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Original research

Removing relative age effects from youth swimming: The development and testing of corrective adjustment procedures

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ABSTRACT

Objectives: (1) Generate accurate estimates of the relationship between decimal age (i.e., chronological and relative) with swimming performance based on longitudinal data. (2) Determine whether corrective adjustment procedures can remove Relative Age Effects (RAEs) from junior/youth swimming.
Design: Longitudinal and repeated years of cross-sectional performance data were examined.
Methods: (1) Participants were 553 male 100 m Freestyle swimmers (10–18 years) who participated in ≥five annual events between 1999–2017. Growth curve modelling quantified the relationship between age and swimming performance, permitting corrective adjustment calculations. (2) Participants were N = 2141 male 100 m Freestyle swimmers (13–16 years) who swam at state/national events in 2015–2017. Relative age distributions for 'All', 'Top 50%', '25%' and '10%' of swimming times were examined based on raw and correctively adjusted swim times. Chi-square, Cramer's *V* and Odds Ratios (OR) determined whether relative age (quartile) inequalities existed according to age-groups, selection level and correctively adjusted swim times.
Results: Based on raw swim times, for 'All' swimmers RAEs was evident at 13 and 14 years-old and dissipated thereafter. But, RAE effect sizes substantially increased with selection level, with large-medium effects between 13–15 years-old (e.g., 15 years — Top 50% Q1 v Q4 OR = 2.28; Top 10% = 6.02). However, when correctively adjusted swim times were examined, RAEs were predominantly absent across age-group and selection levels.
Conclusions: With accurate longitudinal reference data, corrective adjustment procedures effectively removed RAEs from 100 m Freestyle swimming performance, suggesting the potential to improve swimming participation experience and performance evaluation.

1. Introduction

Whether considered from a public health or athlete development perspective, addressing factors that undermine health behaviours, such as sport participation in children and adolescence, are of interest to policy-makers, sporting organisations and practitioners alike. Relative Age Effects (RAEs) represent one important, influential factor leading to differential outcomes across sport and education settings. RAEs reflect an interaction between an individuals' birth-date and the dates used for chronological age grouping in developmental ages and stages.[1] In sporting contexts being relatively older within an age group – compared to being relatively younger – is associated with consistent attainment and selection advantages. These include the likelihood of longer-term participation[2,3] across male[4] and female[5] sporting contexts.

Across junior and youth school-representative-international tiers of soccer,[6] baseball,[7] handball[8] and rugby[9] for instance, participation ratios between the relatively oldest and youngest quartiles have varied from small (e.g., 1.5–1), moderate (3–5–1) and in some cases large (≥5–1). That said, RAE's in females are typically lower and occur at earlier chronological ages.[5] The highest RAEs are commonly associated with selective representative contexts at ages and time points associated with puberty and maturation.[10,11] Recently, studies have identified that individual but still physically

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demanding sports are also associated with RAEs, notably athletic sprinting,[12] tennis,[13] swimming,[14] ski-jumping, cross-country and alpine skiing.[15,16] By comparison, sports with less dependence on physical characteristics and which have a higher technical skill emphasis are less likely to be associated with RAEs.[17]

Several hypotheses have been proposed to explain RAEs,[18,19] but most empirically supported is the 'maturation-selection hypothesis'.[4,20] The hypothesis states that greater chronological age is equated with an increased likelihood of enhanced normative anthropometric growth. Greater height and lean body mass are predictive of better physical capacities such as aerobic power, muscular strength, endurance and speed.[21] In turn, these characteristics provide physical performance advantages in specific tasks.[22] Also during maturation, the timing and tempo of further anthropometric and physical development generate further inter-individual variation, until cessation.[11,23] Unfortunately for the relatively younger (and later maturing), these processes lead to short-term performance disadvantages as shown by their lower likelihood of selection for representative tiers of sport. In the longer-term, recent studies suggest that RAE-related and maturation inequalities may be temporary and transient,[24,25] yet the consequences upon psychological factors (e.g., motivation, enthusiasm and satisfaction) may account for their lower sporting involvement in the junior and adolescent years.

