

AperTO - Archivio Istituzionale Open Access dell'Università di Torino

Corrective Adjustment Procedures as a strategy to remove Relative Age Effects: Validation across male and female age-group long jumping

This is a pre print version of the following article:

Original Citation:

Availability:

This version is available <http://hdl.handle.net/2318/1869846> since 2023-08-02T08:43:32Z

Published version:

DOI:10.1016/j.jsams.2022.04.007

Terms of use:

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)

1 **Abstract**

2 **Objectives:** To validate the application of Corrective Adjustment Procedures (CAPs) to remove
3 Relative Age Effects (RAEs) in youth athletic contexts, this study estimated the longitudinal
4 relationships between decimal age (chronological and relative) and performance in male and female
5 long jumpers. Using trendlines, CAPs were applied, and RAE distributions associated with performance
6 attainment were re-examined.

7 **Design:** Retrospective longitudinal design examining publicly available long-jump competition
8 performance data between 2005-2019.

9 **Methods:** In part I, participants were 689 junior Italian long jumpers (age range=11.01-17.99 years;
10 56.6% females) who participated in \geq three events. Longitudinal modelling and regression equations
11 quantified the sex-specific relationships between decimal age and long jump performance. In part II,
12 equations were utilised to adjust individual performance within an independent sample (N=13,639;
13 50.1% females) of age-matched jumpers. RAE distributions within attainment levels (i.e., Top 25-10%)
14 were examined based on raw and correctively adjusted performance.

15 **Results:** Irrespective of sex, RAEs were prevalent across all age-groups with medium-large effect sizes
16 at 12-16 (males) and 12-14 years (females) of age (Cramer's V range = 0.19-0.34). RAE bias magnitude
17 also increased with attainment level (i.e., Top 25-10%). Following CAPs application, typical RAEs
18 were removed with non-significant deviations in relative age distributions regardless of sex, age-group
19 or attainment level (Top 25 or 10%).

20 **Conclusions:** Based on sex-specific longitudinal reference data, findings provide efficacy for CAPs
21 application to remove RAEs across youth long jumping events. CAPs suggest potential in improving
22 performance evaluation, identification of technically skilled performers, and general sporting
23 experiences.

24
25 **Keywords:** Relative Age Effect, Corrective Adjustment Procedures, Track & Field, Athletics, Athlete
26 Development.

27 **Introduction**

28 With the purpose to efficiently organise participation opportunities, structure youth sport
29 competition, and actually reduce inter-individual developmental differences, sport governing
30 bodies/federations commonly group athletes according into (bi)annual age-group cohorts.¹⁻³
31 Unfortunately however, (bi)annual age-grouping still permits the possibility of chronological age
32 associated differences of up to 12 (or 24) months between individuals, often leading to Relative Age
33 Effects (RAEs).⁴⁻⁶ Spanning from initial 'grassroots' to adult professional levels, RAEs reflect a highly
34 prevalent participation and attainment inequality within youth sport and educational settings.⁵⁻⁷
35 Specifically, RAEs are characterised by asymmetry, where relatively older individuals within a given
36 age-group cohort are overrepresented, while the relatively younger are underrepresented.^{5,8} Although
37 causes are still somewhat being verified, likely accountable factors (to a greater or lesser extent
38 depending on context) include: normative age-based differences in anthropometric development (e.g.,
39 height & weight);^{5,7} potentially added biological maturational variation during maturational years;¹
40 parallel neurological and cognitive developmental differences;^{5,6} social evaluation processes (e.g., coach
41 evaluation relative to age-group peers)⁹ and their consequences upon individual psychology (e.g.,
42 perceived competence, value).^{6,10} Within youth sport, competition tiers or talent identification practices
43 also encourage selective differentiation, and as a consequence, RAEs can be further magnified^{11,12} with
44 the relatively older consistently outperforming their counterparts in youth rankings^{13,14} or being
45 significantly more likely to be selected. Such trends are particularly evident in sport contexts with high
46 physiological demands, such as team (soccer, rugby, basketball)^{8,15,16} and individual sports (e.g., track
47 and field).^{1,17}

