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Original research

Mitigating against relative age effects in youth Track & Field: Validating corrective adjustment procedures across multiple events

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A B S T R A C T

Objectives: With the aim to better identify talented Track & Field performance development, this study estimated the relationships between chronological (decimal) age with 60-m sprint, high jump, triple jump, and pole vault performance. Then, to mitigate against expected Relative Age Effects (RAEs), Corrective Adjustment Procedures (CAPs) were applied to an independent sample.
Design: Mixed-longitudinal design examining public data between 2005 and 2019.
Methods: The performances of 5339 Italian sprinters and jumpers (53.1 %) spanning 11.01–17.99 years of age were examined, with trendlines between chronological age and performance established. Related to an independent sample (N = 40,306; female 45.5 %), trendlines were then utilised to apply CAPs and adjust individual performance. Considering raw and adjusted performance data, RAE distributions were examined for the top 25 % and 10 % performers.
Results: For all male and female events, quadratic models best summarised the relationships between chronological age and performance ($R^2 = 0.74–0.89$). When examining independent athletes in similar event, RAEs were more pronounced in males (Cramer's $V = 0.35–0.14$) than females (Cramer's $V = 0.29–0.07$). For both sexes, RAE magnitude decreased with age and increased according to performance level (i.e., Top25%–Top10%). However, following CAP applications, RAEs were reduced or removed within annual age groups and performance levels.
Conclusions: With RAEs prevalent across Italian youth Track & Field events, findings validate CAPs as a strategy to account for the influence of relative age differences on athletic performance. CAPs help establish a more equitable strategy for performance evaluation and could help improve the efficacy of long-term athlete development programming.

Practical implications

- Youth Track & Field-related sport contexts should understand the transient influence of chronological (relative) age variation on performances within age group events. During youth age groups, performance selection bias and RAE magnitudes can be high. RAE inequalities restrict or detrimentally affect athletes with a relatively younger profile across sport systems with fixed annual age groups.
- This study illustrates how CAPs can effectively account for relative age differences in male and female youth Italian 60-m sprint, high jump, triple jump, and pole vault performance. By adjusting age group performances based on relative age, RAE inequalities can be mitigated completely or minimised.
- Integrated within sport organisational practice, CAPs could improve the accuracy of practitioner evaluation; (de-)selection decision-making; and, help inform longer-term athlete development programming.

1. Introduction

Within sporting athlete identification and development, the examination of performance progression over time (i.e., from youth to adult ages) – often measured in centimetres or seconds within Track & Field – is a fundamental focus for associated organisations and their practitioners. Nonetheless, numerous research studies examining performance

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development and the disparities between successful young and senior athletes emphasise how performance development is often non-linear; should not be considered an accurate or consistent predictor of senior-level success.[1–3] In fact, the road towards achieving senior success is influenced by multiple different intrinsic and extrinsic factors that inevitably impact athletic development. Some factors distort or confound the capability to evaluate and identify accurately genuine youth athletic potential; consequently, affecting transition rates into higher-level athletic programmes and competition.[4–7]

The interaction between fixed (bi-)annual groupings of athletes across youth-age stages and the relative age differences of athletes within such groupings (i.e., potentially up to 12 or 24 months of developmental disparity) is one process proposed to affect performance evaluation and athletic trajectories towards a senior career.[4,5,8] The interactions create Relative Age Effects (RAEs), a phenomenon referring to a higher prevalence of relatively older athletes (i.e., earlier-born within an age group) compared to the relatively younger in a given age-grouped cohort.[9,10] Relatively older athletes, normatively, experience anthropometric, physiological, and psychosocial advantages during youth ages due to normative growth[4]; and thus, temporarily outperform their later-born counterparts, particularly in physically demanding sport contexts.[4,5] Track & Field is no exception, with many (inter-)national samples within studies illustrating consistent and significant over-representations of relatively older athletes.[7,11–18] Overall, RAE magnitudes have been larger in males than females, with Odd Ratios (ORs; i.e., the odds of an athlete born in the first [Q1] compared to the fourth quartile [Q4] within annual groupings) differences for males typically ranging between 1.2 and 2.4, whilst females often have ranged between 1.1 and 1.7.[11] However, RAEs are more pronounced during childhood and adolescence, with higher ORs, reflecting medium-large effect sizes.[13,15,16] Further, the higher the competition level, the higher the RAE magnitude (i.e., highest for the Top 25 % within adolescent age cohorts).[15,17,19,20] For example, in Italian male long jumpers (aged 12–17 years), the probability of being relatively older (Q1) compared to being relatively younger (Q4) was OR = 2.6 higher across the sample, increasing to 3.7 and 4.9 in the best 25–10 % of long-jumpers, respectively.[20]

Across the studies examining the chronological age–performance relationship, significant and consistently large performance differences between the relatively older and younger have been found. For example, in male long jumpers, the relatively older compared to their relatively younger counterparts exhibited annual performance differences (i.e., cm jumped) varying from ~47 % to 5 % across the 12–17 age range.[20] In sprinters aged 8–15 years, the mean annual expected percentage differences ranged from ~10 to 5 %[15]; whilst similar within age-cohort differences have been confirmed in male and female swimmers.[21,22] Overall, such data indicate an expectedly consistent, albeit changing, performance gap between the relatively older and younger within any given age or youth development stage.[23,24] If not explicitly recognised by sporting organisation and practitioners, the consequence is the relatively older appear more talented than their peers; and thereby, are more inclined to be selected into representative levels/squads and given access to development programmes.[4,5] Such trends have also been confirmed by longitudinal studies.[1,7] That said, subsequent longitudinal studies have also confirmed how youth-associated performance differences dissipate into post-maturational growth (i.e., adulthood); and how highly skilled relatively younger athletes were actually more likely by their relative proportion to transition into senior, high performance level, athletes.[7,25,26]

A range of feasible organisational and practitioner strategies have been proposed to mitigate or prevent short-term RAE inequalities in youth ages of sport contexts.[22,25,27,28] Amongst proposed strategies, Corrective Adjustment Procedures (CAPs) are considered most promising for Track & Field[15,17,19] and Swimming,[21,22] given the specificity of performance metrics utilised and the capability to account for expected performance differences within a given age-group and at an individual athlete level. In Track & Field, CAPs have shown initial capability to successfully remove moderate-large RAEs across age groups in national[15,17,20] and international contexts.[19] However, the question arises of how extensively applicable is CAPs for other Track & Field events? Thus, to determine broader applicability, and better improve athlete evaluation processes within the context of Italian Track & Field, the study examined whether RAEs in four additional athletic events (i.e., 60-m sprint, high jump, triple jump, and pole vault) could be mitigated against using CAPs. The study involved two components, first determining the relationships between chronological age with performance across the four events for males and females spanning 11–17 years. The second component was to apply CAPs, determining the capability to mitigate against RAEs when examining an independent sample of age and sex-matched athletes.

2. Methods

Data extractions for 60-m sprint, high jump, triple jump, and pole vault performances were completed from the official Italian Track and Field Federation database (FIDAL; http://www.fidal.it/). This primary dataset was used in Parts I and II, but with a different subset of data (see Parts I and II below). The Top 150 official lists of males and females of youth athletics sprinters and jumpers, aged 11.01–17.99 years, competing between 2005 and 2019 were available and extracted. For the triple and pole vault jump events, the database only provided results for athletes aged 14–17 years, as there were no national competitions before 14 years of age occurred in these events. All performances were obtained from participation in official national competitions, and only results obtained in alignment with respective World Athletics event rules were included. A total of 1,428 60-m sprint (females = 56.0 %) 1,940 high jump (females = 53.8 %), 1,059 triple jump (females = 50.9 %), and 912 pole vault (females = 49.5 %) were considered. Data pertaining to individual seasonal best performance, birthdate, and competition date were considered for each sprinter or jumper. The study was conducted according to the Ethics Committee of the University of Torino (protocol number: 0635113).

