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Original research

Transient Relative Age Effects across annual age groups in National level Australian Swimming

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ABSTRACT

Objectives: To determine the prevalence, magnitude and transient patterning of Relative Age Effects (RAEs) according to sex and stroke event across all age-groups at the Australian National age swimming Championships.
Design: Repeated years of cross-sectional participation data were examined.
Methods: Participants were 6014 unique male (3185) and female (2829) swimmers (aged 12–18 years) who participated in Freestyle (50, 400 m) and/or Breaststroke (100, 200 m) at the National age swimming Championships between 2000–2014 (inclusive). RAE prevalence, magnitude and transience were determined using Chi-square tests and Cramer's *V* estimates for effect size. Odds Ratios (OR) and 95% Confidence Intervals (CI) examined relative age quartile discrepancies. These steps were applied across age-groups and according to sex and each stroke event.
Results: Consistent RAEs with large-medium effect sizes were evident for males at 12–15 years of age respectively, and with large-medium effects for females at 12–14 respectively across all four swimming strokes. RAE magnitude then consistently reduced with age across strokes (e.g., Q1 vs. Q4 OR range 16 year old males = 0.94–1.20; females = 0.68–1.41). With few exceptions, by 15–16 years RAEs had typically dissipated; and by 17–18 years, descriptive and significant inverse RAEs emerged, reflecting overrepresentation of relatively younger swimmers.
Conclusions: Performance advantages associated with relative age (and thereby likely growth and maturation) are transient. Greater consideration of transient performance and participation in athlete development systems is necessary. This may include revising the emphasis of sport programmes according to developmental stages and delaying forms of athlete selection to improve validity.

1. Introduction

Across many youth sports contexts, the procedure of (bi-)annual age-grouping is implemented for logical organisation purposes and to reduce developmental differences between competitors on the basis of safety and equity.[1,2] However in athlete development terms, annual age-grouping still permits the potential for up to 12 months of chronological age difference and potentially greater biological age difference during years associated with maturation.[3] As a consequence, Relative Age Effects (RAEs[4]) can emerge; reflecting outcomes from an interaction between participants' birth dates and the dates used for chronological age grouping.[5] Being relatively older within an age grouping is associated with consistent attainment and selection advantages across junior and representative stages of sport, including an increased likelihood of selection to access further resources within athlete development systems, such as coaching expertise; skill development programmes; and, physical conditioning support.[1,3,6]

RAEs are most prevalent and with the highest effect sizes in male team sports contexts. By comparison, sport and age-matched female contexts have shown either lower RAE effect sizes or have been less prevalent; though fewer samples have been examined.[1,7] At various male junior and youth tiers (i.e., school, local community, representative and international) of soccer,[8,9] baseball,[10]

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handball,[11] rugby[6] and Australian rules football,[12] 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). Higher magnitude RAEs are associated with selective representative contexts at ages associated with puberty and maturation.[13] More recently, studies have identified that individual but still physically demanding sports are also associated with RAEs, notably including athletic sprinting,[5] tennis,[14] ski-jumping, cross-country and alpine skiing.[15,16] By comparison, sports with less dependence on physical characteristics and which have a technical skill emphasis have not been associated with RAEs (e.g., golf & shooting).[17]

Several hypotheses have been proposed to account for RAEs,[3,18] though most supported by evidence is the 'maturation-selection hypothesis'.[1,19,20] The hypothesis states that greater chronological age is equated with an increased likelihood of enhanced anthropometric characteristics from normative growth. Greater height and lean body mass (to a degree) are predictive of better physical capacities such as aerobic power, muscular strength, endurance and speed.[21] In turn, these provide physical performance advantages in specific tasks.[22] Also, during puberty, the timing and tempo of physical development generate further anthropometric and physical variation between individuals until its cessation.[23] Unfortunately for the relatively younger or later maturing, these processes lead to shorter-term disadvantages where they are more likely to be overlooked and excluded[24] at various stages of junior and youth sport, at least until the end of growth and maturation.

