominantly on complex team sports. The earlier peak in RAEs within track and field athletes is likely due to the greater importance of basic physical (e.g., height) and physiological characteristics (e.g., speed) to performance differences amongst relatively untrained athletes (Brazo-Sayavera et al., 2016), and the wide variation in physical development present at this age (Malina, 2011). Thus, athletes are being introduced to formal competitions at precisely that point when their performances are most subject to differences in maturation. Consequently, administrators and coaches need to critically reflect upon the structure of the youth athletic experience at this age grade. Such reflections could consider what level of regional competition is appropriate, the

281 extent to which athletes engage in team or individual competitions, and the emphasis placed
282 on single versus multi-event (e.g., pentathlon) competitions.

283 While the most obvious finding in this analysis is a large benefit of being among the
284 relatively oldest at U13, it is also important to consider how the effect changes across age
285 grades. The continued existence of a biased distribution of births in many events at Senior level
286 suggests that the large initial benefit has a long-lasting effect. However, the markedly reduced
287 size of the RAE at Senior level in comparison to U13 suggests that in the latter stages of their
288 development, the advantage shifts to those relatively late born athletes. An inspection of
289 female 100m sprinters illustrates this point; at U13 the ratio of athletes born in Q1:Q4 was
290 42.4%:9.7%, but by senior level this ratio was 31.3%:22% (Supplementary file 1). This shift in
291 the distribution back towards (but not completely attaining) an even distribution is consistent
292 with what has been observed in rugby league within a UK context (Cobley & Till, 2017). Thus,
293 our data emphasises the need to minimise the relative age-related loss of athletes throughout
294 development, both in terms of Q4 athletes during early adolescence, and Q1 athletes during
295 later adolescence.

296 RAEs were found to be stronger in males at U15 and U17. Furthermore, sex interacted
297 with skill level. Specifically, RAEs were more prominent amongst athletes ranked in the top 20
298 for an age grade relative to their lower ranked peers at U13 and U15 for male athletes, and
299 predominantly at U13 for female athletes. That is, high performing athletes in the youngest age
300 category are more likely to be relative older, and therefore there is a higher probability that
301 they are biologically more developed. That sex was found to interact with skill level is
302 consistent with previous research within athletics (Brazo-Sayavera et al., 2016; Hollings et al.,
303 2014) and is likely to be due to female athletes maturing faster than their male counterparts
304 (Cumming, Standage, Gillison, & Malina, 2008). If clubs, counties, or regions are recruiting

305 development squads at U13, then these results suggest that coaches should reflect on whether
306 decisions relating to selection and content are being biased by athletes' current level of
307 development at the cost of the long term development of the broader athlete pool.

308 Few differences between events emerged, but RAEs were generally weaker for the
309 1500m than for the other events examined at U13, U15 and U17, while both middle distance
310 events showed no RAE in several female samples. Competition has been noted as an important
311 pre-requisite for RAEs (Musch & Grondin, 2001), however, the sample sizes within the current
312 study for the 1500m were equivalent to those for other events. While Saavedra-Garcia et al.
313 (2016) reported less consistent RAEs across events than reported here, the sample sizes in that
314 study (average N = 110 for youth samples) was far fewer than the current study (average N =
315 692). These findings reinforce the conclusion of Hollings et al. (2014) that RAEs are likely to be
316 largest in events with a greater emphasis on speed and/or strength.

317 Despite the change in cut-off date from August 31st to December 31st, and a three year
318 age category, the U20 samples were still biased towards the August cut-off date. Previous
319 studies which have investigated the effect of a system-wide shift in cut-off date on RAEs have
320 consistently found that the RAE shifts to the new date (Helsen, Starkes, & Van Winckel, 2000;
321 Musch & Hay, 1999), however there is a lack of research on the effect of a shift in cut-off date
322 between age groups. Till et al. (2010) included Under 18 community-level rugby league players
323 within their analysis, for whom the cut-off date had shifted to December 31st from August 31st.
324 No RAE was found for these players, possibly due to their age and their playing at the club level
325 only, but Till et al. did not comment on the effect of the shift in cut-off date. Within track and
326 field, our results suggest that the RAE from earlier age grades has already influenced
327 participation, and that maturation-related differences are too low at U20 for any new effect to
328 emerge.

329 Numerous solutions have been proposed to address RAEs, including rotating cut-off
330 dates from year to year (Barnsley et al., 1985), longer (Grondin et al., 1984) or shorter age-
331 group bandwidths (Boucher & Halliwell, 1991), implementing player quotas/average age
332 schemes (Barnsley & Thompson, 1988), physical classification schemes (Cumming, Lloyd,
333 Oliver, Eisenmann, & Malina, 2017), and educating stakeholders regarding RAEs (Andronikos et
334 al., 2015; Musch & Grondin, 2001). Specific to sprinting, Romann and Cobley (2015) have
335 demonstrated how corrective adjustments could be applied to youth results to remove RAEs
336 from top rankings, however additional research is required to determine if this strategy would
337 work for other athletic disciplines. Furthermore, it is important to emphasise that relative age
338 is a proxy measure for development, which is only accurate at the population level. Thus, while
339 relative age has the advantage of being easily accessible and non-invasive, any correction
340 factor based on regression analysis will always contain error at the level of the individual
341 athlete.

342 Methods for rotating the cut-off date have been proposed to provide all athletes with
343 an advantage at different time points in development (e.g., the Novem system; Boucher &
344 Halliwell, 1991). Rotating the cut-off dates on an annual basis would be a considerable
345 administrative challenge. Publishing additional rankings based upon month of birth may be a
346 more feasible solution. Taking the boys U15 100m rankings from 2015 as an extreme example,
347 such an approach would see the sprinter who was ranked 697th out of all boys born in that
348 selection year also ranked 10th out of all August-born U15s; an altogether more encouraging
349 prospect for a young athlete. However, while such alternative rankings would present a better
350 picture for those relatively few late-born athletes whose performances appear on the national
351 rankings, only a small minority of late-born athletes achieve the necessary performances to be
352 ranked. Consequently, for an additional month-based ranking to be effective, administrators

353 also need to consider the criteria for inclusion within the rankings. In light of the dramatic
354 effect that relative age has on rankings at U13, particularly top 20 rankings, and the weak
355 relationship between performances at U13 and later age grades (Kearney & Hayes, 2017), it is
356 worth considering whether publishing national rankings for U13 performances is beneficial.

