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Abstract

This retrospective study aimed to investigate whether corrective adjustment procedures can remove the relative age effect (RAE) from track and field world-class junior sprinters. A total of 2918 male and 3029 female athletes competing in sprint races (100m, 200m, and 400m) and ranked in the first 100 positions of the World Athletics lists between 2000 and 2018 were considered. Longitudinal quadratic trendline equations across ages 16–25 yrs were calculated considering athletes' exact age and respective performance for each discipline and gender. Corrective adjustment calculations from estimated longitudinal quadratic equations were applied at 16yrs. Considering the uncorrected and corrected performance, Chi-square and Odds Ratio were calculated to investigate RAE in top-level athletes (i.e., first top50 and top100 ranked of the whole sample). When analyzing the uncorrected performance moderate to large RAE was observed in Top50 and Top100 (Crammer's V effect size ranged=0.21-0.38). When re-examining the data using the corrective adjustment calculations, the RAE disappeared in all sprint and both genders. Corrective adjustment procedures can remove RAE in world-class sprinters at the beginning of their career. Applying simple equations based on exact age might improve the accuracy of performance evaluation and talent identification in international track and field sprint competitions.

Keywords RAE; athlete development; re-balancing RAE; track and field; youth competition; talent identification.

Introduction

Sports federations usually group young athletes according to their chronological age with the purpose to arrange sports events. This is meant to reduce developmental differences and provide equal opportunities and experiences during competitions (Cobley, Baker, Wattie, & McKenna, 2009; Romann & Cobley, 2015; Wattie, Cobley, & Baker, 2008). Nevertheless, this choice, which is based on annual or biannual age-grouping cohorts, potentially leads to a chronological age difference of up to 12 or 24 months among athletes in the same age-group. This potentially increases the differences in terms of biological age across young athletes (Romann & Cobley, 2015), accentuating physical, cognitive and psychological differences (Cobley et al., 2009; Musch & Grondin, 2001).

One of the most common problems within youth sports is the phenomenon of the relative age effect (RAE). The RAE reflects an asymmetry in birth distribution due to an over- and under-representation of athletes born close (relative older) and far away (relative younger) to the date of selection. In other words, the RAE reflects the possible advantages/disadvantages in early sport success and the process of talent identification (Cobley et al., 2018; Till & Baker, 2020; Wattie, Schorer, & Baker, 2015). The RAE has been observed in several youth sports and is particularly pronounced in sports requiring high physical demands (Cobley et al., 2019), including track and field disciplines (Brustio et al., 2019; Kearney, Hayes, & Nevill, 2018; Romann & Cobley, 2015) and swimming (Abbott et al., 2020; Cobley et al., 2018; Cobley et al., 2019; Costa, Marques, Louro, Ferreira, & Marinho, 2013). Of note, the RAE in females is lower and occurs earlier if compared to males (Smith, Weir, Till, Romann, & Cobley, 2018). According to the *maturation-selection hypothesis* (Cobley et al., 2009), relatively older athletes may have sporting performance advantages due to the favorable anthropometric (e.g., body weight) and physical characteristics (e.g., muscular strength and power, endurance and speed) in comparison with relatively younger peers (Abbott et al., 2020). This advantage may offer a higher likelihood of being selected in the first stage of within a sport (Brustio et al., 2019; Brustio et al., 2018; Lupo et al., 2019). On the other hand, from a long-term point of view, this advantage may be transient (Cobley et al., 2018) or partially disappear during adulthood (Brustio et al., 2019; Lupo et al., 2019) underlining how the relative younger athletes might have the greatest potentiality for later success (McCarthy, Collins, & Court, 2016; Till et al., 2016).

To solve the problem of the RAE, many different solutions have been proposed and studied. These structural solutions, adopting different methodological approaches, highlighted that the disadvantage in terms of biological age can be partially resolved focusing on organizational (e.g., rotating cut-off dates or classifying athletes by maturation status) or practical strategies (e.g., shirt numbering based on month age or correction factor to performance results) (Cobley et al., 2018; Cobley et al., 2019; Mann & van Ginneken, 2017; Romann & Cobley, 2015).