To address relative age and developmental inequalities within junior and developmental sport, a range of feasible organisational and practitioner strategies have been proposed.[26] In individual sport contexts, corrective performance adjustments have been identified as a strategy to remove relative age-related (and potential growth and maturation) differences.[12] In such contexts, objective outcome measurements (i.e., centimetres, grammes & seconds)[27] determine performance relative to similar aged (or age-grouped) others and are less influenced by other (team)-interaction dependencies; and, the influence of relative age on performance can more accurately be quantified. Romann and Cobley[12] developed corrective adjustments when examining a large cross-sectional sample (N = 7761) of 9–15 year-old Swiss sprinters. Expected performance differences from being one day to one year older in each annual age group were calculated. Given the chronological age-group being examined, individual performance times were then adjusted to a standard reference point and a corrected sprint time created. Relative age distributions of corrected sprint performance times were then re-examined. Findings identified that for almost all annual age-groups, relative age attainment discrepancies were removed – if not at least reduced – as RAEs became absent in the 'Top 10%' of sprint times. Corrective adjustments in youth sport contexts could, therefore, help ensure more equitable participation and attainment by removing performance dis-advantages for the relatively younger in age-based competition.

The purpose of the present study was first to generate accurate estimates of the relationship between decimal age (i.e., chronological and relative age) and swimming performance based on longitudinal competition data (Part 1). The second purpose was to determine whether a corrective adjustment procedure could effectively remove RAEs; potentially permitting a more equitable procedure for swimming performance evaluation (Part 2).

2. Methods

2.1. Part 1: Relationship between decimal age and swim performance based on longitudinal data

Participants. Participants were N = 553 male swimmers, aged 10–18, who participated in official long-course 100 m (m) Freestyle events (N = 202), at age-group and/or open-level Australian domestic competitions between 1999-2017 (inclusive). Participants were included if they registered a time within one second of the state level qualification time; who registered multiple years (≥5 years) of performance times at least once per year ranging from 10 to 18 years; and, who were without a disability. Such criteria helped establish an accurate longitudinal estimate of performance change over time (i.e., across and within age-groups).

Procedure. Following University ethics approval (App No: 2017/650), an anonymised dataset containing N = 87,526 registered male swims in the 100 m Freestyle was provided by Swimming Australia. The 100 m Freestyle was sampled as it is one of the most competitive events (i.e., higher participation numbers) in Australia's age-group championship schedule. Performance in the event is also considered informative for athlete evaluation, selection and transfer (i.e., taking up other strokes) purposes.

Data-analysis. Extracted data was initially screened for outliers (i.e., residuals) using box plots. Outliers were removed if an input data error was apparent or if individual swim performance were ≥2 s slower than a previous year's performance. A normative distribution was checked for all those identified (i.e., N = 553). Then, swimmers' exact decimal age (i.e., years and days old) at respective competitive events was plotted against 100 m Freestyle performance time using a longitudinal growth curve model within a multi-level modelling framework[28,29]. Decimal age was centred to zero, representing the first point of observation (e.g., 10.00 years of age) and acted as the independent variable. A hierarchical method was used where repeated observations were nested within individual swimmers. An unstructured covariance type was applied and the fit of the models for fixed and random effects (e.g., intercept and slope) were assessed by comparing the log-likelihoods (-2LL) with changes in critical values for the chi-square statistic and degrees of freedom. The final fixed effect estimate model was a quadratic function ($y = ax^2 + bx + c$), summarising the expected decimal age — performance relationship across ages 10–18 years; this was subsequently used for corrective adjustment calculations.

2.2. Part 2: Testing and application of corrective adjustments on relative age distributions

Participants. To determine whether corrective adjustments could remove RAEs, an independent sample of swimmers (N = 2141 males, aged 13–16 years) who registered 100 m Freestyle performance(s) at state (N = 9) and/or national (N = 2) long course events from 2015 to 2017 in Australia were examined. Swimmers who competed at both state and national events in a given year were included, as dates used for annual-age grouping typically changed by five months as part of competition scheduling (i.e., creating different relative ages).