357 There are a number of limitations with this study. Due to the potential for a biased
358 distribution to exist within the entire population of registered players, RAEs should be
359 calculated relative to all registered players rather than to national statistics (Delorme, Boiché,
360 & Raspaud, 2010c). Indeed, such a biased distribution with the general population has
361 previously been demonstrated in Spanish track and field athletics at U15 level (Brazo-Sayavera
362 et al., 2016). Unfortunately statistics on all registered athletes were not available for this study.
363 However, inspection of the top ranked athletes in this study did reveal substantially higher ORs
364 relative to all athletes at younger age grades, supporting the likelihood of a genuine effect. The
365 selection of the top 20 as representing highly skilled, although consistent with previous
366 research (Morris & Nevill, 2006; Shibli & Barrett, 2011), is somewhat arbitrary, as the depth of
367 performances may not be consistent across events. Future research should consider whether
368 standards based upon the International Association of Athletics Federations scoring tables
369 (Spiriev & Spiriev, 2017) might provide more appropriate criteria. A final limitation arose due to
370 a recent change in the weight of the shot and javelin implements thrown by female athletes at
371 U15 and U17. All records of performances with the previous weight implements were not
372 available from the database. The sample sizes for these categories were considerably lower
373 than for the other events, and consequently, these specific results should be treated with
374 caution.

375 In conclusion, RAEs were evident within the majority of subpopulations of track and
376 field athletes examined. Unlike team sports, where RAEs are typically more pronounced during

377 late adolescence, in this study RAEs were found to be strongest at U13, particularly amongst
378 top ranked U13 athletes. Consequently, national governing bodies need to consider what
379 administrative and stakeholder initiatives are necessary to minimise the effects of RAEs on
380 young athletes' initial experiences of formal competition.
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Table 1

Distribution of births within the general population of the United Kingdom matched to participants within the sample

Category	Relevant years for sample matching	% in quartile 1	% in quartile 2	% in quartile 3	% in quartile 4
Under 13	1993-2003	24.4	25.1	25.9	24.7
Under 15	1991-2001	24.6	25.2	25.8	24.4
Under 17	1989-1999	24.5	25.3	25.8	24.4
Under 20	1986-1996	24.4	25.4	25.8	24.4
Senior	1970-1985	25.0	25.5	25.5	24.0

Table 2.

Relative age effects for women's high jump

Category	N	% Q1	% Q2	% Q3	% Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4
Under 13	1665	40.6	27.2	19.8	12.4	306.8	<0.001	0.43 [0.38, 0.48]	13.4	1.7	-4.8	-10.1
Under 15	1343	36.0	26.2	20.9	16.8	116.6	<0.001	0.29 [0.24, 0.35]	8.5	0.8	-3.5	-5.6
Under 17	671	31.0	24.6	23.4	21.0	16.5	<0.001	0.16 [0.09, 0.23]	3.4	-0.3	-1.2	-1.8
Under 20	234	36.8	27.4	17.5	18.4	24.6	<0.001	0.32 [0.21, 0.46]	3.8	0.6	-2.5	-1.9
Senior	229	34.5	22.7	20.1	22.7	11.8	0.008	0.23 [0.13, 0.36]	2.9	-0.8	-1.6	-0.4

Note: N = number of athletes; Q = quarter of the year, with Q1 Sep-Nov, Q2 Dec-Feb, etc; w = Cohen's w; 95% CI = 95% confidence interval; SR = standardised residual, with SRq1 referring to the standardised residual for quarter 1. The χ^2 tests have 3 degrees of freedom.

Table 3.

Relative age effects as identified by the odds ratio (OR) for the entire population by gender, event, and age group.