The solution of individual's performance correction is a recent and promising method adopted in sports where performance is determined in centimeters, grams, or seconds (Cobley, Abbott, Moulds, Hogan, & Romann, 2020). Previous studies showed that using performance correction may reduce the disadvantages of relatively younger sprinters and swimmers (Abbott et al., 2020; Cobley et al., 2019; Romann, Rossler, Javet, & Faude, 2018). In the context of national Swiss 60m sprinter event, Roman et al. (2015) identified a performance difference about 10% to 5% in annual age-grouping cohorts aged 8-15 yrs and an over-representation of athletes born close to the date of selection for the top tiers. Applying performance correction, based on the expected performance differences from being one day to one year older in each annual age group, the authors found that the RAE became completely absent in top 10% athletes and was removed or at least reduced in top 50% and top 25% athletes. Similar results were obtained in Australian male 100 m Freestyle (Cobley et al., 2019) and female 100 and 200 m breaststroke swimmers (Abbott et al., 2020) where generally a moderate to large RAE was observed in top 25%, and top 10% swimmers. Nevertheless, after a performance correction by using quadratic trendline equations based on longitudinal data, distribution ratios between the relatively older and younger quartiles disappeared in most of the considered age-groups.

The above-mentioned findings clearly emphasize the utility of corrective adjustments for obtaining a symmetry quartile distribution and an accurate performance evaluation, especially in top-level young athletes. Consequently, this would help to understand the real value of young athletes better (Abbott et al., 2020; Cobley et al., 2019). Nevertheless, no study investigated this approach at the international level where the RAE is markedly present (Brustio et al., 2019). Thus, to fill this gap we aimed to examine whether corrective adjustment procedures may remove or at least reduce RAE in world-class athletes track and field sprinters in the early steps of their international career (i.e., at 16 yrs old).

Material and Methods

This study was a further analysis of the data collected for a previously published (blinded for review). Here we maintained the same database but rethinking the analysis with different research questions. Male and female world-class sprinters competing in 100m, 200m, and 400m disciplines ranked in the top 100 official lists of the World Athletics (from 2000 to 2018) and/or who participated in the World U18 and U20 Championships (from 1998 to 2015) were considered for the study. For each sprinter listed in the database, the annual best performance, the date of annual best performance and the birthdate were downloaded and included in an anonymous dataset. Athletes were included in the databases (i.e., primary dataset) only if they presented a minimum of three personal annual best performances, also non-consecutively. Due to the longitudinal nature of the database, all the included performances were recorded during international events from 1988 to 2018. All the data were available in the public database of World Athletics (https://www.worldathletics.org/) and thus no informed consent was obtained. This study was approved by the local ethics committee of the blind for review and conducted according to the declaration of Helsinki.

Statistical Analysis

To calculate performance correction based on longitudinal data, a subset of data was initially extracted from the primary dataset. Specifically, athletes were included in this secondary database only if they presented a minimum of 5 personal annual best performances, also non-consecutively per year ranging from 16 to 24 years. These boundaries were chosen to establish accurate estimates of performance changes up to the expected personal best performance (Boccia, Cardinale, & Brustio, 2020b). Upper extreme outliners (Z-score values>2) of performance times, i.e., those with poorest performances, were identified and removed. The exact age (based on the year and day of athletes' birthdate) at which athletes achieved the performances in the database, was calculated. Subsequently, considering performance time as a dependent variable, separate mixed models for each discipline and gender were used to calculate the best fit model trendline equations (i.e., linear vs quadratic trendline). The exact age of the best performance was considered in the model as a fixed factor while subjects as a random factor. The model fit was assessed with the *likelihood ratio test*.