2.1. Part I

In Part I, we examined a subset of data from the primary database, consisting of longitudinal data from 2005 to 2019. Available data helped establish an accurate estimate relationships between chronological age and performance in each event over time (i.e., across and within age-groups).[20,22] In the first test of CAPs in 60-m Swiss sprinters, Romann & Cobley utilised a linear regression trendline based on cross-sectional data (i.e., from 8 to 15 year). However, given accuracy concern of the cross-sectional trendline and subsequent linear equations, further studies examined longitudinal data and utilised best-fitting quadratic trendlines.

In this study, across all event examined, a minimum of three longitudinal performances (not necessarily consecutive) across their youth career were utilised. For 60 m sprint and high jump athletes, longitudinal data spanning 11.01–17.99 years of age was examined; whilst for triple jump and pole vault, data spanning 13.01–17.99 years of age was examined. The maximum number of measures available from a given athlete was 6 for 60-m sprint and high jump and 4 for triple jump and pole vault. Data entry errors and outliers were detected and removed.[19,20] Exact chronological age was calculated considering the difference between the competition date and birthdate. According to athlete sex and event, the relationships between chronological age (fixed factor) and performance were then examined using mixed-model linear and quadratic regression. In both models, participants were treated as a random factor. Pearson's correlation coefficient (r), adjusted coefficients of determination (R^2), standard errors of estimate (SEE) were calculated. The correlation magnitude was determined using Hopkin's criteria.[29] The final unstandardised coefficients reflected a linear ($y = ax + c$) and quadratic function ($y = ax^2 + bx + c$) were computed summarising the exact chronological age–performance relationship across ages examined. The best-fitting model, using likelihood ratio test, was subsequently utilised for CAP calculations. Further, based on the quadratic model, the estimated performance change (in seconds or metres) and corresponding percentage change for each annual age-group was calculated.

2.2. Part II

Part II examined the primary database (i.e. the entire sample) where cross-sectional participation in events is examined, and with the idea to apply the corrective adjustment trendlines from Part I. Based on age-cutoff dates used by FIDAL and to determine relative age, athletes born between January and March; April and June; July and September; and October and December were, respectively, classified as Quartile 1 (Q1), Quartile 2 (Q2), Quartile 3 (Q3), and Quartile 4 (Q4). To identify initial (raw) RAEs, Chi-Square Goodness of Fit tests (χ^2), with p set at <0.05, were used to detect the difference between observed and expected uniform population quartile distributions for the '90 and 00 (i.e., Q1 = 23.7 %, Q2 = 24.7 %, Q3 = 26.6 % and Q4 = 24.9 %; https://data.un.org/Default.aspx). RAE effect size magnitudes were determined using Cramer's V (thresholds were: $0.06 \le V$ for a *trivial effect*; $0.06 < V \le 0.17$ for a *small effect*; $0.17 < V < 0.29$ for a *medium effect*; and $V \ge 0.29$ for a *large effect*).[20] First and fourth quartile distributions (i.e., Q1 vs Q4) as well as first v second half-year distribution (i.e., Q1&2 v Q3&4) comparisons were calculated using Odds Ratios (ORs) and 95 % confidence intervals (CIs). When CIs encompass the value 1 (e.g., 95 % CI ranging from 0.90 to 1.10), the findings were interpreted as indicative of no significant association. All RAE distribution analyses were performed on the Top 25 % and 10 % performers for each of the annual age-groups (i.e., 12–17 years old).

Subsequently, CAPs were applied to the dataset. Specifically, raw performance times of individual athletes were adjusted using the sex- and event-specific specific reference equations generated in Part I. The chronological ages of each athlete were calculated considering birthdate and date of competition. Individual performances within each age group were increased or decreased in order to be estimated at the exact reference age. Thus, CAPs aimed to align all individual performances converging all performances to be considered at an annual group. For example, in the 12-year-old age group, the reference age was set at 12 years, whilst the chronological age for the individual performance could be between 11.01 and 12.99 years. Indeed, in the extreme condition of an athlete born on 31st December 2012 and competing on 1st January 2024 the age would be 11.01, whilst in the opposite condition of an athlete born on 1st January 2012 and competing on 31st December 2024 the exact age would be 12.99. Thus, once the exact chronological age has been calculated, individual performance was either increased (for athletes who have achieved it between 11.01 and 11.99 years) or reduced (for those who have achieved it between 12.01 and 12.99 years) to a mid-point (i.e., 12.00 years) position of the annual age-group. This adjustment process aims to normalise performances across annual age groups by considering the chronological age differences that can significantly impact athletic performance even within the same annual age-group. For further details of the procedure, see 19,20. Following adjustments of individual performance using trendlines to account for relative age differences, the distributions of who made the Top 25 % and 10 % of performances were re-examined using similar ORs and effect size procedures (as described above). All statistical analyses were performed using custom-written software in MATLAB R2023a (Mathworks, Natick, MA, USA).

3. Results

3.1. Part I

The performances of 5339 sprinters and jumpers (female: n = 2833, 53.1 %) were analysed in Part I. Specifically, 1428 athletes were 60-m sprinters (female: n = 800, 56.0 %), 1940 high jumpers (female: n = 1043, 53.8 %), 1059 triple jumpers (female: n = 520, 50.9 %) and 912 pole vault jumpers (female: n = 410, 49.5 %). The average number of measurement observations per athlete informing the trendlines estimates was 3.5 ± 0.8 (female n = 3.8 ± 0.9) for 60-m sprinters; 3.8 ± 0.9 (female n = 3.9 ± 0.9) for high jumpers; 3.3 ± 0.5 (female n = 3.3 ± 0.5) for triple jumpers; and 3.4 ± 0.5 (female n = 3.4 ± 0.5) for pole vault jumpers. According to sex and for all events, quadratic mixed models generally better fitted the relationships between chronological age and performance than linear mixed models ($p < 0.05$; Log-Likelihood statistics range = 5864.85–272.85). The variance explained by fitted models (both the fixed and random effects) ranged between $R^2 = 0.85$–0.89 for males and $R^2 = 0.75$–0.81 for females. For more details about respective equation models, please see Supplementary Material 1. An illustrative example of a quadratic trendline, with reference to 60 m sprint, is provided in Fig. 1. For graphed summaries of all other events analysed, see Supplementary Material 2. Further, based on quadratic models, the estimated performance change (in seconds or metres) and corresponding percentage change for each annual age-group are provided in Supplementary Material 3. For both sexes and across events, relatively older athletes had performance advantages, although progressively decreased with age (e.g., high jump - male = 13.21–1.86 %; female = 6.65 to −0.23 %).

3.2. Part II

A total of 12,482 athletes competed in the 60 m sprint (females = 49.9 %), 15,109 in the high jump (females = 51.4 %), 5641 in the triple jump (females = 20.5 %) and 7074 in the pole vault (females = 45.1 %) in Part II. Tables 1 and 2 correspondingly summarise RAE quartile distributions according to raw and corrected performances for sprinters and jumpers for male and female athletes. Tables also provide summary Chi-square statistics and ORs for Q1 vs Q4 as well as Q1&2 (first half year) vs Q3&4 (second half year) comparisons.

Across raw performance in male sprinters, RAEs were consistently evident across all age groups (12–17 years), with corresponding large-small effect sizes (i.e., Cramer's $V = 0.35$–0.14). For females, medium-small RAE effect sizes (Cramer's $V = 0.29$–0.07) were apparent, with RAE prevalence at 12–14 years (Cramer's $V = 0.29$–0.17). RAE magnitude decreased with age in both sexes (see ORs in Table 1 - *raw performance* sections), although consistently increased with performance level (i.e., Top 25–10 % performers). When focused on raw performance in jumpers, findings suggested a large-small effect size (Cramer's $V = 0.39$–0.08) and a large-trivial (Cramer's $V = 0.30$–0.06) in males and females, respectively. Again, for both sexes, when annual age groups increased, RAE magnitude decreased; only to amplify again with performance level (i.e., Top 25–10 %). Interestingly, in the female Top 10 % of performers RAEs were not presented in the triple jump (all $p > 0.05$) and disappear consistently in pole vault by 16 years of age. Nevertheless, trend in a favour to Q1 was observed. See Table 2.