48 Related to track and field, several international studies have identified significant over- and
49 under-representations of the relatively older and younger respectively across male and females at
50 different age groups and differing levels of competition.^{1,17-20} Here, RAEs effect sizes have been
51 identified as being larger in adolescent age ranges (e.g., Q1 40% vs. Q4 13%), than post-18 age-groups
52 (e.g., Q1 39% vs. Q4 17%) or adult competition (e.g., Q1 35% vs. Q4 19%)¹⁸ and were further magnified
53 according to selection level.^{18,21} Moreover, RAEs are generally larger in males relative to females in
54 various sport contexts.⁷ An extensive cross-sectional study of international track and field did identify

55 that males had larger RAE magnitude both in junior and senior categories.¹⁷ However, the greatest RAE
56 magnitude in females has been associated with preadolescent (less than 11 years old) and adolescent
57 (12–14 years old) age categories, with declining risk following maturation.^{7,22} This differential timing
58 of peak RAE magnitude has been attributed to earlier chronological age time points for (re-)accelerated
59 growth, less heightened anthropometric and physiological inter-individual differences during
60 maturational years, and, earlier age time points for attaining adult stature relative to males.⁷

61 To address RAE participation and attainment inequalities, a range of feasible strategies have
62 been proposed.²³⁻²⁶ Corrective Adjustment Procedures (CAPs) appears to be a promising strategy,
63 particularly for individual sports where performance is quantified, such as track and field^{1,21} or
64 swimming.^{24,27} During their examination of 8-15 year-old sprinters, Romann and Cobley¹ originally
65 applied CAPs following identification of consistent RAEs. Using a regression trendline summarising
66 the decimal age-performance relationship, they quantitatively adjusted individual performance times
67 given the expected time for the relatively oldest individual in an annual cohort. Following CAPs
68 application, the distributions of who attained the corresponding Top 50-10% of performance times were
69 re-examined. They identified RAEs as being completely absent in the Top 10% sprinters and were either
70 removed or reduced in the Top 50%-25% of sprinters. Since, similar trial results have been obtained
71 when examining youth world-class sprinters,²¹ Australian male 100 m freestyle²⁴ and female 100 and
72 200 m breaststroke swimmers.²⁷ Here, CAPs were able to predominantly remove moderate-large RAEs
73 across age-groups and artificially-created selection levels. These findings provide some initial efficacy
74 for CAPs as a mitigation strategy against RAEs^{24,27} and help more accurately evaluate (alternative)
75 factors influencing youth age-group athletic performance.²¹

76 While prior studies initially developed or tested CAPs in sprinters and swimmers, their validity
77 and potential in other contexts still requires evaluation. Thus, the purposes of the present study (Part I)
78 were to estimate the longitudinal relationships between decimal age (i.e., chronological, and relative)
79 and performance across youth annual age-groups female and male long jumpers. Then, to determine
80 whether CAPs could remove RAE performance attainment inequalities across youth annual age-groups
81 female and male long jumpers (Part II).

82

83 **Methods**

84 **Initial data extraction**

85 All data were collected from the FIDAL (Italian Track and Field Federation;
86 <http://www.fidal.it/>) database and included long jump performance for males and females at officially
87 recognised competitions (i.e., where official measurements were recorded). Aligning with FIDAL
88 classification, long jumpers competing across groups 12-17 ages inclusive were included. For each age
89 category, long jumpers ranked in the Top 150 official lists been 2005-2019 (inclusive) were available
90 for data extraction (principal database). The data reported individual seasonal best performance, name,
91 day of birth, club, competition date, competition venue, and competition date. Only results obtained
92 with legal wind speed (≤ 2 m/s) were included aligning with World Athletics rules.²⁸ This study was
93 approved by the local ethics committee of the University of Torino and conducted according to the
94 declaration of Helsinki.

95 **Part I**

96 To determine the relationship between decimal age and performance, a subset of participants
97 with longitudinal data were extracted and examined from the principal database. Participants were 299
98 male and 390 female long jumpers, who at the time of competition were 11.01-17.99 years of age, and
99 who recorded a valid performance (i.e., seasonal best) in at least three years (not necessarily
100 consecutive). Across longitudinal tracking, the male sample contributed 1,326 performances, while
101 females contributed 1,740 performance distances. The examination of longitudinal data was done to
102 more accurately estimate jump performance progressions over time (i.e., within person change).^{10,24,27}
103 Screening for data entry errors and outliers was conducted, with outliers (i.e., Z-score values > -2) of
104 low performance removed prior to analysis. The exact age, based on the year and day of athletes'
105 birthdate, at which athletes achieved their performances distances was calculated.