Sex	Event	Under 13		Under 15		Under 17		Under 20		Senior	
		N	OR [95% CI]	N	OR [95% CI]	N	OR [95% CI]	N	OR [95% CI]	N	OR [95% CI]
Male	100m	1335	6.3 [4.9, 8.2]	2544	4.2 [3.5, 5.0]	2110	2.6 [2.2, 3.1]	966	2.1 [1.6, 2.7]	1246	1.8 [1.4, 2.3]
	Hurdles	1249	2.7 [2.1, 3.4]	1028	3.6 [2.8, 4.7]	587	3.4 [2.4, 4.8]	250	3.4 [2.0, 5.8]	370	2.3 [1.5, 3.5]
	800m	1383	3.0 [2.4, 3.8]	1834	3.0 [2.5, 3.6]	1385	2.4 [1.9, 3.0]	801	2.1 [1.6, 2.8]	1168	1.7 [1.3, 2.1]
	1500m	1936	1.5 [1.3, 1.8]	2126	2.1 [1.8, 2.5]	1551	1.7 [1.4, 2.1]	850	1.8 [1.4, 2.4]	1407	1.3 [1.1, 1.6]
	High Jump	1234	3.4 [2.7, 4.3]	1298	3.3 [2.6, 4.2]	781	2.2 [1.7, 2.9]	322	2.0 [1.3, 3.1]	368	1.8 [1.2, 2.7]
	Long Jump	1124	3.1 [2.4, 4.0]	1104	3.6 [2.8, 4.7]	974	2.7 [2.1, 3.5]	421	2.0 [1.3, 3.0]	553	2.1 [1.5, 2.9]
	Discus	791	2.7 [2.0, 3.6]	847	3.5 [2.6, 4.7]	555	2.2 [1.6, 3.1]	222	2.8 [1.6, 4.8]	365	1.8 [1.2, 2.7]
	Shot	655	5.5 [3.9, 7.8]	691	4.5 [3.2, 6.3]	480	3.9 [2.7, 5.7]	234	3.2 [1.9, 5.5]	273	2.5 [1.6, 4.0]
	Javelin	1034	2.2 [1.7, 2.8]	824	2.7 [2.0, 3.6]	625	2.0 [1.5, 2.7]	304	2.0 [1.3, 3.1]	535	1.8 [1.3, 2.5]
Female	100m	1719	4.4 [3.6, 5.5]	1943	2.2 [1.8, 2.6]	1019	1.7 [1.3, 2.2]	398	1.9 [1.3, 2.8]	718	1.4 [1.0, 1.9]
	Hurdles	1558	3.1 [2.5, 3.8]	1381	2.3 [1.9, 2.9]	655	1.7 [1.3, 2.3]	217	2.4 [1.4, 4.1]	309	2.2 [1.4, 3.5]
	800m	1645	2.8 [2.3, 3.4]	1462	1.8 [1.5, 2.2]	788	1.2 [0.9, 1.6]	304	1.5 [1.0, 2.3]	523	1.5 [1.1, 2.1]
	1500m	1532	1.6 [1.3, 2.0]	1571	1.2 [1.0, 1.5]	872	1.1 [0.8, 1.4]	372	1.3 [0.9, 1.9]	891	1.2 [0.9, 1.6]
	High Jump	1665	3.3 [2.7, 4.1]	1343	2.1 [1.7, 2.6]	671	1.5 [1.1, 2.0]	234	2.0 [1.2, 3.3]	229	1.5 [0.9, 2.5]
	Long Jump	1343	3.2 [2.5, 4.0]	1330	2.5 [2.0, 3.1]	762	1.9 [1.4, 2.5]	299	3.2 [2.0, 5.1]	339	1.8 [1.2, 2.7]
	Discus	865	2.8 [2.1, 3.7]	1139	2.1 [1.7, 2.7]	667	1.5 [1.1, 2.0]	224	2.3 [1.4, 3.9]	250	1.8 [1.1, 3.0]
	Shot	998	5.0 [3.7, 6.7]	218	2.2 [1.3, 3.8]	84	2.1 [0.9, 5.0]	184	2.0 [1.1, 3.5]	268	2.2 [1.3, 3.6]
	Javelin	960	2.1 [1.6, 2.7]	242	2.1 [1.3, 3.5]	97	1.8 [0.8, 4.0]	211	2.3 [1.3, 4.0]	289	1.6 [1.0, 2.5]

Note: N = number of participants; OR = odds ratio birth quartile 1 versus birth quartile 4; values in square brackets indicate the lower and upper limits of the 95% confidence intervals (CI); shaded cells indicate no relative age effect observed.

Table 4.

Relative age effects as identified by the odds ratio (OR) in male and female athletes of differing skill levels.

Sex	Event	Ranking	Under 13		Under 15		Under 17		Under 20		Senior	
			N	OR [95% CI]	N	OR [95% CI]	N	OR [95% CI]	N	OR [95% CI]	N	OR [95% CI]
Male	Sprints/Hurdles	Top 20	283	14.8 [7.4, 29.6]	366	7.2 [4.4, 11.9]	296	3.5 [2.2, 5.7]	185	2.5 [1.4, 4.6]	117	2.3 [1.1, 4.8]
		Rank 21+	2301	3.6 [3.0, 4.3]	3206	3.8 [3.3, 4.4]	2401	2.7 [2.3, 3.2]	1031	2.3 [1.8, 3.0]	1499	1.8 [1.5, 2.2]
	Middle distance	Top 20	289	4.0 [2.4, 6.6]	316	4.2 [2.6, 6.8]	269	4.1 [2.4, 7.0]	193	1.5 [0.8, 2.7]	132	1.1 [0.6, 2.2]
		Rank 21+	3030	1.8 [1.6, 2.1]	3644	2.4 [2.1, 2.7]	2667	1.9 [1.6, 2.2]	1458	2.0 [1.6, 2.5]	2443	1.5 [1.3, 1.8]
	Jumps	Top 20	324	11.7 [6.4, 21.5]	332	6.6 [4.0, 11]	307	3.9 [2.4, 6.4]	181	1.8 [1.0, 3.3]	106	1.9 [0.9, 4.1]
		Rank 21+	2034	2.8 [2.3, 3.4]	2070	3.1 [2.6, 3.7]	1448	2.2 [1.8, 2.7]	562	2.1 [1.5, 2.9]	815	1.9 [1.4, 2.5]
	Throws	Top 20	377	6.3 [3.9, 10.1]	438	7.6 [4.7, 12.2]	367	3.5 [2.3, 5.4]	212	2.7 [1.5, 4.7]	141	2.8 [1.4, 5.6]
		Rank 21+	2103	2.6 [2.2, 3.1]	1924	2.9 [2.4, 3.5]	1293	2.3 [1.8, 2.9]	548	2.5 [1.8, 3.5]	1075	1.8 [1.4, 2.3]
Female	Sprints/Hurdles	Top 20	297	6.0 [3.5, 10.3]	303	2.4 [1.5, 3.8]	206	1.9 [1.1, 3.3]	119	1.7 [0.8, 3.4]	90	2.7 [1.1, 6.5]
		Rank 21+	2980	3.5 [3.0, 4.1]	3021	2.2 [1.9, 2.5]	1468	1.6 [1.3, 2.0]	496	2.2 [1.5, 3.1]	937	1.5 [1.2, 1.9]
	Middle distance	Top 20	277	3.6 [2.2, 6.0]	247	2.2 [1.3, 3.7]	185	1.2 [0.7, 2.2]	114	1.1 [0.5, 2.3]	111	1.2 [0.6, 2.5]
		Rank 21+	2900	2.0 [1.7, 2.3]	2786	1.4 [1.2, 1.6]	1475	1.2 [1.0, 1.5]	562	1.4 [1.0, 1.9]	1303	1.4 [1.1, 1.7]
	Jumps	Top 20	341	6.7 [4.0, 11.3]	276	4.2 [2.5, 7.1]	204	2.3 [1.3, 4.0]	131	1.8 [0.9, 3.6]	85	1.9 [0.8, 4.4]
		Rank 21+	2667	3.0 [2.6, 3.5]	2397	2.2 [1.9, 2.6]	1229	1.6 [1.3, 2.0]	402	2.9 [1.9, 4.3]	483	1.6 [1.1, 2.3]
	Throws	Top 20	394	4.7 [3.0, 7.3]	205	3.3 [1.8, 5.9]	150	1.6 [0.9, 3.0]	195	2.1 [1.2, 3.7]	108	1.5 [0.7, 3.3]
		Rank 21+	2429	2.8 [2.4, 3.3]	1394	2.0 [1.6, 2.5]	698	1.6 [1.2, 2.2]	424	2.3 [1.6, 3.4]	699	1.9 [1.4, 2.6]