By comparison, altered RAE distributions were observed following CAP application in the Top 25 % & 10 % of performers. Generally speaking, RAEs were removed or reduced in all events and annual age groups (see Tables 1 & 2 *corrected performance*). For males, RAEs predominantly dissipated in all annual age groups. The only exceptions were observed in particular age groups for 60-m sprinters (Top 25 % - 13, 14, 15 & 17 years-old); high jumpers (i.e., Top 25 % - 15, 16 & 17 year-old) where effect sizes were still small. For females, results highlighted that RAEs persisted in raw performance assessments until approximately 14/15 years of age across events; although were more likely to recur in the older (15 years plus) Top 25 & 10 % performance levels. Thus, CAPs were still necessary for application. When applied, corrected distributions were more symmetrical than those observed in raw performance data. Based on CAPs, no ORs for quartile comparison remained for any event in Top 10 % performers (ORs = 0.33–1.99).

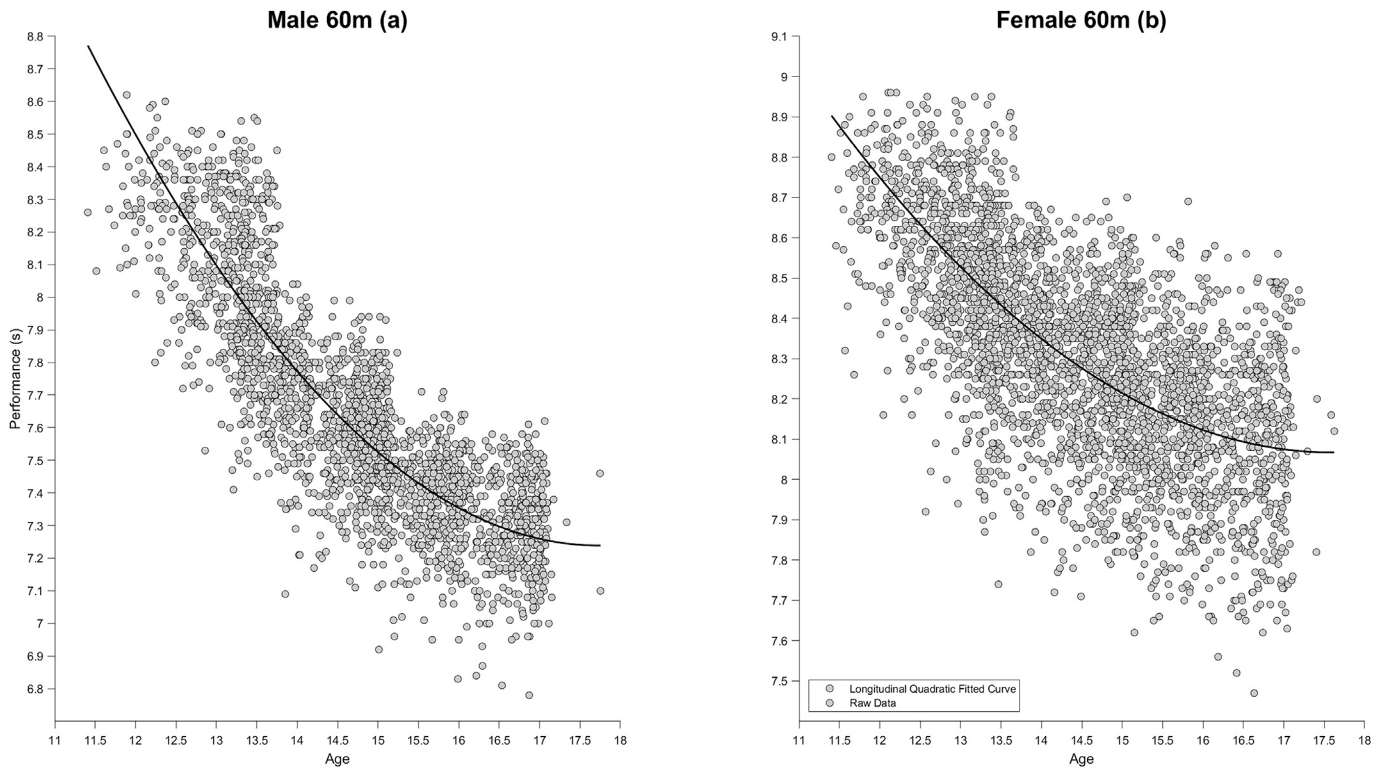

Fig. 1. Quadratic trendline summarising the relationship between chronological age and raw 60-m sprint performance in males (a) and females (b).

4. Discussion

Targeted at accounting for performance discrepancies based on normative inter-athlete developmental differences, CAPs attempt to mitigate against RAE-associated problems, including participation as well as athlete evaluation and (de-)selection biases within sport systems. Still, the external validity of CAPs for sporting events (e.g., Track & Field) is yet to be realised. The present study applied CAPs within multiple youth Track & Field events (i.e., 60-m sprint, high jump, triple jump, and pole vault) with the purpose to illustrate if RAE inequalities can be mitigated. The study aims were to, Part I, quantify and establish the relationships between chronological age and athletic performance for males and females across youth age groups. Using these trendlines, Part II then tested whether CAPs could remove RAEs in a broader independent sample of sex and age-matched athletes.

Part I findings identified significant quadratic trendlines across the four investigated track and field events, with good model fits observed (males $R^2 = 0.85–0.9$; females $R^2 = 0.75–0.81$). When compared with prior cross-sectional and longitudinal studies, the nature of the quadratic age–performance relationships aligned with performance differences between relatively older and younger athletes observed elsewhere in athletic[19,20] and swimming contexts.[21,22] Notably, whilst estimated performance differences between the relatively older and younger were consistently apparent across youth stages, the relative size of these differences markedly reduced with age, becoming trivial or obsolete at earlier ages within female Track & Field events (see Supplementary 1, 2 & 3).

Part II findings identified an overall relative age asymmetry within age group distributions across sprinter and jump events with larger-small and medium-trivial effect sizes in males and females, respectively (see Tables 1 & 2 - *raw performance* sections). On average, the proportion of relatively older (relatively younger) athletes was, on average, approximately 2.9 (male) and 1.8 (female) times higher. Aligning with previous RAE findings[7,11,13,16,17] and somewhat moderated by athlete sex, RAE magnitudes decreased with annual age group but increased with artificially introduced performance level cutoff criteria (i.e., Top 25 % & Top 10 %). Findings related to the 'Top performers' across events highlight the interplay between chronological age system structures; event performance demands; sex-specific growth patterns and their potential relationships with event demands. For instance, relatively older male athletes were approximately, on average, 3.4 (Top 25 %) and 4.7 (Top 10 %) times more likely to be included in the top-level category (see OR Q1 vs Q4 in Tables 1 & 2 - *raw performance* sections); whereas for females it was, on average, 2.3 and 2.4 times more likely to be overrepresented in specific events (see Tables 1 & 2 - *raw performance* sections).

Similar to trials in other Track & Field events, following CAP application, study findings confirmed the capability to remove RAE performance biases.[15,17,19,20] Generally, in the Top 25 % and Top 10 % athletes, relative age asymmetries were mitigated and removed across age groups for both male and female athletes (see Tables 1 and 2 - *corrected performance* sections). In other words, no significant effect sizes or ORs were observed. For example, for the Top 10 % male high jumper athletes at 13 years old, raw data identified, Q1 [relatively older] athletes as being 7.8 (4.3, 14.1) more likely to be represented (vs Q4). Yet following CAP application, the equivalent OR was non-significant; thereby demonstrating the capability of CAPs to remove relative age-associated disparities. The only exceptions were observed in the Top 25 % of male athletes, where CAPs were able only to mitigate relative age inequalities for some age groups and events (i.e., 13, 15, 16, & 17 years old for 60-m sprinters; 15, 16 & 17 years old for high jumpers). Still, even for the exceptions, CAPs certainly substantially reduced the magnitudes of uneven distributions relative to the raw distribution.