In the longer-term, recent studies suggest RAE and maturation inequalities may be transient on athlete development. Based on examining Candian ice-hockey players entering the professional NHL draft (aged 18–20), Deaner et al.,[25] initially identified a typical RAE with 36% and 14.5% being relatively older and younger respectively. However, the relatively younger actually went on to play in 20% of all NHL games played by the sample and were twice as likely to attain career benchmarks (i.e., 400–600+ games played). The relatively older were less likely to play a single NHL game and underperformed given their draft overrepresentation. Similarly, in UK Rugby League, the likelihood of attaining a professional contract at 18+ years old was associated with being relatively younger and later maturing. In their longitudinally data, it was identified that by 15–16+ years old later maturing players 'caught-up' with their early maturing counterparts on performance measures[26–28] illustrating transient patterns. That said, evidence of these transient patterns is still limited and explanatory mechanisms remain speculative. Thus, identifying RAE transiency is significant with important implications for sport systems, their practitioners and athletes.

As an individual sport context with high physiological demands, competitive swimming has received limited RAE examination,[29,30] yet RAE prevalence can be hypothesised. Relative age and maturation relate to physical (e.g., VO_2max; upper and lower body strength) and anthropometric (e.g., height, lean mass) development and these characteristics predict performance.[23,31] The influence of relative age and maturation on performance can also be isolated as other extraneous or confounding inter-athlete factors are not present (e.g., coach selection, team interaction).[12,25] Further at many swimming events, there are often sex-specific age-groups spanning junior and youth ages (e.g. 12–18 years old), divided according to stroke (e.g., freestyle; breaststroke) and distances (50 m & 400 m). Therefore, whilst recognising performance requirements in these events, an examination of transient RAE participation patterns is feasible.

In Australia, swimming is culturally iconic and one of the most popular individual sporting and leisure activities. Twenty-eight–thirty percent of all children and 14–16% of all adults are estimated to participate at some level.[32] Swimming Australia (the National sporting organisation) contains nearly 1000 swimming clubs and 90,000 registered members[33] reflecting participation from grassroots community to the elite National team. Connecting participation to competition, Swimming Australia has a junior and youth competition structure spanning states and territories reflecting regional or state level competition. The culmination and pinnacle of junior competition are the National age Championships. It is in this latter context that the current study resides. Based on a substantial data-set tracking 14 years of participation at the National age Championships, the purpose of this study was to determine the prevalence, magnitude and transient patterning of RAEs according to sex and four stroke events (i.e., Freestyle — 50 m & 400 m; Breastroke — 100 m & 200 m) within and across Australian Swimming age-group competition. If RAE patterns were identified, we rationalised findings held potentially significant and wide-ranging implications for Swimming Australia and their athlete development system.

2. Methods

Following institutional ethical approval, participants were N = 6014 unique male (n = 3185) and female (n = 2829) male and female swimmers (aged 12–18 years). These swimmers had competed in either specific or multiple swimming stroke events at the Australian National age Championships between 2000–2014 (inclusive). Multiple years of cross-sectional data were examined to increase participant numbers in the sampling frame and to capture an accurate representative account of participation trends over time. To participate at the championships, swimmers have to be 12–18 years old, and whether competing in 'heats' only or 'finals' for a given stroke and distance, participation reflected the fastest qualification times in Australia for a given year. Respective age-groups were determined by the swimmer's age on the first day of the annual championship event, with cut-off dates marginally changing each year (often early April). For example, in the year 2000 the cut-off date was 10th April while in 2014 it was 14th April.