106 To determine sex-specific decimal age-performance relationships, the exact decimal age (i.e.,
107 year and date of competition; independent variable) and longest jump performance (m; dependent
108 variable) were examined independently for males and females using mixed model regression. The best
109 fitting model trendline (i.e., linear [$y = ax + c$] vs quadratic [$y = ax^2 + bx + c$]) was evaluated. Decimal
110 age was entered as a fixed factor, while participants were entered as a random factor. Model fit was

111 assessed using the likelihood ratio test. The best fitting model and corresponding regression equation
112 was subsequently taken forward for CAPs calculations used in Part II.

113 **Part II**

114 To determine whether corrective adjustments could remove RAEs, we re-examined the original
115 database which included jumpers (N = 6,812 males and N = 6,827 females, aged 12–17 years) who were
116 ranked in the Top 150 official lists of Italian National federation (FIDAL) from 2005-2019. Participants'
117 age, date of birth, and individual seasonal best performance were again extracted from the database.

118 To determine whether RAEs existed in raw performance distributions, all long jumpers were
119 categorized according to annual-age group and relative age quartile. With reference to FIDAL cut-off
120 date criteria for age-grouping, the following dates were utilised: the relatively oldest were participants
121 born in January-March = Quartile 1 (Q1); those between April-June = Quartile 2 (Q2); July-September
122 = Quartile 3 (Q3); while the relatively youngest were those born between October-December = Quartile
123 4 (Q4). To identify RAEs, differences between observed and expected uniform quartile distributions
124 (i.e., 25% for each quartile) were assessed using Chi-square (χ^2) tests, with p set at < 0.05 , and effect
125 magnitudes determined by Cramer's V . The threshold values for effect size statistics were: $0.06 \leq V$ for
126 a *trivial effect*; $0.06 < V \leq 0.17$ for a *small effect*; $0.17 < V < 0.29$ for a *medium effect*; and $V \geq 0.29$ for
127 a *large effect*.²⁹ Odds Ratios (ORs) and 95% Confidence Intervals [95% CIs] then identified
128 discrepancies between Q1 v Q4 and for Q1+2 v Q3+4 (i.e., half-year distribution comparisons). To
129 assess whether RAE effect sizes changed according to attainment level within each age group, RAEs
130 was calculated according to the Top 25% and 10% of jump performances respectively.

131 To determine whether RAEs existed in correctively adjusted performance distributions, all raw
132 performances were firstly adjusted using the sex-specific reference equations from Part I. Specifically,
133 individual long jump performance at given decimal age were adjusted based on the mean expected
134 performance difference per day. Following this procedure all individual performances were centred on
135 the exact age of a given age-group. For example, considering the 12 years age-group, an athlete can
136 record their seasonal best performance in a decimal age ranged between 11.01-12.99 years. Thus, the
137 adjusted performance corresponds to the raw performance plus/less the expected performance
138 differences per day. Specifically, individual long jump performances recorded between 11.01 and 11.99

139 years old were increased, while individual long jump performances, recorded between 12.01 and 12.99
140 years old were decreased. Differently, performances recorded when athlete was 12.00 years old were
141 not changed. Then, following adjustments, the relative age quartiles distributions (i.e., Q1-4) were re-
142 examined using similar analytical procedures (as described above). Again, sex-specific distributions
143 across age-groups and according to attainment level were assessed, permitting comparisons with raw
144 performance distributions. All analytical steps were performed using custom-written software in
145 MATLAB R2021a (Mathworks, Natick, MA, USA).

146

147 **Results**

148 **Part I**

149 Compared to a linear trendline, a quadratic model fit was identified as significantly better-fitting
150 in summarising the decimal age – performance relationship ($\chi^2 < 0.05$). The variance explained by fitted
151 models was 0.92 and 0.87 for male and female jumpers, respectively. Figure 1 summarises the quadratic
152 trendlines between decimal age (i.e., year and day) and performance for males (Figure 1a) and female
153 jumpers (Figure 1b).