Finally, whilst identifying promising results for CAPs mitigating against relative age-related performance inequalities, it is necessary to caution how both RAEs and sport performance are multi-factorial phenomena. Other factors, including maturational growth timing, tempo and trajectories[21,23] as well as social (e.g., coaches and parents)[30] and sport contexts' physiological demands can all affect RAEs and performance. As such, present findings may not have broad external applicability, and should be considered when applying to other sport contexts.

Table 1
Relative age distribution, chi-square and odds ratio analyses of male and female sprinters. Data examined according to annual-age group for the Raw All, Top 25% & 10% of performances and according to Corrected Top 25% and 10% of performances.

		Male Sprinters 60 m										Female Sprinters 60 m									
Performance level	Age-group	Total N	Q1 %	Q2 %	Q3 %	Q4 %	χ^2	*V*	*ES cat.*	OR Q1 VS Q4	OR Q1&2 VS Q3&4	Total N	Q1 %	Q2 %	Q3 %	Q4 %	χ^2	*V*	*ES cat.*	OR Q1 VS Q4	OR Q1&2 VS Q3&4
Raw performance All	12 yrs	229	47.6	26.2	15.7	10.5	85.5***	0.35	Large	4.8 [2.7, 8.5]	2.8 [1.9, 4.2]	437	43.9	25.2	19.0	11.9	113.7***	0.29	Medium	3.9 [2.6, 5.8]	2.2 [1.7, 3.0]
	13 yrs	2063	46.1	27.4	17.5	9.1	715.5***	0.34	Large	5.4 [4.4, 6.5]	2.8 [2.4, 3.2]	1851	36.6	26.0	22.2	15.2	213.1***	0.20	Medium	2.5 [2.1, 3.1]	1.7 [1.5, 1.9]
	14 yrs	481	44.3	30.1	16.6	8.9	159.1***	0.33	Large	5.2 [3.4, 7.9]	2.9 [2.2, 3.8]	769	33.3	28.3	22.9	15.5	65.5***	0.17	Small	2.3 [1.7, 3.0]	1.6 [1.3, 2.0]
	15 yrs	1504	38.2	30.3	19.3	12.2	280.2***	0.25	Medium	3.3 [2.6, 4.1]	2.2 [1.9, 2.5]	1211	30.9	25.8	23.5	19.8	43.9***	0.11	Small	1.6 [1.3, 2.1]	1.3 [1.1, 1.5]
	16 yrs	787	36.7	30.0	19.9	13.3	119.9***	0.23	Medium	2.9 [2.1, 3.9]	2.0 [1.6, 2.5]	966	28.2	26.9	23.6	21.3	18.3***	0.08	Small	1.4 [1.1, 1.8]	1.2 [1.0, 1.5]
	17 yrs	1188	30.4	29.1	23.9	16.6	68.1***	0.14	Small	1.9 [1.5, 2.4]	1.5 [1.3, 1.7]	996	27.6	26.1	25.2	21.1	13.8**	0.07	Small	1.4 [1.1, 1.8]	1.2 [1.0, 1.4]
Raw performance Top 25%	12 yrs	57	54.4	17.5	17.5	10.5	28.0***	0.40	Large	5.2 [1.6, 16.3]	2.6 [1.2, 5.6]	110	45.5	24.5	17.3	12.7	31.9***	0.31	Large	3.7 [1.7, 8.3]	2.3 [1.3, 4.1]
	13 yrs	517	50.1	26.1	15.7	8.1	233.0***	0.39	Large	6.5 [4.3, 9.7]	3.2 [2.5, 4.2]	492	38.4	26	21.3	14.2	72.6***	0.22	Medium	2.8 [2.0, 4.1]	1.8 [1.4, 2.3]
	14 yrs	127	49.6	26.0	14.2	10.2	55.2***	0.38	Large	5.2 [2.4, 11.3]	3.1 [1.8, 5.3]	205	38.0	26.3	22.4	13.2	30.1***	0.22	Medium	3.0 [1.7, 5.4]	1.8 [1.2, 2.7]
	15 yrs	396	40.7	30.6	17.2	11.6	94.6***	0.28	Medium	3.7 [2.4, 5.7]	2.5 [1.8, 3.3]	307	31.3	28.7	23.5	16.6	18.6***	0.14	Small	2.0 [1.2, 3.1]	1.5 [1.1, 2.1]
	16 yrs	208	40.9	30.3	18.3	10.6	51.8***	0.29	Medium	4.1 [2.2, 7.6]	2.5 [1.6, 3.7]	248	29.4	26.2	23.0	21.4	6.1	0.09	Small	1.5 [0.9, 2.4]	1.3 [0.9, 1.8]
	17 yrs	317	34.7	26.8	23	15.5	29.8***	0.18	Medium	2.4 [1.5, 3.8]	1.6 [1.2, 2.2]	262	27.1	27.1	26.0	19.8	4.5	0.08	Small	1.4 [0.9, 2.4]	1.2 [0.8, 1.7]
Raw performance Top 10%	12 yrs	23	52.2	21.7	17.4	8.7	13.3**	0.44	Large	7.2 [1.1, 48.6]	2.8 [0.8, 9.9]	48	50.0	22.9	16.7	10.4	21.5***	0.39	Large	5.2 [1.5, 18.5]	2.7 [1.1, 6.4]
	13 yrs	208	54.8	23.6	13.5	8.2	123.1***	0.44	Large	7.1 [3.8, 13.5]	3.6 [2.4, 5.6]	190	43.7	26.3	20.5	9.5	53.0***	0.30	Large	4.8 [2.5, 9.3]	2.3 [1.5, 3.6]
	14 yrs	50	54.0	30.0	6.0	10.0	31.3***	0.46	Large	5.4 [1.6, 18.8]	5.3 [2, 13.5]	82	32.9	31.7	19.5	15.9	9.3*	0.19	Medium	2.2 [0.9, 5.4]	1.8 [1.0, 3.5]
	15 yrs	155	39.4	25.8	19.4	15.5	24.4***	0.23	Medium	2.7 [1.4, 5.1]	1.9 [1.2, 3.0]	127	32.3	28.3	26.0	13.4	11.9*	0.18	Medium	2.6 [1.2, 5.5]	1.5 [0.9, 2.5]
	16 yrs	88	43.2	26.1	18.2	12.5	21.4***	0.28	Medium	3.6 [1.5, 8.9]	2.3 [1.2, 4.2]	102	34.3	24.5	25.5	15.7	8.3*	0.16	Small	2.3 [1.0, 5.2]	1.4 [0.8, 2.5]
	17 yrs	123	36.6	22.8	23.6	17.1	12.7**	0.19	Medium	2.3 [1.1, 4.7]	1.5 [0.9, 2.4]	104	26.9	27.9	31.7	13.5	7.1	0.15	Small	2.1 [0.9, 4.8]	1.2 [0.7, 2.1]
Corrected performance Top 25%	12 yrs	57	29.8	19.3	21.1	29.8	2.5	0.12	Small	1.0 [0.4, 2.7]	1.0 [0.5, 2.0]	109	26.6	19.3	26.6	27.5	2.0	0.08	Small	1.0 [0.5, 2.1]	0.9 [0.5, 1.5]
	13 yrs	516	32.2	25.0	24.8	18.0	26.1***	0.13	Small	1.9 [1.3, 2.7]	1.3 [1.0, 1.7]	463	27.0	23.5	25.1	24.4	2.7	0.04	Trivial	1.2 [0.8, 1.7]	1.0 [0.8, 1.3]
	14 yrs	120	27.5	28.3	22.5	21.7	2.7	0.09	Small	1.4 [0.7, 2.8]	1.3 [0.8, 2.1]	192	25.5	26.6	26.6	21.4	1.6	0.05	Trivial	1.3 [0.7, 2.2]	1.1 [0.7, 1.6]
	15 yrs	376	29.5	29.8	22.1	18.6	18.3***	0.13	Small	1.7 [1.1, 2.5]	1.5 [1.1, 2.0]	303	25.4	26.7	25.1	22.8	1.6	0.04	Trivial	1.2 [0.7, 1.8]	1.1 [0.8, 1.5]
	16 yrs	197	27.9	31.0	21.8	19.3	8.3*	0.12	Small	1.5 [0.9, 2.7]	1.4 [1.0, 2.1]	242	25.2	25.2	23.6	26.0	1.2	0.04	Trivial	1.0 [0.6, 1.7]	1.0 [0.7, 1.5]
	17 yrs	297	30.6	26.6	25.3	17.5	13.5**	0.12	Small	1.9 [1.2, 3.0]	1.3 [1.0, 1.9]	249	25.3	26.9	26.5	21.3	2.0	0.05	Trivial	1.3 [0.8, 2.1]	1.1 [0.8, 1.6]
Corrected performance Top 10%	12 yrs	23	13.0	17.4	21.7	47.8	5.8	0.29	Medium	0.3 [0.1, 1.9]	0.4 [0.1, 1.5]	44	22.7	18.2	27.3	31.8	1.6	0.11	Small	0.8 [0.2, 2.6]	0.7 [0.3, 1.6]
	13 yrs	206	30.6	24.3	23.3	21.8	5.6	0.10	Small	1.5 [0.8, 2.5]	1.2 [0.8, 1.8]	185	28.1	21.1	28.6	22.2	3.4	0.08	Small	1.3 [0.7, 2.4]	1.0 [0.6, 1.5]
	14 yrs	48	29.2	29.2	14.6	27.1	4.0	0.17	Small	1.2 [0.4, 3.6]	1.4 [0.6, 3.2]	77	26.0	27.3	24.7	22.1	0.7	0.05	Trivial	1.2 [0.5, 3.1]	1.1 [0.6, 2.2]
	15 yrs	150	28.0	24.7	26.0	21.3	1.7	0.06	Trivial	1.4 [0.7, 2.6]	1.1 [0.7, 1.8]	121	25.6	25.6	28.1	20.7	1.1	0.06	Trivial	1.3 [0.6, 2.7]	1.1 [0.6, 1.8]
	16 yrs	79	31.6	22.8	25.3	20.3	2.9	0.11	Small	1.6 [0.7, 4.0]	1.2 [0.6, 2.2]	97	27.8	25.8	26.8	19.6	1.8	0.08	Small	1.5 [0.7, 3.4]	1.2 [0.7, 2.0]
	17 yrs	119	31.1	24.4	26.9	17.6	5.6	0.13	Small	1.9 [0.9, 4.0]	1.3 [0.8, 2.1]	100	22.0	28.0	33.0	17.0	4.4	0.12	Small	1.4 [0.6, 3.1]	1.0 [0.6, 1.8]