In this study, data pertaining to Freestyle (50 m & 400 m) and Breaststroke (100 m & 200 m) were examined to reflect a sampling frame acknowledging between stroke and within stroke factors. Freestyle was sampled as it is considered to be the fastest of the four strokes, while Breaststroke is regarded as the slowest.[34,35] Due to mechanical and drag differences associated with these strokes,[36] they are also associated with different energetic requirements[37] and which interact with distance. Thus, two different distances for each stroke were examined. However, as we wanted to examine RAE trends across males and female and across multiple years of annual Championships, constraints related to stroke distances sampled were apparent. As the National Age Championships mimics the Olympic event schedule, the 50 m and 400 m Freestyle reflected the shortest and longest distances where both sexes participated and permitted an assessment as to whether physiological factors attenuated RAE trends. However, equivalent distances in Breaststroke were not available, and the 100 m and 200 m were the only events available. That said, these sampled stroke events did reflect the most competitive (i.e., higher participation numbers) in the Championship schedule and were considered informative for athlete evaluation and selection purposes.

In collaboration with Swimming Australia, participation data associated with the National age Championships was retrieved from two secure databases (i.e., 'Team Manager' and 'Event Manager') by two employees. Data was then systematically screened for data entry errors, with multiple identified and corrected. Data entry accuracy was also randomly checked with coaches and former participating athletes. Screening checked that only one participant

entry was permitted for a given stroke and distance per year. In other words, multiple registering for heats and a final in one stroke and distance were removed. If a participant competed in another stroke, distance or year of the Championship the entry remained as strokes were examined independently. An anonymised dataset containing only swimmer date of birth, sex, year of Championship event, date applied for annual age group cut-offs, age-group, swimming stroke and distance, date of performance and performance time was then transferred for further analysis.

To confirm RAEs were not associated with broader population birth patterns, the number and distribution of births in the Australian population were examined. Monthly live birth data was accessed from the Australian Bureau of Statistics.[38] Mean monthly birth rates in Australia from 1981–2001, coinciding with the month and birth years of swimmers, were extracted. Considering the specific and marginally altering annual dates used for age-group cut-offs at the age Championships (i.e., early April), wider population birth distributions were grouped from April 1st into quartiles. Across the sampling period, 5,253,444 live births occurred and were evenly distributed (i.e., Q1: April–Jun = 24.89%; Q2: July–Sept = 25.02%; Q3: Oct–Dec = 25.56%; Q4: Jan–Mar = 24.53%, $w = 0.01$). For data analysis purposes, the finding suggests that a theoretically equal distribution of participants could be expected. Secondly, if RAEs were identified, they were unlikely to be associated with broader population trends and more likely associated with processes within the swimming system.

For both male and females in age-groups (i.e., 12–18 years) and according to each of the four identified strokes examined, Chi-square tests were initially deployed across relative age quartiles (i.e., Q1–Q4) to determine differences between observed and normatively expected distributions. Post hoc tests, using Cramer's V, identified the magnitude of effect size between Q1 and Q4 frequency counts. Magnitude estimates ranging between $0.06 < V \leq 0.17$ were used to indicate a small effect size, $0.17 < V < 0.29$ a medium effect, and, $V \geq 0.29$ a large effect size.[39] In addition, Odds Ratios (OR) and matching 95% Confidence Intervals (CI) between quartiles (i.e., Q1 vs. Q4; Q2 vs. Q4; Q3 vs. Q4) provided a common risk indicator of effect size. OR estimates and accompanying CI's >1 identified an odds increase in favour of Q1, while OR's and CI's below 0 indicated a risk reduction with Q4's more likely to be participating. Q4 swimmers were used as the referent group in all quartile comparisons.

3. Results

Table 1 summarises relative age (quartile) distributions, Chi-square, effect size estimation and categorization, as well as Odds Ratio analyses for male participants according to stroke, distance and age-group. Results identified that regardless of event examined, RAEs were particularly prevalent in the 12–14 years old age groups with large-medium effect sizes respectively. Across strokes, Q1 vs. Q4 OR's identified that at 12 years old, the relatively older were between 8.00–23.50 times more likely to participate than the relatively younger. Thereafter, while RAEs remained, they reduced in effect size with age across strokes and distances (i.e., 13 years old — Q1 vs. Q4 OR range = 2.05–2.92; 14 years = 1.77–2.29). By 15 (200 m Breaststroke) or 16 years (400 m Freestyle & 100 m Freestyle) and often around the peak of participant numbers at the Championships, RAE related inequalities dissipated (except for 50 m Freestyle where typical RAEs remained). Of particular note however, by 17–18 years of age descriptive inverse RAE patterns had emerged (e.g., see 400 m Freestyle — Q4 > Q1). Supplementary material 1a & b and 2a & b provides a visual summary of RAEs transiency across age-groups in male Freestyle (50 m and 400 m) and Breaststroke (100m & 200 m) respectively.