Note: N = number of participants; OR = odds ratio birth quartile 1 versus birth quartile 4; values in square brackets indicate the lower and upper limits of the 95% confidence intervals (CI). Sprints/hurdles: 100m, hurdles; Middle distance: 800m, 1500m; Jumps: long jump, high jump; Throws: shot, discus, javelin.

Table 5.

Variation in relative age effects across age categories in male and female athletes.

Sex	Event Group	Under 13		Under 15		Under 17		Under 20		Senior	
		N	OR [95% CI]	N	OR [95% CI]	N	OR [95% CI]	N	OR [95% CI]	N	OR [95% CI]
Male	Sprints/Hurdles	772	10.5 [7, 15.7]	1194	3.7 [2.9, 4.7]	887	3.0 [2.3, 4.0]	412	2.8 [1.9, 4.2]	693	2.0 [1.5, 2.7]
	Middle distance	1189	1.8 [1.4, 2.3]	1413	2.2 [1.8, 2.7]	960	1.9 [1.5, 2.5]	564	2.3 [1.6, 3.2]	1158	1.4 [1.1, 1.8]
	Jumps	791	4.6 [3.3, 6.3]	867	3.9 [2.9, 5.2]	558	2.4 [1.7, 3.4]	226	1.5 [0.9, 2.5]	378	2.0 [1.3, 3.0]
	Throws	799	5.7 [4.1, 8.0]	754	4.0 [2.9, 5.5]	522	2.5 [1.8, 3.5]	247	2.7 [1.6, 4.5]	515	2.1 [1.5, 3.0]
Female	Sprints/Hurdles	1190	6.9 [5.2, 9.2]	1055	2.2 [1.7, 2.8]	493	1.5 [1.1, 2.1]	193	2.7 [1.5, 4.8]	339	2.1 [1.4, 3.2]
	Middle distance	1197	2.3 [1.8, 2.9]	1094	1.3 [1.0, 1.6]	560	1.1 [0.8, 1.5]	230	1.7 [1.0, 2.8]	641	1.4 [1.0, 1.9]
	Jumps	1150	3.8 [2.9, 4.9]	949	2.6 [2.0, 3.4]	473	1.7 [1.2, 2.4]	213	2.2 [1.3, 3.7]	252	1.6 [1.0, 2.6]
	Throws	1031	5.0 [3.7, 6.7]	793	2.3 [1.7, 3.1]	351	1.5 [1.0, 2.3]	207	1.9 [1.1, 3.3]	366	1.7 [1.1, 2.5]

Note: N = number of participants; OR = odds ratio birth quartile 1 versus quartile 4; values in square brackets indicate the lower and upper limits of the 95% confidence intervals (CI). Sprints/hurdles: 100m, hurdles; Middle distance: 800m, 1500m; Jumps: long jump, high jump; Throws: shot, discus, javelin.

Supplementary File 1

Relative age effects for female and male athletes at each category of age group and event