Table notes: Q1, first quartile percentage; Q2, second quartile percentage; Q3, third quartile percentage; Q4, fourth quartile percentage; χ2, Chi-square value; ***, $p < 0.001$; **, $p < 0.1$; *, $p < 0.5$; V, Cramer's V effect size. OR, odds ratio and 95% confidence intervals (95% CI); Q1 VS Q4, first versus last quartile; Q1 & 02 VS Q3 &4 first versus last the half year's distribution.

Table 2
Relative age distribution, chi-square and odds ratio analyses of male and female jumpers. Data examined according to annual-age group for the Raw All, Top 25% & 10% of performances and according to Corrected Top 25% and 10% of performances.

		Male High Jumpers										Female High Jumpers									
Performance level	Age-group	Total N	Q1 %	Q2 %	Q3 %	Q4 %	χ^2	*V*	*ES cat.*	OR Q1 VS Q4	OR Q1 & 2 VS Q3 & 4	Total N	Q1 %	Q2 %	Q3 %	Q4 %	χ^2	*V*	*ES cat.*	OR Q1 VS Q4	OR Q1 & 2 VS Q3 & 4
Raw performance All	12 yrs	277	49.5	28.9	13.0	8.7	127.4***	0.39	Large	6 [3.4, 10.3]	3.6 [2.5, 5.3]	538	42.4	29.2	19.0	9.5	145.6***	0.30	Large	4.7 [3.2, 6.9]	2.5 [2.0, 3.2]
	13 yrs	2194	42.1	27.7	19.6	10.7	538.4***	0.29	Medium	4.1 [3.4, 5.0]	2.3 [2.0, 2.6]	2241	34.9	28.1	21.9	15.1	232.6***	0.19	Medium	2.4 [2.0, 2.9]	1.7 [1.5, 1.9]
	14 yrs	700	42.7	29.3	17.6	10.4	192.4***	0.30	Large	4.3 [3.1, 6.0]	2.6 [2.1, 3.2]	1067	30.5	27.5	24.8	17.2	50.2***	0.13	Small	1.9 [1.5, 2.4]	1.4 [1.2, 1.6]
	15 yrs	1722	36.1	29.4	21.2	13.2	241.1***	0.22	Medium	2.9 [2.3, 3.5]	1.9 [1.7, 2.2]	1432	29.5	26.5	24.3	19.7	40.8***	0.10	Small	1.6 [1.3, 2.0]	1.3 [1.1, 1.5]
	16 yrs	1183	33.3	30.1	20.7	15.9	114.8***	0.18	Medium	2.2 [1.7, 2.8]	1.7 [1.5, 2.0]	1357	27.5	25.9	23.9	22.7	15.1**	0.06	Trivial	1.3 [1.0, 1.6]	1.1 [1.0, 1.3]
	17 yrs	1264	31.3	30.2	22.0	16.5	92.8***	0.16	Small	2.0 [1.6, 2.5]	1.6 [1.4, 1.9]	1134	27.2	25.6	24.8	22.4	10.5*	0.06	Trivial	1.3 [1.0, 1.6]	1.1 [1.0, 1.3]
Raw performance Top 25%	12 yrs	80	51.3	36.3	5.0	7.5	53.1***	0.47	Large	7.2 [2.5, 20.8]	7.0 [3.2, 15.5]	183	49.2	26.2	15.8	8.7	79.3***	0.38	Large	6.0 [3.1, 11.8]	3.1 [2.0, 4.8]
	13 yrs	569	47.6	28.3	15.5	8.6	227.0***	0.36	Large	5.8 [4.0, 8.6]	3.2 [2.5, 4.1]	595	34.5	29.1	22.7	13.8	66.4***	0.19	Medium	2.6 [1.9, 3.7]	1.7 [1.4, 2.2]
	14 yrs	175	43.4	32.0	14.9	9.7	59.8***	0.34	Large	4.8 [2.4, 9.4]	3.1 [1.9, 4.9]	322	34.2	28.6	24.5	12.7	36.6***	0.19	Medium	2.8 [1.8, 4.6]	1.7 [1.2, 2.3]
	15 yrs	516	37.8	31.6	19.4	11.2	102.2***	0.26	Medium	3.5 [2.4, 5.2]	2.3 [1.8, 2.9]	400	30.3	28.0	23.0	18.8	16.9**	0.12	Small	1.7 [1.1, 2.5]	1.4 [1.1, 1.9]
	16 yrs	300	35.3	31.0	17.7	16.0	41.0***	0.21	Medium	2.3 [1.5, 3.7]	2.0 [1.4, 2.8]	386	32.4	26.7	22.3	18.7	22.2***	0.14	Small	1.8 [1.2, 2.8]	1.4 [1.1, 1.9]
	17 yrs	344	29.4	30.8	22.1	17.7	19.6***	0.14	Small	1.7 [1.1, 2.7]	1.5 [1.1, 2.1]	290	32.1	23.8	23.8	20.3	11.7**	0.12	Small	1.6 [1.0, 2.6]	1.3 [0.9, 1.8]
Raw performance Top 10%	12 yrs	36	58.3	38.9	0	2.8	35.9***	0.58	Large	21.0 [2.3, 191.2]	35 [4.3, 283.7]	84	60.7	17.9	14.3	7.1	65.0***	0.51	Large	8.9 [3.1, 25.4]	3.7 [1.9, 7.2]
	13 yrs	277	48.4	30.0	15.2	6.5	124.9***	0.39	Large	7.8 [4.3, 14.1]	3.6 [2.5, 5.3]	345	36.5	28.7	21.2	13.6	47.5***	0.21	Medium	2.8 [1.8, 4.4]	1.9 [1.4, 2.6]
	14 yrs	74	44.6	32.4	14.9	8.1	26.6***	0.35	Large	5.5 [1.9, 16.3]	3.4 [1.7, 6.8]	143	39.9	27.3	22.4	10.5	29.2***	0.26	Medium	4.0 [1.9, 8.4]	2.0 [1.3, 3.3]
	15 yrs	175	40.0	29.7	18.9	11.4	39.7***	0.27	Medium	3.8 [2.0, 7.2]	2.3 [1.5, 3.6]	170	34.1	25.3	23.5	17.1	12.7**	0.16	Small	2.1 [1.1, 3.9]	1.5 [1.0, 2.3]
	16 yrs	138	35.5	33.3	18.1	13.0	23.4***	0.24	Medium	2.8 [1.4, 5.8]	2.2 [1.4, 3.6]	152	33.6	27.0	22.4	17.1	11.2*	0.16	Small	2.1 [1.1, 4.0]	1.5 [1.0, 2.4]
	17 yrs	129	29.5	30.2	20.9	19.4	6.1***	0.13	Small	1.6 [0.8, 3.2]	1.5 [0.9, 2.4]	127	36.2	20.5	26.0	17.3	12.5**	0.18	Medium	2.2 [1.1, 4.5]	1.3 [0.8, 2.2]
Corrected performance Top 25%	12 yrs	69	24.6	27.5	23.2	24.6	0.5	0.05	Trivial	1.1 [0.4, 2.8]	1.1 [0.6, 2.1]	135	33.3	20.7	23.7	22.2	7.0	0.13	Small	1.6 [0.8, 3.1]	1.2 [0.7, 1.9]
	13 yrs	549	27.3	25.5	23.0	24.2	6.1	0.06	Trivial	1.2 [0.9, 1.7]	1.1 [0.9, 1.4]	560	22.7	26.1	27.0	24.3	0.8	0.02	Trivial	1.0 [0.7, 1.4]	1.0 [0.8, 1.2]
	14 yrs	175	28.6	29.7	21.1	20.6	7.4	0.12	Small	1.5 [0.8, 2.7]	1.4 [0.9, 2.1]	268	27.2	25.7	28.4	18.7	6.1	0.09	Small	1.5 [0.9, 2.5]	1.1 [0.8, 1.6]
	15 yrs	431	29.2	28.5	23.0	19.3	16.0	0.11	Small	1.6 [1.1, 2.4]	1.4 [1.0, 1.8]	358	27.1	26.3	24.3	22.3	3.7	0.06	Trivial	1.3 [0.8, 1.9]	1.1 [0.9, 1.5]
	16 yrs	296	28.7	30.1	19.9	21.3	13.4	0.12	Small	1.4 [0.9, 2.3]	1.4 [1.0, 2.0]	339	31.6	26.8	21.8	19.8	16.0**	0.13	Small	1.7 [1.1, 2.6]	1.4 [1.0, 1.9]
	17 yrs	316	28.2	28.8	23.1	19.9	9.5	0.10	Small	1.5 [1.0, 2.3]	1.3 [1.0, 1.8]	284	32.7	24.3	23.6	19.4	14.8	0.13	Small	1.8 [1.1, 2.9]	1.3 [1.0, 1.9]
Corrected performance Top 10%	12 yrs	28	32.1	28.6	10.7	28.6	3.1	0.19	Medium	1.1 [0.3, 4.6]	1.6 [0.5, 4.5]	54	33.3	24.1	25.9	16.7	3.2	0.14	Small	2.0 [0.7, 6.1]	1.4 [0.6, 2.9]
	13 yrs	219	26.0	26.9	23.7	23.3	1.9	0.05	Trivial	1.2 [0.7, 2.0]	1.1 [0.8, 1.6]	224	22.8	27.2	27.2	22.8	1.2	0.04	Trivial	1.1 [0.6, 1.8]	1.0 [0.7, 1.5]
	14 yrs	70	28.6	31.4	21.4	18.6	3.8	0.13	Small	1.5 [0.6, 4.1]	1.5 [0.8, 2.9]	107	25.2	27.1	29.9	17.8	3.4	0.10	Small	1.5 [0.7, 3.4]	1.1 [0.6, 1.9]
	15 yrs	172	28.5	30.2	23.3	18.0	8.1	0.13	Small	1.7 [0.9, 3.1]	1.4 [0.9, 2.2]	143	25.9	25.2	27.3	21.7	1.0	0.05	Trivial	1.3 [0.7, 2.5]	1.0 [0.7, 1.7]
	16 yrs	118	30.5	31.4	20.3	17.8	8.3	0.15	Small	1.8 [0.8, 3.8]	1.6 [1.0, 2.7]	136	28.7	28.7	23.5	19.1	4.6	0.11	Small	1.6 [0.8, 3.2]	1.3 [0.8, 2.2]
	17 yrs	126	26.2	29.4	20.6	23.8	3.4	0.09	Small	1.1 [0.6, 2.3]	1.3 [0.8, 2.1]	113	36.3	20.4	25.7	17.7	10.5	0.18	Medium	2.1 [1.0, 4.5]	1.3 [0.8, 2.2]
		Male triple jumpers										Female triple jumpers									
Raw performance All	14 yrs	705	38.6	27.2	20.3	13.9	113.2***	0.23	Medium	2.9 [2.1, 4.0]	1.9 [1.6, 2.4]	941	30.4	28.6	22.2	18.8	44.3***	0.13	Small	1.7 [1.3, 2.2]	1.4 [1.2, 1.7]
	15 yrs	1529	32.4	27.3	23.2	17.1	97.2***	0.15	Small	2.0 [1.6, 2.5]	1.5 [1.3, 1.7]	1414	30.6	27.9	23.4	18.1	66.0***	0.12	Small	1.8 [1.4, 2.2]	1.4 [1.2, 1.6]