Procedure. Similar data collection, extraction and performance criteria procedures as outlined in Part 1 were implemented, with data reflecting performances at long-course state and national competitions. According to the respective swim events sampled and dates applied for annual-age grouping, participants were assigned to chronological age (e.g., 13 years old) and relative age quartiles given their decimal age. For example, at 13 years old, quartile categories were Q1 = 13.75–13.99 years; Q2 = 13.50–13.74; Q3 = 13.25–13.49 years and Q4 = 13.00–13.24. The number and percentage distributions of swimmers within each age group (13–16 years old) and according to relative age quartiles (Q1–Q4) were then determined (see Table 1), providing an assessment of relative age distributions for 'All' swimmer sampled at each age group. Next, for each age group examined (13–16 years), the relative age distributions of raw 100 m Freestyle swims were sub-examined according to the 'Top 50%', '25%' and '10%' of performance times. This step resembled the introduction of selection criteria, similar to event qualification and criteria for representative selection.

Table 1
Relative age distribution, chi-square and odds ratio analysis of male 100 m swimmers (aged 13–16 years) at state and national level championships for 2015–2017 (inclusive). Raw and correctively adjusted times presented for the Top 50%, 25% & 10% of 100 m Freestyle times.

Performance Level	Age-group	Total *N*	Q1%	Q2%	Q3%	Q4%	X^2	*P*	*V*	*ES cat.*	OR Q1 v Q4	(95%CI)	OR Q2 v Q4	(95%CI)	OR Q3 v Q4	(95%CI)
Raw All swimmers	13 years	488	39.10	27.30	16.00	17.60	66.34	0.0001*	0.21	Medium	2.22*	(1.55–3.18)	1.55*	(1.07–2.24)	0.91	(0.61–1.35)
	14 years	548	32.10	28.80	21.00	18.10	28.16	0.0001*	0.13	Small	1.77*	(1.26–2.50)	1.59*	(1.13–2.25)	1.16	(0.81–1.66)
	15 years	566	28.80	26.10	23.90	21.20	7.09	0.06	0.06	Small	1.36	(0.98–1.89)	1.23	(0.88–1.72)	1.13	(0.80–1.58)
	16 years	538	26.00	28.30	24.50	21.20	5.72	0.12	0.06	No	1.23	(0.87–1.73)	1.33	(0.95–1.88)	1.16	(0.82–1.63)
Raw Top 50% of swim times	13 years	244	43.00	30.30	15.60	11.10	61.85	0.0001*	0.29	Large	3.87*	(2.23–6.73)	2.73*	(1.55–4.81)	1.41	(0.77–2.58)
	14 years	275	36.40	30.50	18.20	14.90	33.93	0.0001*	0.20	Medium	2.44*	(1.49–4.00)	2.05*	(1.24–3.38)	1.22	(0.72–2.08)
	15 years	285	34.40	28.40	22.10	15.10	23.52	0.0001*	0.17	Small	2.28*	(1.40–3.70)	1.88*	(1.15–3.08)	1.46	(0.88–2.43)
	16 years	270	28.90	27.80	23.70	19.60	5.82	0.12	0.08	Small	1.47	(0.91–2.40)	1.42	(0.87–2.31)	1.21	(0.74–1.99)
Raw Top 25% of swim times	13 years	123	45.50	31.00	14.60	8.90	40.52	0.0001*	0.33	Large	5.11*	(2.26–11.59)	3.48*	(1.51–8.05)	1.64	(0.67–4.05)