Using 16 yrs as reference age, the mean expected performance differences per decimal age were calculated considering the whole sample (i.e., primary dataset). Thus, all performances (from this moment called *uncorrected performances*) were adjusted (thus generating the *corrected performance*) using the mean expected performance differences per day. Using 16 yrs as reference age, it is possible that athletes performed his/her annual best performance when he/she was from ~15.01 (e.g., athletes born on 31st December 2000 performing the annual best performance on the 1st January 2016) to ~16.99 yrs old (e.g., athletes born on 1st January 2000 and performing the annual best performance on the 31st December 2016). Thus, for an athlete that was 16.0 yrs old when recorded his/her performance the corrected performance corresponds to the uncorrected performance while for an athlete that was 15.01 or 16.99 yrs when recorded his/her performance the corrected performance corresponds to the uncorrected performance less/plus the expected performance differences per year. Then, considering the uncorrected and corrected performances, an all-time athletes' ranking of 16 yrs old sprinters was created and two subgroups of athletes were defined: the first 100 (Top100) and 50 (Top50) athletes' subgroups.

For each sprinter, the quartile of the birthdate was calculated. The following criteria were used: sprinters born between January and March in the 1st quartile (Q1), between April and June in the 2nd quartile (Q2), between July and September in the 3rd quartile (Q3) and between October and December in the 4th quartile (Q4) (Brustio et al., 2019). The differences between observed and expected quartile distributions in the Top100 and Top50 sprinters, both using the uncorrected and corrected performances, were investigated by the means of Chi-square (χ^2). The magnitudes of the differences were calculated as Crammer's V effect size. Threshold values for effect size statistics were: ≤ 0.17, small; > 0.18, moderate $V \geq 0.29$ large (Cohen, 2013). For the first and the last quartile (i.e., Q1-Q4) and the first and the second semester of the year (i.e., Q12-Q34), odds ratios (ORs) and 95% confidence intervals [95% CIs] were calculated. A uniform distribution (i.e., 25% for each quartile) was adopted as expected distribution (Brustio et al., 2019; Brustio et al., 2018). All the above analysis was performed separately for each discipline and gender and by custom-written software in MATLAB R2020b (Mathworks, Natick, MA, USA).

Results

A total of 1462 (female: 51.3%; total performances n=9506), 1299 (female: 56.1%; total performances n=8227) and 1316 (female: 46.8%; total performances n=8287) sprinters of 100m, 200m and 400m was analyzed to create longitudinal trendline equation. For all disciplines and gender longitudinal quadratic trendline equations (i.e., $y=ax^2+bx+c$) provided evidence of a significant improvement of model fit if compared to linear model (χ^2<0.05) and therefore considered for the corrective adjustment calculations. The variance explained (adjusted R^2) by the fitted models ranged between 0.572 and 0.614. From longitudinal quadratic trendline equations, the expected performances were estimated to reduce in 16yrs sprinters aged from 15.01 to 16.99 of approximately: 10.89 to 10.77s (male sprinters) and 12.06 to 11.95s (female sprinters) for the 100m discipline; 21.97 to 21.72s (male sprinters) and 24.69 to 24.45s (female sprinters) for the 200m discipline; 48.87 to 48.28s (male sprinters) and 55.71 to 55.22s (female sprinters) for the 400m discipline. Fig. 1 shows a representative example of the quadratic trendline equation between exact age (i.e., year and day) and uncorrected performances in 100 m male sprinters.

<Insert Fig.1 about here>

The chi-square statistics, effect size estimation, ORs, and 95% CIs in the Top100 and Top50 sprinters considering the uncorrected and corrected performances for each discipline are presented in Table 1.

<Insert Table 1 about here>

When analyzing the uncorrected performances, moderate to large effect sizes in male sprinters were observed in Top100 (Crammer's V effect size ranged = 0.22–0.32). Differently, in Top50 only a large effect was observed in 400 m sprinters (Crammer's V effect size = 0.38). In general, female sprinters showed lower trends. Predominantly, moderate effect sizes were identified in Top100 in 100m (Crammer’s V effect size = 0.21) and 400 m sprinters (Crammer’s V effect size = 0.22) while in the Top50 moderate to large effect size was observed in all disciplines (Crammer’s V effect size ranged = 0.28–0.32).