Female

100m	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	1719	42.4	27.5	20.5	9.7	405.0	<0.001	0.49 [0.44, 0.53]	15.0	2.0	-4.4	-12.5	4.4 [3.5, 5.4]	2.8 [2.2, 3.5]	2.1 [1.7, 2.6]
	Under 15	1943	35.4	26.8	21.6	16.3	159.8	<0.001	0.29 [0.24, 0.33]	9.6	1.4	-3.7	-7.2	2.2 [1.8, 2.6]	1.6 [1.3, 1.9]	1.3 [1.1, 1.6]
	Under 17	1019	30.5	27.4	24.1	18.0	35.5	<0.001	0.19 [0.13, 0.25]	3.9	1.3	-1.1	-4.2	1.7 [1.3, 2.2]	1.5 [1.2, 1.9]	1.3 [1.0, 1.7]
	Under 20	398	37.4	25.9	17.1	19.6	43.1	<0.001	0.33 [0.24, 0.43]	5.2	0.2	-3.4	-1.9	1.9 [1.3, 2.8]	1.3 [0.9, 1.9]	0.9 [0.6, 1.4]
	Senior	718	31.3	24.5	22.1	22.0	16.3	<0.001	0.15 [0.09, 0.23]	3.4	-0.5	-1.8	-1.1	1.4 [1.0, 1.9]	1.1 [0.8, 1.5]	1.0 [0.7, 1.4]
Hurdles	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	1558	39.7	25.9	21.5	13.0	246.4	<0.001	0.40 [0.35, 0.45]	12.2	0.6	-3.4	-9.3	3.1 [2.5, 3.8]	2.0 [1.6, 2.5]	1.7 [1.4, 2.1]
	Under 15	1381	37.4	26.9	19.7	16.0	154.7	<0.001	0.33 [0.28, 0.39]	9.6	1.3	-4.5	-6.3	2.3 [1.8, 2.9]	1.7 [1.4, 2.1]	1.2 [1.0, 1.5]
	Under 17	655	33.7	23.8	22.1	20.3	31.5	<0.001	0.22 [0.15, 0.30]	4.8	-0.7	-1.9	-2.1	1.7 [1.3, 2.3]	1.2 [0.9, 1.6]	1.1 [0.8, 1.5]
	Under 20	217	40.6	22.1	20.3	17.1	31.3	<0.001	0.38 [0.26, 0.52]	4.8	-0.9	-1.6	-2.2	2.4 [1.4, 4.1]	1.3 [0.7, 2.3]	1.2 [0.7, 2.1]
	Senior	309	35.3	24.9	23.9	15.9	22.0	<0.001	0.27 [0.17, 0.38]	3.6	-0.2	-0.5	-2.9	2.2 [1.4, 3.5]	1.6 [1.0, 2.6]	1.5 [0.9, 2.4]
800m	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	1645	37.5	27.0	22.2	13.3	212.8	<0.001	0.36 [0.31, 0.41]	10.7	1.6	-2.9	-9.3	2.8 [2.3, 3.4]	2.0 [1.6, 2.5]	1.7 [1.4, 2.1]
	Under 15	1462	32.4	25.2	24.1	18.3	60.0	<0.001	0.20 [0.15, 0.25]	6.0	0.1	-1.3	-4.7	1.8 [1.5, 2.2]	1.4 [1.1, 1.7]	1.3 [1.0, 1.6]
	Under 17	788	27.4	25.1	25.5	22.0	4.8	0.189	0.08 [0.06, 0.15]	1.7	-0.1	-0.2	-1.4	1.2 [0.9, 1.6]	1.1 [0.8, 1.5]	1.2 [0.9, 1.6]
	Under 20	304	32.9	24.0	20.7	22.4	12.7	0.005	0.20 [0.12, 0.32]	3.0	-0.5	-1.8	-0.7	1.5 [1.0, 2.3]	1.1 [0.7, 1.7]	0.9 [0.6, 1.4]
	Senior	523	33.1	22.9	22.2	21.8	18.4	<0.001	0.19 [0.12, 0.28]	3.7	-1.1	-1.5	-1.0	1.5 [1.1, 2.1]	1.1 [0.8, 1.6]	1.0 [0.7, 1.4]
1500m	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	1532	30.0	26.4	24.5	19.1	41.4	<0.001	0.16 [0.12, 0.22]	4.4	1.1	-1.1	-4.4	1.6 [1.3, 2.0]	1.4 [1.1, 1.7]	1.3 [1.1, 1.6]
	Under 15	1571	26.1	25.2	26.2	22.5	3.9	0.275	0.05 [0.04, 0.10]	1.2	0.0	0.3	-1.5	1.2 [1.0, 1.5]	1.1 [0.9, 1.3]	1.2 [1.0, 1.5]
	Under 17	872	25.0	24.1	27.6	23.3	2.1	0.547	0.05 [0.06, 0.11]	0.3	-0.7	1.0	-0.7	1.1 [0.8, 1.4]	1.0 [0.8, 1.3]	1.2 [0.9, 1.6]
	Under 20	372	28.5	25.0	24.2	22.3	3.6	0.313	0.10 [0.09, 0.20]	1.6	-0.1	-0.6	-0.8	1.3 [0.9, 2.0]	1.1 [0.7, 1.7]	1.1 [0.7, 1.7]
	Senior	891	27.7	26.7	23.1	22.4	6.1	0.105	0.08 [0.06, 0.15]	1.6	0.7	-1.4	-1.0	1.2 [0.9, 1.6]	1.2 [0.9, 1.6]	1.0 [0.8, 1.3]