	14 years	138	39.90	34.80	13.00	12.30	34.41	0.0001*	0.29	Medium	3.24*	(1.58–6.67)	2.83*	(1.37–5.86)	1.06	(0.47–2.39)
	15 years	142	43.00	29.60	16.90	10.50	35.27	0.0001*	0.29	Medium	4.10*	(1.97–8.52)	2.82*	(1.33–5.98)	1.61	(0.73–3.57)
	16 years	137	30.70	26.30	18.20	24.80	4.41	0.22	0.10	Small	1.24	(0.64–2.38)	1.06	(0.54–2.06)	0.73	(0.36–1.48)
Raw Top 10% of swim times	13 years	50	56.00	24.00	16.00	4.00	29.68	0.0001*	0.44	Large	14.00*	(2.73–71.80)	6.00*	(1.11–32.51)	4.00	(0.70–22.71)
	14 years	56	42.90	35.70	12.50	8.90	19.05	0.0001*	0.34	Large	4.82*	(1.43–16.27)	4.01*	(1.17–13.72)	1.40	(0.36–5.51)
	15 years	60	50.00	35.00	6.70	8.30	32.13	0.0001*	0.42	Large	6.02*	(1.84–19.76)	4.22*	(1.26–14.16)	0.81	(0.18–3.60)
	16 years	55	36.40	27.30	21.80	14.50	5.63	0.131	0.18	Medium	2.51	(0.83–7.62)	1.88	(0.60–5.88)	1.50	(0.47–4.83)
Corrected Top 50% of swim times	13 years	244	33.60	27.90	17.60	20.90	15.02	0.002*	0.14	Small	1.61	(0.98–2.65)	1.33	(0.80–2.22)	0.84	(0.49–1.44)
	14 years	275	29.10	28.40	20.30	22.20	6.41	0.09	0.09	Small	1.31	(0.82–2.10)	1.28	(0.80–2.05)	0.91	(0.56–1.50)
	15 years	284	26.70	25.40	24.30	23.60	0.62	0.89	0.03	No	1.13	(0.71–1.80)	1.08	(0.67–1.72)	1.03	(0.64–1.65)
	16 years	270	27.40	26.70	24.40	21.50	2.30	0.51	0.05	No	1.27	(0.79–2.06)	1.24	(0.77–2.01)	1.13	(0.70–1.85)
Correct Top 25% of swim times	13 years	123	32.50	27.60	21.10	18.80	5.74	0.12	0.12	Small	1.73	(0.85–3.54)	1.47	(0.71–3.04)	1.12	(0.53–2.38)
	14 years	138	26.80	31.10	19.60	22.50	4.19	0.24	0.10	Small	1.19	(0.61–2.33)	1.38	(0.71–2.67)	0.87	(0.43–1.75)
	15 years	142	24.70	27.50	23.90	23.90	0.50	0.91	0.03	No	1.03	(0.53–2.00)	1.15	(0.60–2.21)	1.00	(0.51–1.95)
	16 years	135	23.70	23.70	22.20	30.40	2.18	0.53	0.07	Small	0.78	(0.40–1.51)	0.78	(0.40–1.51)	0.73	(0.37–1.43)
Corrected Top 10% of swim times	13 years	50	26.00	22.00	30.00	22.00	0.88	0.83	0.08	Small	1.18	(0.38–3.63)	1.00	(0.32–3.15)	1.36	(0.45–4.12)
	14 years	56	21.40	33.90	16.10	28.60	4.13	0.24	0.16	Small	0.75	(0.26–2.15)	1.19	(0.44–3.21)	0.56	(0.19–1.69)
	15 years	58	22.40	31.00	22.50	24.10	1.16	0.76	0.08	Small	0.93	(0.33–2.65)	1.29	(0.47–3.53)	0.93	(0.33–2.66)
	16 years	55	30.90	21.80	21.80	25.50	1.22	0.74	0.09	Small	1.21	(0.43–3.39)	0.85	(0.29–2.50)	0.85	(0.29–2.50)

Tables Notes: Q1–Q4 = Quartile 1–4; Q1–Q4% = Relative age quartile (3 months combined) percentage of total number; χ^2 = Chi-Square value; *P* = Probability value; *V* = Cramer's *V* effect size; *ES cat.* = Effect size category; OR = Odds Ratio comparison; 95%CI = 95% Confidence intervals for quartile comparisons.

* Significance $p < 0.05$.

