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

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Abstract

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

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

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

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

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

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

Introduction

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

Related to track and field, several international studies have identified significant over- and under-representations of the relatively older and younger respectively across male and females at different age groups and differing levels of competition.[1,17-20] Here, RAEs effect sizes have been identified as being larger in adolescent age ranges (e.g., Q1 40% vs. Q4 13%), than post-18 age-groups (e.g., Q1 39% vs. Q4 17%) or adult competition (e.g., Q1 35% vs. Q4 19%)[18] and were further magnified according to selection level.[18,21] Moreover, RAEs are generally larger in males relative to females in various sport contexts.[7] An extensive cross-sectional study of international track and field did identify that males had larger RAE magnitude both in junior and senior categories.[17] However, the greatest RAE magnitude in females has been associated with preadolescent (less than 11 years old) and adolescent (12–14 years old) age categories, with declining risk following maturation.[7,22] This differential timing of peak RAE magnitude has been attributed to earlier chronological age time points for (re-)accelerated growth, less heightened anthropometric and physiological inter-individual differences during maturational years, and, earlier age time points for attaining adult stature relative to males.[7]

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

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

Methods

Initial data extraction

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

Part I

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

To determine sex-specific decimal age-performance relationships, the exact decimal age (i.e., year and date of competition; independent variable) and longest jump performance (m; dependent variable) were examined independently for males and females using mixed model regression. The best fitting model trendline (i.e., linear [$y = ax + c$] vs quadratic [$y = ax^2 + bx + c$]) was evaluated. Decimal age was entered as a fixed factor, while participants were entered as a random factor. Model fit was assessed using the likelihood ratio test. The best fitting model and corresponding regression equation was subsequently taken forward for CAPs calculations used in Part II.

Part II

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

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

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

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

Results

Part I

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

<Insert Figure 1 about here>

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

<Insert Table 1 about here>

Part II

<Insert Table 2 about here>

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

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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.

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

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

Discussion

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

Similar to previous studies in national[1] or international[21] sprinters and swimmers (ranged aged: 10-18 years),[24,30] results identified significant curvilinear relationships between decimal age and long jump performance for males and females. Based on trendlines long jump performances increased from 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. Within the same age-group (e.g., 12 years old), the relative difference in performance estimates from being the relatively youngest (11.01 years) to the relatively oldest (i.e., 12.00) progressed from relatively larger to smaller differences (e.g., about 48-5 % in males 12-17 %; see Table 1). In comparison, for females annual jump performance difference magnitudes were lower, with progressively lowering percentage differences within younger age-groups. The earlier (1-2 years) reductions in within year performance differences, may also reflect the earlier occurrence of maturation and attainment of adult stature.[31]

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

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

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

Conclusion

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

Practical Implications

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

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Figure Legends

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