154 <Insert Figure 1 about here>

155 The estimated performance change (m) and percentage change according to age-group (i.e., 12-
156 17 years) is summarised in Table 1. The estimated performance difference within a given age-group
157 decreased consistently with age (i.e., males = 47.51% at 12 to 5.37% at 17 years old; females = 28.12%
158 at 12 years to 0.84% at 17 years of age).

159 <Insert Table 1 about here>

160 **Part II**

161 <Insert Table 2 about here>

162 Table 2 summarises both the raw performance and correctively adjusted relative age quartile
163 distributions, including Chi-square statistics, Odds Ratio from 12-17 years of age for male and female
164 jumpers. In Italian athletics, as there is a bi-annual age grouping process, the prevalence in the official
165 lists of athletes 13 and 15 years old is greater than those of 12 and 14 years old (see Table 2). Findings
166 identified that RAEs were evident across raw male and female samples, with notable prevalence at 12-

Commentato [GB1]: Please check

Commentato [SC2R1]: Gennaro, I would try to avoid mention or talking about the bi-annual grouping process in the paper – unless mentioned elsewhere and explained well. Will introduce confusion and further comments from reviewers – possibly!?

Which item or issue are you responding too – I couldn't match it on the reviewer comments.

If you address the concern without mention of the dual-year grouping, I would do that.

167 16 years of age with medium-large effect size in males. At similar age-groups, small-medium RAE
168 effect sizes were apparent in females. Quartile comparison odds ratios decreased with age in both sexes
169 (see Table 2 - *raw performance* sections). Of note when performance level increased (i.e., Top25% and
170 Top10%), RAE magnitude also, expectedly, increased.

171 When re-analysing distributions following CAPS application, results generally identified a
172 removal (or reduction) of RAEs (see Table 2 - *corrected performance* sections). Specifically, for male
173 jumpers, RAEs predominantly dissipated in both the Top25% and Top10% of performance in all age
174 groups, except 12 years of age. At 12 years of age, CAPs generated an RAE reversal (i.e.,
175 disproportionate number of jumpers born in the second-half of the year compared to the first-half) with
176 a medium and large effect size in the Top25% and Top10%, respectively. For females, CAPs led to
177 more consistent evenly distributed quartile distributions when compared to distributions in raw data
178 (e.g., 12 and 13 years of age). In fact, no significant odds ratio was apparent for an age-group quartile
179 comparison (OR range = 0.57-1.02), suggesting consistent RAE removal.

180

181 **Discussion**

182 The purpose of this study was to validate the capability of CAPs to remove RAE inequalities in a unique
183 youth athletic context. The study initially estimated the longitudinal relationships between decimal age
184 and performance in female and male long jumpers. Afterward, CAPs were applied to an independent
185 sample of long jumpers. That latter step enabled the testing of whether CAPs could remove or
186 substantially reduce RAE magnitudes.

187 Similar to previous studies in national¹ or international²¹ sprinters and swimmers (ranged aged:
188 10-18 years),^{24,30} results identified significant curvilinear relationships between decimal age and long
189 jump performance for males and females. Based on trendlines long jump performances increased from
190 4.18 and 4.04 m at 12 years-old to 6.59 and 5.33 m at 17 years for male and female jumpers, respectively.
191 Within the same age-group (e.g., 12 years old), the relative difference in performance estimates from
192 being the relatively youngest (11.01 years) to the relatively oldest (i.e., 12.00) progressed from relatively
193 larger to smaller differences (e.g., about 48.5 % in males 12-17 %; see Table 1). In comparison, for
194 females annual jump performance difference magnitudes were lower, with progressively lowering

195 percentage differences within younger age-groups. The earlier (1-2 years) reductions in within year
196 performance differences, may also reflect the earlier occurrence of maturation and attainment of adult
197 stature.³¹

198 In Part II, consistent significant overall asymmetries in relative age distributions were observed
199 with large-small effect size in males and medium-small effect size in females (see Table 2 'All').
200 Corroborating with previous RAE findings where samples across age-groups, performance levels and
201 sex were examined within a sport context,^{2,7,15,17} the proportion of relatively older long jumpers in this
202 study was on average 2.7 (male) and 1.9 times (female) higher than relatively younger jumpers. While
203 effect size decreased with age-group, as expected when (artificial) selection or performance levels were
204 introduced (i.e., Top25% and 10% of performances), RAE sizes again increased.^{5,7} Relatively older
205 jumpers were approximately 4-5 times more likely to be included in the Top25% and Top10% ranking
206 (see OR Q1 v Q4 in Table 2). For female jumpers, such a trend only existed between 12-14 years age,
207 with only descriptive inequalities persisting across 15-17 years of age.