This permitted examination of whether RAE effect sizes changed according to selection level.

Finally, to test whether corrective adjustments could remove RAEs across age-groups (13–16) and according to performance level (i.e., 'Top 50%', '25%' and '10%'), all raw performance times were adjusted using expected within annual-age performance differences generated from the quadratic estimates described in *Part 1*. Thus, individual performance times registered at a given decimal age were adjusted based on the expected longitudinal trend line identified in *Part 1* to the relatively oldest decimal age within each age-group. For example, for two males in the 13 years age-group, one turning 13 years old on the first day of eligibility (i.e., 13.00) and the second who was 13.99 years on the day of competition, had their 100 m Freestyle times reduced by −3.50 s and 0.00 s respectively. The distribution of who made the 'Top 50%', '25%' and '10%' of performance times within each annual age group (13–16 years) were then re-examined using similar analytical steps.

Data-analysis. To examine and compare relative age distributions for 'All' swimmers, quartile distributions of 'Raw Top 50%–Top 10%' and the distributions of the 'Correctively Adjusted Top 50%–Top 10%' at each age-age group (13–16 years), chi-square tests (X^2) were applied with p set at 0.05. Post-hoc Cramer's V determined the magnitude of effect size between frequency count distributions, while Odds Ratios (ORs) provided more specific relative age quartile comparisons. For $df = 3$ which is the case for all comparisons of relative age quartiles, $0.06 < V \leq 0.17$ indicated a 'small effect'; $0.17 < V < 0.29$ a 'medium effect'; and, $V \geq 0.29$ a large effect.[30] Odds Ratios and matching 95% Confidence Intervals (CI) estimated effect sizes of specific comparisons (e.g., Q1 v Q4) with Q4 acting as the referent group.

3. Results

3.1. Part 1

Fig. 1 illustrates the curvilinear (quadratic) relationship between decimal age (i.e., including chronological and relative age) and 100 m Freestyle swimming performance. Decimal age significantly predicted 100 m Freestyle performance, $F(1, 455.16) = 2125.9$, $p < 0.001$. The final fixed and random effects model showed decimal age had a significant negative linear and positive quadratic relationship with performance time. Estimates of the relationship included intercept, linear and quadratic components. The quadratic relationship showed significant variance in intercepts ($\text{Var}(u_{0j}) = 0.91$, $X^2(1) = 1470.35$, $p < 0.001$) and slopes ($\text{Var}(u_{1j}) = 0.28$, $X^2(2) = 115.86$, $p < 0.001$) across individuals compared with fixed effects only. In addition, the slopes and intercepts negatively and significantly covaried ($\text{Cov}(u_{0j}, u_{oj}) = -0.33$, $X^2(3) = 1{,}228.86$, $p < 0.001$).

3.1.1. Part 2–Raw distributions

Table 1 summarises results from the analysis of relative age distributions for 'All' sampled swimmers within the 13–16 year-old age groups and according to applied selection criteria for the raw (unadjusted) swimming times. For 'All' the sample, a classical RAE was evident at 13 and 14 years of age with a medium and small effect size respectively. RAEs then dissipated by 15 and 16 years of age. However, when applying selection criteria on raw swimming times (i.e., 'Top 50%–10%'), RAEs extended into 15 years-old (e.g., Top 50% - $X^2 = 23.52$, $p = 0.001$; Q1 v Q4 OR = 2.28) and effect sizes became substantially increased with each selection level step. Medium-large RAE effect sizes were evident for 13–15 year-olds in the 'Top 25%' and 'Top 10%' of raw race times (e.g., 15 years - Top 25% $X^2 = 35.27$, $p = 0.001$; Q1 v Q4 OR = 4.10; Top 10% $X^2 = 32.13$, $p = 0.001$; Q1 v Q4 OR = 6.02). At 16 years-old only descriptive (non-significant) RAE patterns were observed in the Top 50%–10% of raw swimming times; though it should be acknowledged that sample sizes became smaller with selection level.