Long Jump	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI]	OR [95% CI]	OR [95% CI]
														Q1:Q4	Q2:Q4	Q3:Q4
	Under 13	1343	41.0	27.8	18.5	12.7	260.2	<0.001	0.44 [0.39, 0.49]	12.3	2.0	-5.3	-8.8	3.2 [2.5, 4.0]	2.2 [1.7, 2.8]	1.5 [1.2, 1.9]
	Under 15	1330	36.7	27.0	21.5	14.8	141.1	<0.001	0.33 [0.27, 0.38]	8.9	1.3	-3.1	-7.1	2.5 [2.0, 3.1]	1.8 [1.4, 2.3]	1.5 [1.2, 1.9]
	Under 17	762	35.3	24.8	21.0	18.9	53.0	<0.001	0.26 [0.20, 0.34]	6.0	-0.3	-2.6	-3.1	1.9 [1.4, 2.5]	1.3 [1.0, 1.7]	1.1 [0.8, 1.5]
	Under 20	299	45.8	20.1	19.7	14.4	75.8	<0.001	0.50 [0.40, 0.62]	7.5	-1.8	-2.1	-3.5	3.2 [2.0, 5.1]	1.4 [0.8, 2.3]	1.4 [0.8, 2.3]
	Senior	339	36.6	22.4	20.4	20.6	24.7	<0.001	0.27 [0.18, 0.38]	4.3	-1.1	-1.9	-1.3	1.8 [1.2, 2.7]	1.1 [0.7, 1.7]	1.0 [0.6, 1.6]
High Jump	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI]	OR [95% CI]	OR [95% CI]
														Q1:Q4	Q2:Q4	Q3:Q4
	Under 13	1665	40.6	27.2	19.8	12.4	306.8	<0.001	0.43 [0.38, 0.48]	13.4	1.7	-4.8	-10.1	3.3 [2.7, 4.1]	2.2 [1.8, 2.7]	1.6 [1.3, 2.0]
	Under 15	1343	36.0	26.2	20.9	16.8	116.6	<0.001	0.29 [0.24, 0.35]	8.5	0.8	-3.5	-5.6	2.1 [1.7, 2.6]	1.6 [1.3, 2.0]	1.2 [1.0, 1.5]
	Under 17	671	31.0	24.6	23.4	21.0	16.5	<0.001	0.16 [0.09, 0.23]	3.4	-0.3	-1.2	-1.8	1.5 [1.1, 2.0]	1.2 [0.9, 1.6]	1.1 [0.8, 1.5]
	Under 20	234	36.8	27.4	17.5	18.4	24.6	<0.001	0.32 [0.21, 0.46]	3.8	0.6	-2.5	-1.9	2.0 [1.2, 3.4]	1.5 [0.9, 2.5]	1.0 [0.6, 1.8]
	Senior	229	34.5	22.7	20.1	22.7	11.8	0.008	0.23 [0.13, 0.36]	2.9	-0.8	-1.6	-0.4	1.5 [0.9, 2.5]	1.0 [0.6, 1.7]	0.9 [0.5, 1.5]
Shot	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI]	OR [95% CI]	OR [95% CI]
														Q1:Q4	Q2:Q4	Q3:Q4
	Under 13	998	43.4	29.4	18.6	8.6	278.5	<0.001	0.53 [0.47, 0.59]	12.1	2.7	-4.5	-10.2	5.0 [3.7, 6.7]	3.4 [2.5, 4.6]	2.2 [1.6, 3.0]
	Under 15	218	37.6	24.3	21.1	17.0	22.0	<0.001	0.32 [0.20, 0.45]	3.9	-0.2	-1.4	-2.2	2.2 [1.3, 3.8]	1.4 [0.8, 2.5]	1.2 [0.7, 2.1]
	Under 17	84	34.5	31.0	17.9	16.7	8.7	0.034	0.32 [0.19, 0.54]	1.9	1.0	-1.4	-1.4	2.1 [0.9, 5.1]	1.9 [0.8, 4.6]	1.1 [0.4, 2.8]
	Under 20	184	41.3	22.3	15.8	20.7	30.4	<0.001	0.41 [0.28, 0.55]	4.6	-0.8	-2.7	-1.0	2.0 [1.1, 3.5]	1.1 [0.6, 2.0]	0.8 [0.4, 1.5]
	Senior	268	37.7	21.3	23.9	17.2	24.7	<0.001	0.3 [0.20, 0.43]	4.2	-1.4	-0.5	-2.3	2.2 [1.3, 3.6]	1.2 [0.7, 2.0]	1.4 [0.8, 2.3]
Discus	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI]	OR [95% CI]	OR [95% CI]
														Q1:Q4	Q2:Q4	Q3:Q4
	Under 13	865	36.8	26.5	23.5	13.3	101.8	<0.001	0.34 [0.28, 0.41]	7.3	0.8	-1.4	-6.7	2.8 [2.1, 3.7]	2.0 [1.5, 2.7]	1.8 [1.3, 2.4]
	Under 15	1139	37.1	24.3	21.2	17.3	106.4	<0.001	0.31 [0.25, 0.36]	8.5	-0.6	-3.0	-4.9	2.1 [1.7, 2.7]	1.4 [1.1, 1.8]	1.2 [0.9, 1.5]
	Under 17	667	31.8	25.5	21.4	21.3	22.3	<0.001	0.18 [0.12, 0.26]	3.8	0.1	-2.2	-1.6	1.5 [1.1, 2.0]	1.2 [0.9, 1.6]	1.0 [0.7, 1.4]
	Under 20	224	40.6	20.5	21.4	17.4	32.2	<0.001	0.38 [0.26, 0.51]	4.9	-1.4	-1.3	-2.1	2.3 [1.4, 3.9]	1.2 [0.7, 2.1]	1.2 [0.7, 2.1]
	Senior	250	34.4	23.2	23.2	19.2	12.4	0.006	0.22 [0.13, 0.35]	3.0	-0.7	-0.7	-1.6	1.8 [1.1, 3.0]	1.2 [0.7, 2.0]	1.2 [0.7, 2.0]
Javelin	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI]	OR [95% CI]	OR [95% CI]
														Q1:Q4	Q2:Q4	Q3:Q4
	Under 13	960	33.5	26.8	23.8	15.9	65.0	<0.001	0.26 [0.20, 0.32]	5.7	1.1	-1.3	-5.4	2.1 [1.6, 2.7]	1.7 [1.3, 2.2]	1.5 [1.1, 2.0]
	Under 15	242	34.7	25.6	23.1	16.5	17.0	<0.001	0.26 [0.16, 0.39]	3.2	0.1	-0.8	-2.5	2.1 [1.2, 3.5]	1.6 [0.9, 2.7]	1.4 [0.8, 2.4]
	Under 17	97	35.1	24.7	20.6	19.6	6.4	0.094	0.26 [0.18, 0.46]	2.1	-0.1	-1.0	-1.0	1.8 [0.8, 4.0]	1.3 [0.6, 3.0]	1.1 [0.5, 2.6]
	Under 20	211	38.9	27.5	17.1	16.6	29.9	<0.001	0.38 [0.25, 0.51]	4.2	0.6	-2.5	-2.3	2.3 [1.3, 4.0]	1.7 [1.0, 3.0]	1.0 [0.5, 1.8]
	Senior	289	35.6	24.6	17.6	22.1	20.7	<0.001	0.27 [0.17, 0.39]	3.6	-0.3	-2.6	-0.7	1.6 [1.0, 2.5]	1.1 [0.7, 1.8]	0.8 [0.5, 1.3]