Table 2 summarises data related to female participants according to stroke, distance and age-group. Results identified that typical RAEs were prevalent in the 12–13 years old age groups with large-medium effect sizes respectively. In 50 m Freestyle, significant RAE discrepancies remained until 15 years of age. Specific OR comparisons were also in alignment, identifying regardless of stroke OR's between 4.00–9.00 in Q1 vs. Q4 comparisons at 12 years old, reducing linearly to approximately 1.10–1.39 by 14 years of age. By 15 years of age typical RAEs either had small effect sizes (50 m Freestyle), had dissipated (e.g., 100 m & 200 m Breaststroke) or descriptive inverse RAE patterns had emerged (400 m Freestyle). At 16 and 17 stroke specific trends emerged, though distributions all progressively moved toward favouring the relatively younger (e.g., 200 m Breaststroke). By 17 and 18 in the 400 m Freestyle, significant inverse RAE patterns were evident with small-medium effect sizes. Q1 vs. Q4 comparisons identified the relatively older as potentially being 68% less likely to compete in the 18-year-old 400 m Freestyle (95% CI 0.11–0.92). Transiency toward overrepresentation in relatively younger swimmers was also supported by significant trends in Breaststroke (100 m and 200m) at 18 years of age. Fig. 1a & b provides visual summary of transient RAEs across age-groups in female Freestyle (50 m and 400 m), while Supplementary material 3a & b graphically summarises data related to Breaststroke (100 m & 200 m).

4. Discussion

The purpose of the present study was to determine the prevalence, magnitude and transient patterning of RAEs across Australian National level age-group competition according to sex and stroke (distance). Findings identified that regardless of swimming stroke examined, consistent RAEs with large-medium effect sizes were apparent for males at 12–15 years of age, and with large-medium effects for females at 12–14. Again irrespective of stroke and distance, RAE magnitude then consistently and progressively reduced with age-group (Q1 vs. Q4 OR range — 14-year-old male = 1.77–2.29; female =1.10–1.39) so that by 15–16 years (with a few notable exceptions) RAEs were typically absent or minimal. However, by 17–18 years, descriptive and significant inverse RAEs had emerged, reflecting over representations of relatively younger swimmers in National level swimming and at a time point close to senior (adult) competition transition.

Efficacy for present findings is reinforced by the examination of 14 years of annual competition participation data at all age-groups of the National age Championships. From within the dataset, Freestyle (50 m & 400m) and Breaststroke (100 m & 200 m) events were sampled, and a standard analytical approach applied to aid comprehensive analysis. Present findings add to existing literature in several ways. They highlight (i) how RAE effect sizes in earlier age groups are transient, reducing and potentially reversing at later age stages; (ii) examine RAE prevalence in an under-examined individual sport context; and (iii) identify similar RAE prevalence and magnitudes in female swimming events, adding to limited data available related to female sport contexts.[1]

Present findings also indirectly support the 'maturation-selection hypothesis'[1,19,20] of RAEs. Historically speaking, swimming has been synonymous with 'earlier age' athlete development programmes, 'early specialisation' practices (e.g., high intensive training loads) and tiers of selection and representation during ages associated with growth and maturation (males 12–15; females 11–14).[13] On this basis, it perhaps less surprising that the relatively older and/or 'early maturing' have benefitted from anthropometric and physical advantages underpinning performance, accounting for their over-representation in corresponding age-groups. Support is also gained from the consistency in transient patterns between

Table 1
Distribution, Chi-square and Odds Ratio analysis of male participants at the National Swimming Championships (2000–2014 inclusive) according to stroke, stroke distance, annual age-group and quartile.