3.1.2. Correctively adjusted distributions

Following adjustment of 'All' individual performance times based on the longitudinal trendline equation and re-tabulation of relative age distributions, Table 1 summarises results according to 'Top 50%–10%' of performance times. Critically, bar only one exception (i.e., Top 50% 13 year olds), there was no general RAEs apparent (i.e., Q1 distribution > Q2–Q4) across the age groups and selection levels examined. Further, there was no significant odds ratio comparisons for any particular quartile distribution comparison, whether Q1 v Q2–Q4 or otherwise (e.g., Q2 v Q4) for any age or selection level. In other words, corrective adjustments lead to a return of normative (expected) relative age distributions (≈25% per quartile). Only for the 'Corrected Top 50%' 13 year-old group did a general significant RAE remain (Q1 = 33.6%–Q4 = 15.02%; $X^2 = 15.02$, $p = 0.002$; *ES* = small). To graphically summarise changes in relative age distributions according to 'Raw' and 'Correctively adjusted' swim times, see Supplementary Material 1 which illustrates data related to (a) 13 years and (b) 16 years of age.

4. Discussion

The purpose of this study was first to generate accurate estimates of the longitudinal relationship between decimal age (i.e., chronological and relative age) and 100 m Freestyle swimming performance. The second purpose was to determine whether corrective adjustments could effectively remove RAEs previously identified across and within youth swimming.[14] In the original corrective adjustment study with sprinters,[12] a linear regression equation based on cross-sectional data estimated expected performance changes; however such data may not necessarily have accurately estimated developmental changes over time. The present study addressed this concern by examining a large (>550) longitudinal dataset which contained ≥ five data-points from each swimmer, permitting a growth modelling analysis to estimate performance change over time. While acknowledging inter-individual swimmer variability in intercepts and slope characteristics for performance change over time, findings identified that an overall significant and consistent curvilinear (quadratic) trend was apparent. Performance times were estimated to generally reduce from approximately 78.5 s at 10 years-old to 55.5 s by 18 years (see Fig. 1). Curvilinear slope characteristics were then utilised to generate expected performance differences within chronological age-groups, permitting more equitable performance comparisons between swimmers who may have competed in the same event on a given day, but who differed in terms of decimal age by a range of 1 day to almost a year (0.99 years).

When examining the relative age distributions of 'All' swimmers sampled from state and national level 100 m Freestyle events aged 13–16, findings expectedly identified typical RAE prevalence. RAEs with medium effect sizes were evident at 100 m Freestyle events for swimmers aged 13 years. However, RAE magnitude also expectedly dissipated with age (e.g., 'small effects' at 15 year-old; 'no effects' at 16 years-old). Correspondingly, Q1 v Q4 odds ratio comparisons also reduced with age, reducing from OR = 2.22 at 13 years to 1.23 at 16 years. These findings directly align with prior swimming-related data which highlighted RAE transiency across similar aged males who participated in 50 m and 400 m Freestyle events at Australian national level championships over a fifteen year period.[14]

When simulated selection/qualification criteria were applied to the sampled swimming times, the benefit of being relatively older became evident when examining RAE distributions in the