Male

100m	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	1335	48.2	26.4	17.7	7.6	502.4	<0.001	0.61 [0.56, 0.67]	17.6	1.0	-5.9	-12.5	6.3 [4.9, 8.2]	3.5 [2.7, 4.6]	2.3 [1.7, 3.0]
	Under 15	2544	43.6	27.8	18.4	10.3	641.7	<0.001	0.50 [0.46, 0.54]	19.3	2.6	-7.4	-14.4	4.2 [3.5, 5.0]	2.7 [2.3, 3.2]	1.8 [1.5, 2.2]
	Under 17	2110	37.6	27.7	20.3	14.4	265.9	<0.001	0.36 [0.31, 0.40]	12.2	2.2	-5.0	-9.3	2.6 [2.2, 3.1]	1.9 [1.6, 2.3]	1.4 [1.2, 1.7]
	Under 20	966	37.4	25.8	19.0	17.8	100.5	<0.001	0.32 [0.26, 0.39]	8.1	0.3	-4.2	-4.1	2.1 [1.6, 2.7]	1.4 [1.1, 1.8]	1.1 [0.8, 1.4]
	Senior	1246	33.8	25.4	21.7	19.1	58.2	<0.001	0.22 [0.16, 0.27]	6.2	-0.1	-2.6	-3.6	1.8 [1.4, 2.3]	1.3 [1.0, 1.6]	1.1 [0.9, 1.4]
Hurdles	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	1249	37.3	26.4	22.7	13.6	152.6	<0.001	0.35 [0.30, 0.41]	9.2	1.0	-2.2	-7.9	2.7 [2.1, 3.4]	1.9 [1.5, 2.4]	1.7 [1.3, 2.2]
	Under 15	1028	43.7	25.3	19	12.1	235.6	<0.001	0.48 [0.42, 0.54]	12.3	0.1	-4.3	-8.0	3.6 [2.8, 4.7]	2.1 [1.6, 2.8]	1.6 [1.2, 2.1]
	Under 17	587	44.3	26.2	16.5	12.9	145.8	<0.001	0.50 [0.42, 0.58]	9.7	0.5	-4.4	-5.6	3.4 [2.4, 4.8]	2.0 [1.4, 2.9]	1.3 [0.9, 1.9]
	Under 20	250	43.2	29.2	14.8	12.8	63	<0.001	0.50 [0.38, 0.63]	6.0	1.2	-3.4	-3.7	3.4 [2.0, 5.8]	2.3 [1.3, 4.0]	1.2 [0.7, 2.2]
	Senior	370	35.9	29.5	18.9	15.7	37.2	<0.001	0.32 [0.22, 0.42]	4.2	1.5	-2.5	-3.3	2.3 [1.5, 3.5]	1.9 [1.2, 2.9]	1.2 [0.8, 1.9]
800m	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	1383	40.0	27.3	19.6	13.2	234.9	<0.001	0.41 [0.36, 0.47]	11.7	1.6	-4.6	-8.6	3.0 [2.4, 3.8]	2.1 [1.7, 2.6]	1.5 [1.2, 1.9]
	Under 15	1834	41.7	25.9	18.6	13.7	341.7	<0.001	0.43 [0.39, 0.48]	14.8	0.6	-6.0	-9.3	3.0 [2.5, 3.6]	1.9 [1.6, 2.3]	1.4 [1.1, 1.7]
	Under 17	1385	36.0	26.4	22.3	15.3	130.0	<0.001	0.31 [0.26, 0.36]	8.7	0.8	-2.6	-6.9	2.4 [1.9, 3.0]	1.7 [1.4, 2.1]	1.5 [1.2, 1.9]
	Under 20	801	37.6	23.5	21.2	17.7	78.9	<0.001	0.31 [0.22, 0.34]	7.5	-1.1	-2.6	-3.8	2.1 [1.6, 2.8]	1.3 [1.0, 1.7]	1.2 [0.9, 1.6]
	Senior	1168	33.9	24.2	22.4	19.4	52.6	<0.001	0.21 [0.16, 0.27]	6.1	-0.8	-2.1	-3.2	1.7 [1.3, 2.1]	1.2 [0.9, 1.5]	1.2 [0.9, 1.5]
1500m	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	1936	30.7	24.9	23.3	21.0	46.9	<0.001	0.16 [0.11, 0.20]	5.6	-0.1	-2.2	-3.3	1.5 [1.3, 1.8]	1.2 [1.0, 1.4]	1.1 [0.9, 1.3]
	Under 15	2126	35.1	25.6	22.4	16.8	156.8	<0.001	0.27 [0.23, 0.31]	9.8	0.4	-3.1	-7.1	2.1 [1.8, 2.5]	1.5 [1.3, 1.8]	1.3 [1.1, 1.6]
	Under 17	1551	32.7	26.0	22.2	19.0	69.4	<0.001	0.21 [0.16, 0.26]	6.5	0.6	-2.8	-4.3	1.7 [1.4, 2.1]	1.4 [1.1, 1.7]	1.2 [1.0, 1.5]
	Under 20	850	34.1	26.4	20.2	19.3	52.3	<0.001	0.25 [0.17, 0.29]	5.7	0.6	-3.2	-3.0	1.8 [1.4, 2.4]	1.4 [1.1, 1.8]	1.0 [0.8, 1.3]
	Senior	1407	30.3	23.2	23.0	23.5	22.8	<0.001	0.13 [0.08, 0.18]	4.0	-1.7	-1.8	-0.4	1.3 [1.1, 1.6]	1.0 [0.8, 1.2]	1.0 [0.8, 1.2]
Long Jump	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	1124	38.8	27.0	21.7	12.5	170.9	<0.001	0.39 [0.33, 0.45]	9.7	1.3	-2.7	-8.2	3.1 [2.4, 4.0]	2.1 [1.6, 2.7]	1.7 [1.3, 2.2]
	Under 15	1104	40.9	28.0	19.7	11.5	214.2	<0.001	0.44 [0.38, 0.50]	10.9	1.9	-4.0	-8.7	3.6 [2.8, 4.7]	2.4 [1.8, 3.1]	1.7 [1.3, 2.2]
	Under 17	974	38.6	27.0	20.1	14.3	134.0	<0.001	0.37 [0.31, 0.43]	8.9	1.1	-3.5	-6.4	2.7 [2.1, 3.5]	1.9 [1.4, 2.5]	1.4 [1.1, 1.9]
	Under 20	421	34.4	28.0	20.7	16.9	32.5	<0.001	0.28 [0.19, 0.38]	4.2	1.1	-2.1	-3.1	2.0 [1.3, 3.0]	1.7 [1.1, 2.5]	1.2 [0.8, 1.8]
	Senior	553	37.8	24.6	19.3	18.3	52.4	<0.001	0.31 [0.23, 0.39]	6.0	-0.4	-2.9	-2.8	2.1 [1.5, 2.9]	1.3 [0.9, 1.8]	1.1 [0.8, 1.6]