	16 yrs	1102	29.9	28.1	23.3	18.7	44.3***	0.12	Small	1.7 [1.3, 2.1]	1.4 [1.2, 1.6]	1212	27.3	27.8	23.4	21.5	21.9***	0.08	Small	1.3 [1.1, 1.7]	1.2 [1.1, 1.4]
	17 yrs	1150	30.6	27.7	22.2	19.6	48.4***	0.12	Small	1.6 [1.3, 2.1]	1.4 [1.2, 1.7]	1038	25.3	27.4	24.2	23.1	7.8	0.05	Trivial	1.2 [0.9, 1.5]	1.1 [0.9, 1.3]
Raw performance Top 25%	14 yrs	180	45.0	31.1	16.7	7.2	66.4***	0.35	Large	6.5 [3.2, 13.4]	3.2 [2.0, 5.0]	235	29.8	26.4	24.7	19.1	7.5	0.10	Small	1.6 [1.0, 2.8]	1.3 [0.9, 1.9]
	15 yrs	388	38.4	26.8	21.4	13.4	60.7***	0.23	Medium	3.0 [2.0, 4.6]	1.9 [1.4, 2.5]	354	31.6	26.8	24.9	16.7	20.0***	0.14	Small	2.0 [1.3, 3.1]	1.4 [1.0, 1.9]
	16 yrs	280	35.0	28.6	22.1	14.3	32.1***	0.20	Medium	2.6 [1.6, 4.3]	1.8 [1.2, 2.5]	304	24.7	28.9	26.3	20.1	5.4	0.08	Small	1.3 [0.8, 2.1]	1.2 [0.8, 1.6]
	17 yrs	288	34.0	29.2	19.8	17.0	28.2***	0.18	Medium	2.1 [1.3, 3.4]	1.7 [1.2, 2.4]	262	25.2	30.5	25.2	19.1	7.4*	0.10	Small	1.4 [0.8, 2.3]	1.3 [0.9, 1.8]
Raw performance Top 10%	14 yrs	72	41.7	36.1	16.7	5.6	27.0***	0.35	Large	7.9 [2.3, 27.3]	3.5 [1.7, 7.2]	95	33.7	21.1	26.3	18.9	5.4	0.14	Small	1.9 [0.8, 4.2]	1.2 [0.7, 2.1]
	15 yrs	154	40.3	29.2	19.5	11.0	34.6***	0.27	Medium	3.9 [1.9, 7.8]	2.3 [1.4, 3.7]	144	29.9	25.7	27.1	17.4	5.8	0.12	Small	1.8 [0.9, 3.6]	1.3 [0.8, 2.0]
	16 yrs	112	37.5	32.1	22.3	8.0	24.3***	0.27	Medium	4.8 [2.0, 11.8]	2.3 [1.3, 4.0]	124	29.0	32.3	21.0	17.7	8.4	0.15	Small	1.8 [0.8, 3.6]	1.6 [1.0, 2.6]
	17 yrs	115	33.9	31.3	20.0	14.8	14.6***	0.21	Medium	2.5 [1.1, 5.3]	1.9 [1.1, 3.2]	104	26.9	26.0	26.9	20.2	1.4	0.07	Small	1.4 [0.6, 3.1]	1.1 [0.7, 1.9]
Corrected performance Top 25%	14 yrs	176	25.6	27.3	24.4	22.7	1.5	0.05	Trivial	1.2 [0.7, 2.2]	1.1 [0.7, 1.7]	235	23.0	23	28.1	26.0	0.6	0.03	Trivial	0.9 [0.6, 1.6]	0.9 [0.6, 1.2]
	15 yrs	382	28.5	25.7	25.4	20.4	7.0	0.08	Small	1.5 [1.0, 2.2]	1.2 [0.9, 1.6]	354	26.0	25.1	27.4	21.5	2.5	0.05	Trivial	1.3 [0.8, 1.9]	1.1 [0.8, 1.4]
	16 yrs	276	26.4	27.2	25.0	21.4	3.4	0.06	Trivial	1.3 [0.8, 2.1]	1.2 [0.8, 1.6]	303	19.8	28.1	27.4	24.8	3.4	0.06	Trivial	0.8 [0.5, 1.3]	0.9 [0.7, 1.3]
	17 yrs	288	27.8	28.5	22.6	21.2	7.4	0.09	Small	1.4 [0.9, 2.2]	1.3 [0.9, 1.8]	260	22.3	30.4	25.8	21.5	5.1	0.08	Small	1.1 [0.7, 1.8]	1.1 [0.8, 1.6]
Corrected performance Top 10%	14 yrs	71	29.6	32.4	19.7	18.3	5.0	0.15	Small	1.7 [0.7, 4.5]	1.6 [0.8, 3.2]	94	24.5	17.0	30.9	27.7	3.2	0.11	Small	0.9 [0.4, 2.1]	0.7 [0.4, 1.3]
	15 yrs	153	24.2	30.7	24.8	20.3	3.7	0.09	Small	1.3 [0.7, 2.4]	1.2 [0.8, 1.9]	141	25.5	22.7	29.8	22.0	1.4	0.06	Trivial	1.2 [0.6, 2.4]	0.9 [0.6, 1.5]
	16 yrs	110	25.5	29.1	26.4	19.1	2.4	0.09	Small	1.4 [0.6, 3.0]	1.2 [0.7, 2.1]	121	24.8	28.1	24.0	23.1	1.0	0.05	Trivial	1.1 [0.5, 2.3]	1.1 [0.7, 1.9]
	17 yrs	115	28.7	27.8	21.7	21.7	3.6	0.10	Small	1.4 [0.7, 3.0]	1.3 [0.8, 2.2]	104	24.0	25.0	27.9	23.1	0.2	0.02	Trivial	1.1 [0.5, 2.4]	1.0 [0.6, 1.7]
							Male pole vault										Female pole vault				
Raw performance All	14 yrs	763	27.4	27.1	25.7	19.8	14.5**	0.08	Small	1.5 [1.1, 2.0]	1.2 [1.0, 1.5]	771	29.7	26.5	23.1	20.8	21.5	0.10	Small	1.5 [1.1, 2.0]	1.3 [1.1, 1.6]