Except for 100m, the ORs and 95% CIs of Q1 versus Q4 (see Table 1 Q1-Q4) and Q1+Q2 versus Q3+Q4 (see Table 1 Q12-Q34) showed that male sprinters born in the first quartile (or in the first semester) of the year were, on the average, 3.34 (or 1.87) more likely to be included in Top100 category, respectively. In Top50 category the same pattern was evident only in 400m (OR for Q1-Q4 = 4.00; OR for Q12-Q34 = 2.33). Nevertheless, in 100 and 200m, a trend suggested that the likelihood of being included in Top50 category is higher for an athlete born in the first quartile or in the first semester rather than the counterpart. Differently, only the 400m female sprinters born in the first quartile of the year were 2.46 and 3.33 more likely to be included in the Top100 and Top50 category, respectively. Nevertheless, in the other sprinter disciplines, a trend suggested that the likelihood of being included in 16 yrs list was higher for an athlete born in the first quartile or the first semester rather than the counterpart.

Performance adjustments were effective in removing (at least in part) the RAE (see right part of the table 1, corrected performances). Indeed, a more even quartile distribution was observed when re-examining the RAE using the corrected performances. Predominantly the RAE disappears both in Top100 and Top50 category. This trend was evident in both genders. The only exception was in 200 m male (χ^2=8.240; moderate effect size) and female sprinters (χ^2=8.480; moderate effect size) for the Top100 category (χ^2=8.240; moderate effect size). Nevertheless, when examining the ORs and 95% CIs of Q1 versus Q4 (see table Q1-Q4) and Q12 versus Q34 (see table Q12-Q34) there were no significant results (all p> 0.05) both for male and female sprinters for any discipline and top-tiers.

Discussions

This study examined the presence of RAE in word-class sprinters in the early stages of their career (i.e., 16 yrs old) and investigated whether corrective adjustment procedures may remove or at least reduce the RAE. Since the RAE is known to be affected by the level of competitiveness (Romann & Cobley, 2015), we examined the RAE and RAE correction specifically on the top-tiers, i.e. the top 100 and top 50 athletes. The results showed an asymmetry in birthdate distribution in top 100 and top 50 sprinter athletes at 16 years old and that the RAE increases as competitiveness level increases. Nevertheless, using the corrective adjustment procedures, the RAE was effectively removed, underlining the potential usefulness of this method for improving the accuracy of performance evaluation and talent selection in a youth context.

When examining the Top100 athletes of uncorrected performances, the RAE was apparent in both genders. Male sprinters showing a general higher magnitude effect size. However, when the selection criteria increased (i.e., from the Top100 to the Top50 category) the RAE trends were less evident for male sprinters. According to the *Underdog Hypothesis* (see Gibbs, Jarvis, & Dufur, 2012; Smith & Weir, 2020) these results may suggest the late birth benefits to career benchmarks. On the other hand, it is possible that the relatively small sample size in Top50 category may affect the results. Indeed, the trend in distribution was in favor of the athletes born in the first part of the year. These are just speculations that remain to be confirmed by future studies. The ORs were generally lower if compared to national sprinters, confirming that the competitiveness level may affect the magnitude of the RAE (Kearney et al., 2018; Romann et al., 2018). For example, in top 10% Swiss 60m sprinters (aged: 8-15 yrs old) Roman et al. (2015) found large RAE (OR=3.34 [2.58–4.32]). Nevertheless, the considered different age group and discipline make difficult the comparison. Of note, the data confirmed that the RAE in females was generally lower than in male sprinters (Brustio et al., 2019) and weaker in 100 and 200 m in comparison with 400m male sprinters (see Crammer's V effect size and OR) confirming that the RAE is likely to be larger in events with a greater emphasis on metabolic requirements (Hollings, Hume, & Hopkins, 2014; Kearney et al., 2018). Together, the results suggested that according to the maturation-selection hypothesis (Cobley et al., 2009) it is possible to suppose that relatively older athletes may have (Boccia, Cardinale, & Brustio, 2020a; Boccia, Cardinale, & Brustio, 2021) more favorable anthropometric and physical characteristics to be considered top-level athletes in youth International athletic competitions. On the other hand, relatively older athletes may have more chances to be included in youth talented programs and decrease the constraints for the sports activity (Cobley et al., 2018; Till & Baker, 2020; Wattie et al., 2015) even if, from a long-term point of view, excelling during youth is not a strong predictor of success at senior level (Boccia et al., 2019; Boccia et al., 2020b; Boccia et al., 2021; Boccia et al., 2017; Kearney & Hayes, 2018).