High Jump	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	1234	41.6	25.5	20.5	12.4	237.6	<0.001	0.44 [0.38, 0.50]	12.2	0.3	-3.7	-8.7	3.4 [2.7, 4.3]	2.1 [1.6, 2.7]	1.7 [1.3, 2.2]
	Under 15	1298	41.7	27.6	18.2	12.6	261.7	<0.001	0.45 [0.40, 0.50]	12.4	1.7	-5.4	-8.7	3.3 [2.6, 4.2]	2.2 [1.7, 2.8]	1.4 [1.1, 1.8]
	Under 17	781	36.1	27.0	20.2	16.6	73.0	<0.001	0.31 [0.24, 0.38]	6.6	1.0	-3.1	-4.4	2.2 [1.6, 2.9]	1.6 [1.2, 2.2]	1.2 [0.9, 1.6]
	Under 20	322	37.6	25.5	18.0	18.9	34.3	<0.001	0.33 [0.23, 0.44]	4.8	0.0	-2.8	-2.0	2.0 [1.3, 3.1]	1.3 [0.8, 2.0]	1.0 [0.6, 1.6]
	Senior	368	34.8	22.8	22.6	19.8	19.1	<0.001	0.23 [0.14, 0.33]	3.8	-1.0	-1.1	-1.6	1.8 [1.2, 2.7]	1.2 [0.8, 1.8]	1.1 [0.7, 1.7]
Shot	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	655	49.0	26.0	16.2	8.9	252.3	<0.001	0.62 [0.55, 0.70]	12.7	0.4	-4.9	-8.1	5.5 [3.9, 7.8]	2.9 [2.0, 4.2]	1.8 [1.2, 2.6]
	Under 15	691	43.8	27.6	18.8	9.7	180.6	<0.001	0.51 [0.44, 0.59]	10.2	1.3	-3.6	-7.8	4.5 [3.2, 6.3]	2.9 [2.0, 4.1]	1.9 [1.3, 2.7]
	Under 17	480	46.9	20.4	20.6	12.1	137.8	<0.001	0.54 [0.45, 0.63]	9.9	-2.1	-2.2	-5.5	3.9 [2.7, 5.7]	1.7 [1.1, 2.6]	1.7 [1.1, 2.6]
	Under 20	234	45.3	24.4	16.2	14.1	60.2	<0.001	0.51 [0.39, 0.64]	6.5	-0.3	-2.9	-3.2	3.2 [1.9, 5.5]	1.7 [1.0, 3.0]	1.2 [0.7, 2.2]
	Senior	316	35.8	30.4	19.6	14.2	34.6	<0.001	0.33 [0.23, 0.44]	3.8	1.7	-2.1	-3.6	2.5 [1.6, 4.0]	2.1 [1.3, 3.4]	1.4 [0.9, 2.3]
Discus	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	791	39.2	26.2	20.1	14.5	114.0	<0.001	0.38 [0.31, 0.45]	8.4	0.6	-3.2	-5.7	2.7 [2.0, 3.6]	1.8 [1.3, 2.4]	1.4 [1.0, 1.9]
	Under 15	847	43.0	27.3	17.5	12.3	192.2	<0.001	0.48 [0.41, 0.54]	10.8	1.2	-4.8	-7.2	3.5 [2.6, 4.7]	2.2 [1.6, 3.0]	1.4 [1.0, 1.9]
	Under 17	555	34.4	28.8	21.1	15.7	47.5	<0.001	0.29 [0.21, 0.38]	4.7	1.7	-2.2	-4.2	2.2 [1.6, 3.1]	1.8 [1.3, 2.6]	1.3 [0.9, 1.9]
	Under 20	222	45.0	22.5	16.2	16.2	53.3	<0.001	0.49 [0.37, 0.62]	6.2	-0.8	-2.8	-2.5	2.8 [1.6, 4.8]	1.4 [0.8, 2.5]	1.0 [0.6, 1.8]
	Senior	365	34.5	26.8	19.2	19.5	22.5	<0.001	0.25 [0.16, 0.35]	3.6	0.5	-2.4	-1.8	1.8 [1.2, 2.7]	1.4 [0.9, 2.1]	1.0 [0.6, 1.6]
Javelin	Category	N	%Q1	%Q2	%Q3	%Q4	χ^2	P	w [95% CI]	SRq1	SRq2	SRq3	SRq4	OR [95% CI] Q1:Q4	OR [95% CI] Q2:Q4	OR [95% CI] Q3:Q4
	Under 13	1034	33.8	28.8	22.1	15.3	85.0	<0.001	0.29 [0.23, 0.35]	6.1	2.4	-2.3	-6.1	2.2 [1.7, 2.8]	1.9 [1.5, 2.5]	1.4 [1.1, 1.8]
	Under 15	824	38.1	30.1	17.5	14.3	126.0	<0.001	0.39 [0.33, 0.46]	7.8	2.8	-4.7	-5.9	2.7 [2.0, 3.6]	2.1 [1.6, 2.8]	1.2 [0.9, 1.6]
	Under 17	625	35.5	26.1	20.5	17.9	49.1	<0.001	0.28 [0.21, 0.36]	5.6	0.4	-2.6	-3.3	2.0 [1.5, 2.8]	1.5 [1.1, 2.1]	1.1 [0.8, 1.5]
	Under 20	304	39.5	18.1	22.7	19.7	38.3	<0.001	0.35 [0.25, 0.47]	5.3	-2.5	-1.1	-1.6	2.0 [1.3, 3.1]	0.9 [0.6, 1.5]	1.2 [0.8, 1.9]
	Senior	535	33.5	23.4	24.3	18.9	22.6	<0.001	0.21 [0.13, 0.29]	3.9	-1.0	-0.6	-2.4	1.8 [1.3, 2.5]	1.2 [0.8, 1.7]	1.3 [0.9, 1.9]

Note: N = number of participants, Q = Quarter of birth (Q1 Sep-Nov; Q2 Dec-Feb; Q3 Mar-May; Q4 Jun-Aug), SR = standardized residual, OR = odds ratio, CI = confidence interval. The χ^2 tests have 3 degrees of freedom.