	15 yrs	1004	27.1	28.3	25.5	19.1	24.0***	0.09	Small	1.5 [1.2, 1.9]	1.2 [1.0, 1.5]	935	26.1	27.9	23.4	22.6	11.8	0.06	Trivial	1.2 [0.9, 1.6]	1.2 [1.0, 1.4]
	16 yrs	1067	25.9	29.6	23.2	21.3	22.6***	0.08	Small	1.3 [1.0, 1.6]	1.3 [1.1, 1.5]	802	27.7	25.8	23.6	22.9	9.8	0.06	Trivial	1.3 [1.0, 1.7]	1.2 [0.9, 1.4]
	17 yrs	1050	25.4	30.6	22.4	21.6	27.5***	0.09	Small	1.2 [1.0, 1.6]	1.3 [1.1, 1.5]	682	29.0	28.9	21.8	20.2	24.7	0.11	Small	1.5 [1.1, 2.0]	1.4 [1.1, 1.7]
Raw performance Top 25%	14 yrs	191	31.4	31.4	23	14.1	18.7***	0.18	Medium	2.4 [1.3, 4.4]	1.7 [1.1, 2.6]	253	30.8	24.5	25.7	19.0	9	0.11	Small	1.7 [1.0, 2.8]	1.2 [0.9, 1.8]
	15 yrs	269	27.1	34.9	22.3	15.6	24.5***	0.17	Small	1.8 [1.0.1, 3]	1.6 [1.2, 2.3]	238	33.2	21.8	22.7	22.3	12.2	0.13	Small	1.6 [1.0, 2.6]	1.2 [0.9, 1.8]
	16 yrs	294	25.9	34.7	20.7	18.7	20.2***	0.15	Small	1.4 [0.9, 2.3]	1.5 [1.1, 2.1]	214	33.6	24.8	21.5	20.1	12.7	0.14	Small	1.7 [1.0, 3.0]	1.4 [1.0, 2.1]
	17 yrs	274	25.5	32.1	21.5	20.8	10.7***	0.11	Small	1.3 [0.8, 2.1]	1.4 [1.0, 1.9]	200	36.0	27.0	18.0	19.0	22.1	0.19	Medium	2.0 [1.2, 3.5]	1.7 [1.1, 2.6]
Raw performance Top 10%	14 yrs	78	37.2	32.1	20.5	10.3	16.2***	0.26	Medium	3.8 [1.4, 10.6]	2.3 [1.2, 4.4]	96	32.3	25.0	25.0	17.7	5.0	0.13	Small	1.9 [0.8, 4.3]	1.3 [0.8, 2.4]
	15 yrs	104	29.8	33.7	22.1	14.4	10.1*	0.18	Medium	2.2 [0.9, 4.9]	1.7 [1.0, 3.0]	100	38.0	15.0	22.0	25.0	13.1	0.21	Medium	1.6 [0.7, 3.4]	1.1 [0.7, 2.0]
	16 yrs	133	29.3	35.3	21.8	13.5	15.3**	0.20	Medium	2.2 [1.1, 4.7]	1.8 [1.1, 3.0]	93	31.2	22.6	22.6	23.7	3.1	0.11	Small	1.4 [0.6, 3.1]	1.2 [0.7, 2.1]
	17 yrs	108	25.0	37.0	21.3	16.7	10.5*	0.18	Medium	1.6 [0.7, 3.5]	1.6 [1.0, 2.8]	72	36.1	19.4	16.7	27.8	8.5	0.20	Medium	1.4 [0.6, 3.3]	1.3 [0.7, 2.4]
Corrected performance Top 25%	14 yrs	191	20.4	29.8	26.7	23.0	3.3	0.08	Small	1.0 [0.5, 1.7]	1.0 [0.7, 1.5]	193	23.8	22.3	27.5	26.4	0.8	0.04	Trivial	0.9 [0.5, 1.7]	0.9 [0.6, 1.3]
	15 yrs	251	21.5	31.5	23.9	23.1	6.1	0.09	Small	1.0 [0.6, 1.6]	1.1 [0.8, 1.6]	234	28.6	20.1	24.8	26.5	5.2	0.09	Small	1.1 [0.7, 1.9]	1.0 [0.7, 1.4]
	16 yrs	267	21.3	31.8	22.8	24.0	7.5	0.10	Small	0.9 [0.6, 1.5]	1.1 [0.8, 1.6]	201	28.9	23.9	22.4	24.9	3.4	0.07	Small	1.2 [0.7, 2.1]	1.1 [0.8, 1.7]
	17 yrs	263	21.7	32.3	22.4	23.6	8.4	0.10	Small	1.0 [0.6, 1.6]	1.2 [0.8, 1.7]	171	33.3	25.7	19.9	21.1	10.2	0.14	Small	1.7 [0.9, 3.0]	1.4 [0.9, 2.2]
Corrected performance Top 10%	14 yrs	76	22.4	30.3	23.7	23.7	1.2	0.07	Small	1.0 [0.4, 2.5]	1.1 [0.6, 2.1]	77	20.8	23.4	31.2	24.7	1.1	0.07	Small	0.9 [0.4, 2.2]	0.8 [0.4, 1.5]
	15 yrs	100	19.0	30.0	28.0	23.0	2.2	0.09	Small	0.9 [0.4, 2.0]	1.0 [0.6, 1.7]	94	27.7	17.0	23.4	31.9	5.3	0.14	Small	0.9 [0.4, 2.0]	0.8 [0.5, 1.4]
	16 yrs	107	24.3	29.9	22.4	23.4	2.1	0.08	Small	1.1 [0.5, 2.4]	1.2 [0.7, 2.0]	80	30.0	17.5	23.8	28.8	3.8	0.13	Small	1.1 [0.5, 2.6]	0.9 [0.5, 1.7]
	17 yrs	105	21.9	32.4	21.0	24.8	3.9	0.11	Small	0.9 [0.4, 2.0]	1.2 [0.7, 2.1]	68	33.8	17.6	17.6	30.9	7.5	0.19	Medium	1.2 [0.5, 2.9]	1.1 [0.5, 2.1]