208 When CAPs were applied to the Top25% and 10% of performers, relative age inequalities were
209 predominantly removed, irrespective of sex, age-group, and selection criteria (no significant effect size
210 or OR). In other words, no significant differences in quartile or half year distributions were apparent.
211 For example, focusing on the Top10% of male jumpers at 13 years old, raw data identified a Q1 v Q4
212 distribution OR of 6.86 [3.26, 14.30]. Following CAPs, the equivalent distribution OR was 0.86 [0.47,
213 1.58]. The only exception occurred in male jumpers at 12 years old, where following CAPs a significant
214 RAE reversal in favour of the relatively youngest was apparent for both the Top25% and Top10% of
215 performers (see Table 2). In other words, relatively young long jumpers were more likely to be
216 overrepresented.^{21,23} However, this finding should be considered carefully as less initial male
217 longitudinal data was available to inform regression estimates and raw sample sizes were comparatively
218 lower in this age-group category. In relation to the latter, as larger percentage distribution changes are
219 more likely in smaller samples, a greater sample would likely help identify greater distribution accuracy.
220 These points reinforce the importance of sufficient sampling, and given current data, suggest a potential
221 need for age-range restraint in CAPs application until further data is available.

222 Based on a substantial dataset containing longitudinal data tracking long jump performance
223 across multiple years, present findings predominantly validate and provide efficacy to CAPs application
224 within long-jumping, similar to youth athletic contexts.^{1,21,24,27} Practically, results demonstrate the
225 capability to more equitably evaluable performance in long jumping while accounting for chronological
226 age related inter-individual differences. CAPs application at junior local-national levels in Italian long-
227 jumping could help minimize (or at least reduce) the occurrence of RAE bias, help prevent advantages
228 based on earlier anthropometric development as opposed to performers being recognised on the basis of
229 technical and biomechanical skill/proficiency. Such procedures may establish greater accuracy in
230 performance evaluation given the developmental stage of a performer in the sporting context,^{24,27}
231 particularly valuable considering coach decision-making, selection, and access to athlete developmental
232 programmes (national federation) is predominantly determined by raw performance criteria^{13,14,32,33}
233 Relatedly, coaching knowledge and awareness of RAEs, the occurrence of inter-individual
234 developmental differences, and CAPs could help promote modifications to long jump performance
235 evaluation for the betterment of young athletes. Nonetheless, it is still important to understand that other
236 factors, such as the influence of social agents (i.e., as parents, coaches or the athletes themselves), may
237 still amplify RAEs.³⁴ Further, other developmental factors (e.g., maturation status) may also need to be
238 considered.³⁰ Finally, as CAPs is based on adjustment considerate of a reference population, being able
239 to still understand factors impacting inter-individual variability, or developmental change, over time
240 remains problematic.²⁵

241 **Conclusion**

242 To conclude, present results provide validity and efficacy to CAPs as a strategy to remove RAEs
243 in Italian long-jumping specifically, with potential relevance to other track and field events or youth
244 sport contexts. Local – national governing body stakeholders could consider CAPs as a potential data-
245 driven strategy to help account for inter-individual developmental differences in performance, reduce
246 sport drop-out, increase motivation, and help sustain participation across youth developmental age
247 ranges. CAPs may also help improve the accuracy of performance evaluation and long-term talent
248 identification.

249

250 **Practical Implications**

- 251 • Track & field-related sports systems and practitioners need to be aware of the inter-individual
252 developmental differences (e.g., relative age) occurring within youth age groups which likely
253 lead to participation and performance attainment inequalities.
- 254 • Study findings validate the application of Corrective Adjustment Procedures (CAPs) to address
255 relative age differences in the context of youth Italian long jumping for males and females,
256 although with some caution as to the age-range of CAPs application. If sufficient reference data
257 is available, CAPs should be implemented at a sex and age-group matched level within long
258 jumping. CAPs could practically be utilised within long-jumping by either event organisers
259 and/or individual coaches.
- 260 • More broadly, CAPs development and application has the potential to help improve youth
261 athlete participation experiences (e.g., self-evaluation and motivation), particularly for those
262 commonly disadvantaged by fixed annual-age groups and/or dates applied for youth
263 competition. CAPs could help improve accuracy in coach evaluation and talent identification.