Stroke	Age-group	Total *N*	Q1%	Q2%	Q3%	Q4%	X^2	*P*	*V*	*ES cat.*	OR Q1 vs. Q4	(95%CI)	OR Q2 vs. Q4	(95%CI)	OR Q3 vs. Q4	(95%CI)
50 m Freestyle	12 years old	81	0.59	0.22	0.11	0.07	54.56	0.000*	0.47	Large	8.00*	2.80–22.83	3.00*	1.01–9.11	1.50	0.45–4.99
	13 years old	621	0.43	0.26	0.17	0.15	123.39	0.000*	0.26	Medium	2.92*	2.11–4.05	1.77*	1.26–2.49	1.13	0.79–1.62
	14 years old	787	0.39	0.26	0.18	0.17	93.70	0.000*	0.20	Medium	2.29*	1.72–3.04	1.55*	1.15–2.08	1.08	0.80–1.47
	15 years old	715	0.35	0.25	0.20	0.20	43.98	0.000*	0.14	Small	1.73*	1.29–2.32	1.23	0.91–1.67	0.97	0.71–1.32
	16 years old	708	0.31	0.24	0.19	0.26	19.18	0.000*	0.10	Small	1.20	0.90–1.60	0.96	0.71–1.28	0.75	0.55–1.02
	17 years old	279	0.29	0.24	0.17	0.29	11.19	0.011*	0.12	Small	1.00	0.64–1.57	0.82	0.51–1.30	0.59	0.36–0.95
	18 years old	268	0.27	0.22	0.22	0.29	4.12	0.249	0.07	Small	0.92	0.58–1.47	0.77	0.48–1.24	0.74	0.46–1.20
400 m Freestyle	12 years old	40	0.60	0.28	0.08	0.05	31.00	0.000*	0.51	large	12.00*	2.22–64.90	5.50	0.96–31.43	1.50	0.20–11.00
	13 years old	269	0.37	0.32	0.16	0.15	40.90	0.000*	0.23	Medium	2.44*	1.48–4.01	2.10*	1.27–3.47	1.02	0.59–1.77
	14 years old	339	0.37	0.32	0.15	0.17	49.50	0.000*	0.22	Medium	2.23*	1.44–3.45	1.93*	1.24–3.00	0.89	0.55–1.45
	15 years old	345	0.32	0.26	0.21	0.21	9.86	0.020*	0.10	Small	1.47	0.97–2.24	1.20	0.78–1.85	0.99	0.64–1.53
	16 years old	325	0.29	0.26	0.19	0.25	6.61	0.086	0.08	Small	1.16	0.76–1.77	1.04	0.67–1.60	0.77	0.49–1.20
	17 years old	124	0.24	0.30	0.16	0.30	6.26	0.100	0.13	Small	0.81	0.41–1.62	1.00	0.51–1.96	0.54	0.26–1.13
	18 years old	113	0.23	0.22	0.19	0.36	8.17	0.043*,[a]	0.16	Small	0.63	0.31–1.30	0.61	0.30–1.25	0.51	0.24–1.07
100 m Breaststroke	12 years old	70	0.67	0.23	0.07	0.03	72.51	0.000*	0.59	large	23.50*	4.93–112.12	8.00*	1.60–40.12	2.50	0.43–14.66
	13 years old	460	0.38	0.28	0.18	0.16	53.97	0.000*	0.20	Medium	2.35*	1.62–3.42	1.72*	1.17–2.52	1.15	0.77–1.72
	14 years old	531	0.34	0.28	0.17	0.17	47.52	0.000*	0.17	Medium	2.00*	1.41–2.83	1.64*	1.15–2.33	1.00	0.69–1.46
	15 years old	546	0.30	0.26	0.21	0.22	11.93	0.008*	0.09	Small	1.37	0.98–1.91	1.19	0.85–1.67	0.95	0.67–1.35
	16 years old	514	0.27	0.23	0.22	0.28	6.39	0.094	0.06	Small	0.97	0.69–1.35	0.81	0.58–1.15	0.77	0.54–1.08
	17 years old	227	0.29	0.25	0.20	0.26	3.43	0.330	0.07	Small	1.08	0.65–1.80	0.93	0.56–1.57	0.77	0.45–1.31
	18 years old	175	0.23	0.21	0.23	0.33	5.73	0.125	0.10	Small	0.72	0.40–1.29	0.63	0.35–1.14	0.72	0.40–1.29
200 m Breaststroke	12 years old	45	0.71	0.18	0.07	0.04	52.87	0.000*	0.63	large	16.00*	3.07–83.34	4.00	0.69–23.16	1.50	0.21–10.77
	13 years old	375	0.35	0.29	0.18	0.17	33.95	0.000*	0.17	Medium	2.05*	1.35–3.09	1.66*	1.09–2.53	1.06	0.68–1.65
	14 years old	419	0.32	0.31	0.20	0.18	26.62	0.000*	0.15	Small	1.77*	1.20–2.62	1.72*	1.16–2.55	1.09	0.72–1.65
	15 years old	438	0.29	0.27	0.21	0.23	7.28	0.064	0.07	Small	1.29	0.89–1.88	1.19	0.82–1.74	0.94	0.64–1.38
	16 years old	407	0.27	0.25	0.21	0.28	5.24	0.155	0.07	Small	0.94	0.64–1.37	0.87	0.59–1.28	0.73	0.49–1.08
	17 years old	186	0.30	0.22	0.24	0.25	2.60	0.457	0.07	Small	1.17	0.67–2.05	0.85	0.47–1.53	0.94	0.53–1.67
	18 years old	129	0.26	0.23	0.20	0.31	3.25	0.355	0.09	Small	0.83	0.42–1.61	0.75	0.38–1.48	0.65	0.32–1.30