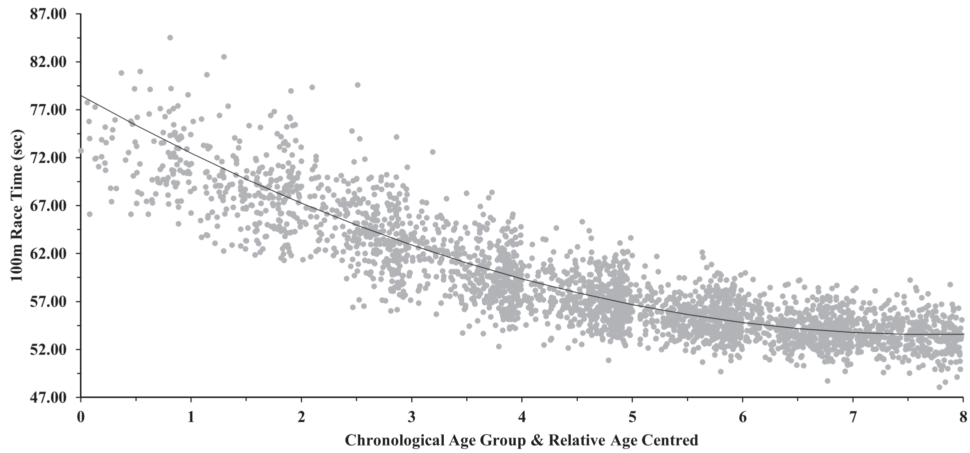

Fig. 1. Curvilinear relationship between chronological & relative age (centred 0–8 = 10–18 years respectively) and 100 m Freestyle swimming performance.

'Top 50%'–'Top 10%' for each age group. Each progressive selection criteria effectively magnified RAE bias. For instance in the 13 year-old 'Top 50%', Q1 v Q4 OR = 3.87; 'Top 25%' = 5.11; and in the 'Top 10%' = 14.00 (see also Supplementary Material 1). RAE magnification due to selection criteria was apparent for each age-group examined, albeit less substantial in terms of magnitude by 16 years of age. As there were only small samples in the 'Top 10%', this may account for why X^2 and OR comparisons were not significant and only descriptively apparent. Present findings are also consistent with previous trends observed in individual[12] and male team sport contexts[4] where being the relatively oldest and/or early maturing provide important, but potentially short-term, performance/selection benefits.[20,23,25]

Critical to this study, when corrective adjustments based on longitudinal curvilinear estimates were applied to all swimmers and the compositions of the "Top 50%"–'Top 10%' of swimming times at each age group were re-examined, RAE inequalities were removed irrespective of selection criteria and age-group (see Table 1; Supplementary Material 1). Given baseline RAEs and RAEs identified in raw (unadjusted) swim times, these findings highlight success in the application of corrective adjustment procedures. Only for the 'Corrected Top 50%' 13 year old group did a general RAE trend remain ($X^2 = 15.02$, $p = 0.002$; *ES* = small). This exception was likely due to the initial size of RAE bias in the original sample (e.g., see 'All' 13 years old), and so there was still more swimmers by proportion who would achieve applied selection criteria in correctively adjusted swim times.

As a method and based on study results, corrective adjustment procedures demonstrate the capability to more accurately compare between individuals based on their specific decimal age, swimming performance times, and given reference to a broader population dataset. If developed more extensively, consideration of relative age and maturation status would be beneficial as greater inter-individual variability resulting from growth and development could be considered. Likewise, onward development and testing will need to determine the validity and specificity (i.e., participant characteristics as well as stroke and distance variability demands) requirements for corrective adjustments. Practically, such information may better inform and assist swimmer performance evaluation, swimmer motivation as well as coach-athlete interaction particularly during occasions of competition dis-advantage. Determining the feasibility for how and when corrective adjustments can be applied in swimming, and whether positive outcomes can be attained (e.g., longer-term participation) are important future directions for young swimmers, practitioners (e.g., coaches) and swimming organisations alike.

5. Conclusion

Based on accurate longitudinal reference data summarising the relationship between decimal age (i.e., chronological and relative age), corrective adjustment procedures were able to remove RAEs from 100 m Freestyle swimming. Findings highlight the potential capability to remove relative age-related participation and performance inequalities from youth swimming events; improve youth swimming participation experiences; and, the potential for greater accuracy in performance evaluation.

Practical implications

- Swimming-associated sport systems and practitioners could potentially remove relative age-related participation and performance attainment inequalities at an individual-cohort level using corrective adjustment procedures.
- If practically utilised, corrective adjustment procedures in swimming need to be developed based on an accurate and substantial reference dataset matched in terms of participant sex as well as swim stroke and distance.
- Corrective adjustment procedures have the potential to improve youth swimming participation and competition experiences for swimmers disadvantaged by common annual-age grouping and standardised dates for competition.

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Appendix A. Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jsams.2018.12.013.

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