264 **References**

- 265 1. Romann M, Cobley S. Relative Age Effects in Athletic Sprinting and Corrective Adjustments
266 as a Solution for Their Removal. *PLoS One*. 2015; 10(4):e0122988.
- 267 2. Cobley S, Baker J, Wattie N, McKenna J. Annual age-grouping and athlete development: a
268 meta-analytical review of relative age effects in sport. *Sports Med*. 2009; 39(3):235-256.
- 269 3. Wattie N, Cobley S, Baker J. Towards a unified understanding of relative age effects. *J Sports*
270 *Sci*. 2008; 26(13):1403-1409.
- 271 4. Barnsley RH, Thompson AH, Barnsley PE. Birthdate and performance: The relative age effect.
272 *Can J Hist Sport Phys Educ*. 1985; 51:23-28.
- 273 5. Cobley S, Baker J, Wattie N, McKenna J. Annual age-grouping and athlete development: a
274 meta-analytical review of relative age effects in sport. *Sports Med*. 2009; 39(3):235-256.
- 275 6. Musch J, Grondin S. Unequal Competition as an Impediment to Personal Development: A
276 Review of the Relative Age Effect in Sport. *Dev Rev*. 2001; 21(2):147-167.
- 277 7. Smith KL, Weir PL, Till K, Romann M, Cobley S. Relative Age Effects Across and Within
278 Female Sport Contexts: A Systematic Review and Meta-Analysis. *Sports Med*. 2018:1-30.
- 279 8. Brustio PR, Lupo C, Ungureanu AN, Frati R, Rainoldi A, Boccia G. The relative age effect is
280 larger in Italian soccer top-level youth categories and smaller in Serie A. *PLoS One*. 2018;
281 13(4):e0196253.
- 282 9. Wattie N, Schorer J, Baker J. The relative age effect in sport: A developmental systems model.
283 *Sports Med*. 2015; 45(1):83-94.
- 284 10. Cobley S, Abbott S, Moulds K, Hogan C, Romann M. Re-balancing the Relative Age Effect
285 Scales Meta-analytical Trends, Causes, and Corrective Adjustment Procedures as a Solution,
286 Chapter 11, in *Relative Age Effects in Sport International Perspectives*. C. J, Dixon JC, Horton
287 S, Chittle L, J. B, ed^eds. New York, Taylor & Francis, 2020.
- 288 11. Till K, Baker J. Challenges and [Possible] Solutions to Optimizing Talent Identification and
289 Development in Sport. *Front Psychol*. 2020; 11(664).
- 290 12. Wattie N, Cobley S, Baker J. Towards a unified understanding of relative age effects. *J Sports*
291 *Sci*. 2008; 26(13):1403-1409.
- 292 13. Boccia G, Cardinale M, Brustio PR. Elite Junior Throwers Unlikely Remain at the Top Level
293 in the Senior Category. *Int J Sports Physiol Perform*. 2021; 16(9):1281–1287.
- 294 14. Boccia G, Cardinale M, Brustio PR. Performance progression of elite jumpers: Early
295 performances do not predict later success. *Scand J Med Sci Sports*. 2021; 31(1):132-139.
- 296 15. Till K, Cobley S, Wattie N, O'Hara J, Cooke C, Chapman C. The prevalence, influential factors
297 and mechanisms of relative age effects in UK Rugby League. *Scand J Med Sci Sports*. 2010;
298 20(2):320-329.