To provide RAE corrections we analyzed the performance progression of word-class sprinters across ages 16–25 yrs and estimated the performance difference based on decimal yrs using longitudinal quadratic trendline equations. To our knowledge, this study is the first that provides information on corrective adjustment procedures in world-class junior sprinters. A similar approach was only previously provided in national track and field youth sprinters (ranged aged: 8-15 yrs) (Romann & Cobley, 2015) or swimmers (ranged aged: 10-18 yrs) (Abbott et al., 2020; Cobley et al., 2019). With this approach, we were able to estimate developmental performance changes (Abbott et al., 2020; Cobley et al., 2019; Cobley et al., 2020). Results suggested that the percentage differences in performance at 16yrs old ranged from 1.10% to 1.23% for male and from 0.88% to 0.95% for female sprinters. These differences were lower if compared to Roman et al. (2015) (mean year difference about 7%), but in line with annual percentual improvement observed in world-class sprinters (Boccia et al., 2020b). Our higher competition level (i.e., word-class athletes) and age (i.e., 16 yrs), and the difference distance investigated may explain the difference. Nevertheless, despite the small percentage differences observed, different trends in quartile distribution were observed when considering corrected performances. Using corrective adjustment procedures based on world-class sprinters across ages 16–25 yrs, the asymmetry in quartile distribution disappeared (all p values < 0.05), irrespective of gender and tiers considered. A more even birthdate distribution suggests the removal of RAE in these groups of athletes. Correspondingly, the ORs analyses between the first versus the last quartile and between the first and second semester suggested a more equal birthdate distribution with respect to uncorrected performances. Only Top100 200m male and female sprinters still presented a moderate RAE after performance adjustments. Nevertheless, it necessary to note that after performance adjustments a more equal distribution was observed if compared to the uncorrected performance time.

Some limitation should be pointed out. We calculated the RAE at 16yrs of age because the World Athletics database is consistently updated from 16 yrs of age on. It is well known that RAE is larger at lower ages, particularly before 16 yrs of age. Consequently, future studies investigating younger ages might find an even larger effect of corrective procedures than we did. The present analysis did not evaluate for other factors, such as training history, sport specialization, and maturation, that may influence the athletes' performance evolution progress (Cobley et al., 2020). Then it should be pointed out that the corrective adjustment procedure is only one of the possible strategies to remove RAE (Cobley et al., 2020).

Together, these results provide further evidence for the usefulness of this method to remove RAE-related inequalities in sports participation and performance. Given that RAE was observed in 16 yrs top tiers when using unadjusted performances, results suggested a practical strategy to solve the problem with RAE. The corrective adjustment procedures may successfully re-balance age distribution also in world-class junior sprinters at international level as previously observed in national sprinters (Romann & Cobley, 2015) and swimmers (Abbott et al., 2020; Cobley et al., 2019). Practically, the application of this procedure may have implications during athletes' developmental and talent identification process. The correction of the performance according to birthdate may remove inequality in physical characteristics and provide a more plausible understanding of the real athletes’ potential, consequently improving the evaluation procedures. Sports federations, coaches and practitioners should consider this approach to correct performances and consequently increase the equality in the access to talent identification and race participation.

To summarize, the present results underline the usefulness of corrective adjustment procedures to remove RAE in top-level sprinters competing in international level competitions. Corrective adjustment procedures may minimize the RAE and provide practical strategies to solve the asymmetry in birthdate distribution in the centimeters, grams, or seconds sports context and create solution to minimize disadvantages in terms of biological age in the early steps of an international career. This data driven strategy may improve the accuracy of performance evaluation and long-term talent identification.

Acknowledgements

Blinded for review.

Declaration of interest statement

The authors report no conflict of interest.

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Figure Legends

Figure 1 Representative example of quadratic equation model considering chronological age and performance times in 100 m male sprinters.