Table notes: Q1, first quartile percentage; Q2, second quartile percentage; Q3, third quartile percentage; Q4, fourth quartile percentage; $\chi 2$, Chi-square value; ***, $p < 0.001$; **, $p < 0.1$; *, $p < 0.5$; V, Cramer's V effect size. OR, odds ratio and 95% confidence intervals (95% CI); Q1 VS Q4, first versus last quartile; Q1 & 02 VS Q3 &4 first versus last the half year's distribution.

5. Conclusion

Overall, with RAEs identified as prevalent across multiple youth Italian youth Track & Field events, study finds validity and efficacy to CAPs as a strategy to account for relative age-associated developmental differences. For sport contexts where individual performance is determined by established measurement (i.e., second; centimetres), CAPs can be an effective strategy to more equitably evaluate athletic youth sport performance.

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CRediT authorship contribution statement

Paolo Riccardo Brustio: Conceptualisation, Methodology, Data analysis, Writing – original draft, Writing – review & editing. **Gennaro Boccia**: Conceptualisation, Methodology, Writing – original draft, Writing – review & editing. **Shaun Abbott**: Methodology, Writing – review & editing; **Antonio La Torre**: Data collection; Writing – review & editing. **Alberto Rainoldi**: Supervision, Writing – review & editing. **Stephen Cobley**: Methodology, Supervision, Writing – original draft, Writing – review & editing.

Declaration of interest statement

The authors declare no conflict of interest.

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References

1. Boccia G, Cardinale M, Brustio PR. Elite junior throwers unlikely remain at the top level in the senior category. *Int J Sports Physiol Perform* 2021;16(9):1281-1287.
2. Brustio PR et al. Don't throw the baby out with the bathwater: talent in swimming sprinting events might be hidden at early age. *Int J Sports Physiol Perform* 2022;17(11):1550-1557.
3. Brustio PR et al. Being a top swimmer during the early career is not a prerequisite for success: a study on sprinter strokes. *J Sci Med Sport* 2021;24(12):1272-1277.
4. Cobley S et al. Annual age-grouping and athlete development: a meta-analytical review of relative age effects in sport. *Sports Med* 2009;39(3):235-256.
5. Smith KL et al. Relative age effects across and within female sport contexts: a systematic review and meta-analysis. *Sports Med* 2018:1-30.
6. Till K, Baker J. Challenges and [possible] solutions to optimizing talent identification and development in sport. *Front Psychol* 2020;11:00664.
7. Brustio PR, Stival M, Boccia G. Relative age effect reversal on the junior-to-senior transition in world-class athletics. *J Sports Sci* 2023:1-7.
8. Brustio PR et al. Small relative age effect appears in professional female Italian team sports. *Int J Environ Res Public Health* 2021;19(1).
9. Cobley S, Till K. Participation trends according to relative age across youth UK Rugby League. *Int J Sports Sci Coach* 2017;12(3):339-343.
10. Wattie N, Cobley S, Baker J. Towards a unified understanding of relative age effects. *J Sports Sci* 2008;26(13):1403-1409.
11. Brustio PR et al. Relative age influences performance of world-class track and field athletes even in the adulthood. *Front Psychol* 2019;10:1395.
12. Campbell E et al. Contextual factors and sporting success: the relationship between birth date and place of early development on the progression of Jamaican track and field athletes from junior to senior level. *PLoS One* 2019;14(12):e0227144.
13. Kearney PE, Hayes PR, Nevill A. Faster, higher, stronger, older: relative age effects are most influential during the youngest age grade of track and field athletics in the United Kingdom. *J Sports Sci* 2018;36(20):2282-2288.
14. Hollings SC, Hume PA, Hopkins WG. Relative-age effect on competition outcomes at the World Youth and World Junior Athletics Championships. *Eur J Sport Sci* 2014;14(sup1):S456-S461.
15. Romann M, Cobley S. Relative age effects in athletic sprinting and corrective adjustments as a solution for their removal. *PLoS One* 2015;10(4):e0122988.
16. Kirkeberg A et al. Relative age effect among the best Norwegian track and field athletes of all time: comparisons of explosive and endurance events. *Front Psychol* 2022;13:858095.
17. Difernand A et al. Relative age effects in track-and-field: identification and performance rebalancing. *Front Physiol* 2022;13:1082174.
18. Bezuglov E et al. The relative age effect in the best track and field athletes aged 10 to 15 years old. *Sports (Basel)* 2022;10(7).
19. Brustio PR, Boccia G. Corrective procedures remove relative age effect from world-class junior sprinters. *J Sports Sci* 2021;39(22):2603-2610.
20. Brustio PR et al. Corrective adjustment procedures as a strategy to remove relative age effects: validation across male and female age-group long jumping. *J Sci Med Sport* 2022;25(8):678-683.
21. Abbott S et al. Testing the application of corrective adjustment procedures for removal of relative age effects in female youth swimming. *J Sports Sci* 2020;38(10):1077-1084.
22. Cobley S et al. Removing relative age effects from youth swimming: the development and testing of corrective adjustment procedures. *J Sci Med Sport* 2019;22(6):735-740.
23. Hogan C et al. Maturation-based Corrective Adjustment Procedures (Mat-CAPs) in youth swimming: evidence for restricted age-group application in females. *PLoS One* 2022;17(10):e0275797.
24. Rüeger E et al. Why age categories in youth sport should be eliminated: insights from performance development of youth female long jumpers. *Front Physiol* 2023:14.
25. Cobley S et al. Transient relative age effects across annual age groups in national level Australian swimming. *J Sci Med Sport* 2018;21(8):839-845.
26. Deaner RO, Lowen A, Cobley S. Born at the wrong time: selection bias in the NHL draft. *PLoS One* 2013;8(2):e57753.
27. Webdale K et al. Solving sport's 'relative age' problem: a systematic review of proposed solutions. *Int Rev Sport Exerc* 2020;13(1):187-204.
28. Kelly AL et al. "Birthday-banding" as a strategy to moderate the relative age effect: a case study into the England squash talent pathway. *Front Sports Act Living* 2020;2(17):573890.
29. Hopkins WG. A scale of magnitudes for effect statistics. A new view of statistics. 2002;502(411):321.
30. Hancock DJ, Adler AL, Côté J. A proposed theoretical model to explain relative age effects in sport. *Eur J Sport Sci* 2013;13(6):630-637.