- 299 16. Lupo C, Boccia G, Ungureanu AN, Frati R, Marocco R, Brustio PR. The Beginning of Senior
300 Career in Team Sport Is Affected by Relative Age Effect. *Front Psychol.* 2019; 10(1465).
- 301 17. Brustio PR, Kearney PE, Lupo C, et al. Relative Age Influences Performance of World-Class
302 Track and Field Athletes Even in the Adulthood. *Front Psychol.* 2019; 10:1395.
- 303 18. Kearney PE, Hayes PR, Nevill A. Faster, higher, stronger, older: Relative age effects are most
304 influential during the youngest age grade of track and field athletics in the United Kingdom. *J*
305 *Sports Sci.* 2018; 36(20):2282-2288.
- 306 19. Hollings SC, Hume PA, Hopkins WG. Relative-age effect on competition outcomes at the
307 World Youth and World Junior Athletics Championships. *Eur J Sport Sci.* 2014;
308 14(sup1):S456-S461.
- 309 20. Campbell E, Irving R, Poudevigne M, et al. Contextual factors and sporting success: The
310 relationship between birth date and place of early development on the progression of Jamaican
311 track and field athletes from junior to senior level. *PLoS One.* 2019; 14(12):e0227144.
- 312 21. Brustio PR, Boccia G. Corrective procedures remove relative age effect from world-class junior
313 sprinters. *J Sports Sci.* 2021.
- 314 22. Smith KL, Weir PL. Late Birthday Benefits. The “Underdog Hypothesis”, in *Relative Age*
315 *Effects in Sport International Perspectives.* C. J, Dixon JC, Horton S, Chittle L, J. B, ed^eds.
316 New York, Taylor & Francis, 2020.
- 317 23. Cogley S, Abbott S, Dogramaci S, et al. Transient Relative Age Effects across annual age groups
318 in National level Australian Swimming. *J Sci Med Sport.* 2018; 21(8):839-845.
- 319 24. Cogley S, Abbott S, Eisenhuth J, Salter J, McGregor D, Romann M. Removing relative age
320 effects from youth swimming: The development and testing of corrective adjustment
321 procedures. *J Sci Med Sport.* 2019; 22(6):735-740.
- 322 25. Webdale K, Baker J, Schorer J, Wattie N. Solving sport’s ‘relative age’ problem: A systematic
323 review of proposed solutions. *Int Rev Sport Exerc.* 2020; 13(1):187-204.
- 324 26. Kelly AL, Jackson DT, Taylor JJ, Jeffreys MA, Turnnidge J. “Birthday-Banding” as a Strategy
325 to Moderate the Relative Age Effect: A Case Study Into the England Squash Talent Pathway.
326 *Front Sports Act Living.* 2020; 2(17):573890.
- 327 27. Abbott S, Moulds K, Salter J, Romann M, Edwards L, Cogley S. Testing the application of
328 corrective adjustment procedures for removal of relative age effects in female youth swimming.
329 *J Sports Sci.* 2020:1-8.
- 330 28. Athletic W. Book of Rules. [https://www.worldathletics.org/about-iaaf/documents/book-of-](https://www.worldathletics.org/about-iaaf/documents/book-of-rules)
331 [rules.](https://www.worldathletics.org/about-iaaf/documents/book-of-rules)
- 332 29. Cohen J. *Statistical power analysis for the behavioral sciences*, Academic press; 2013.
- 333 30. Abbott S, Hogan C, Castiglioni MT, et al. Maturity-related developmental inequalities in age-
334 group swimming: The testing of ‘Mat-CAPs’ for their removal. *J Sci Med Sport.* 2021;
335 24(4):397-404.

- 336 31. Brustio PR, Cardinale M, Lupo C, Varalda M, De Pasquale P, Boccia G. Being a top swimmer
337 during the early career is not a prerequisite for success: A study on sprinter strokes. *J Sci Med*
338 *Sport*. 2021; 24(12):1272-1277.
- 339 32. Boccia G, Cardinale M, Brustio PR. World-Class Sprinters' Careers: Early Success Does Not
340 Guarantee Success at Adult Age. *Int J Sports Physiol Perform*. 2020; 16(3):367-374.
- 341 33. Boccia G, Moise P, Franceschi A, et al. Career Performance Trajectories in Track and Field
342 Jumping Events from Youth to Senior Success: The Importance of Learning and Development.
343 *PLoS One*. 2017; 12(1):e0170744.
- 344 34. Hancock DJ, Adler AL, Côté J. A proposed theoretical model to explain relative age effects in
345 sport. *Eur J Sport Sci*. 2013; 13(6):630-637.

346

347 **Figure Legends**

348 **Figure 1.** Longitudinal quadratic trendline summarizing the relationship between chronological age and
349 raw long jump performance in males (Figure 1 a) and females (Figure 1 b).