Notes: Q1–Q4 = Quartile 1–4; Q1–Q4% = Quartile 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; 95%CI = 95% Confidence Intervals.

* Significance $p < 0.05$.

[a] Inverse RAEs (Q4 > Q1).

Table 2
Distribution, Chi-square and Odds Ratio analysis of female participants at the National Swimming Championships (2000–2014 inclusive) according to stroke, stroke distance, annual age-group and quartile.

Stroke	Age-group	Total *N*	Q1%	Q2%	Q3%	Q4%	X^2	*P*	*V*	*ES cat.*	OR Q1 vs. Q4	(95%CI)	OR Q2 vs. Q4	(95%CI)	OR Q3 vs. Q4	(95%CI)
50 m Freestyle	12 years old	163	0.43	0.29	0.18	0.10	39.18	0.000*	0.28	Medium	4.12	2.08–8.17*	2.76	1.37–5.59*	1.71	0.81–3.57
	13 years old	628	0.37	0.29	0.16	0.18	72.14	0.000*	0.20	Medium	2.02	1.47–2.77*	1.62	1.18–2.24*	0.87	0.61–1.23
	14 years old	802	0.30	0.30	0.19	0.21	28.55	0.000*	0.11	Small	1.39	1.06–1.84*	1.41	1.07–1.86*	0.92	0.68–1.23
	15 years old	723	0.27	0.28	0.20	0.25	12.12	0.007*	0.07	Small	1.07	0.80–1.43	1.10	0.83–1.47	0.78	0.57–1.05
	16 years old	639	0.24	0.26	0.23	0.27	2.52	0.471	0.04	no	0.89	0.66–1.22	0.98	0.72–1.33	0.86	0.63–1.17
	17 years old	332	0.22	0.27	0.23	0.28	3.54	0.315	0.06	no	0.79	0.51–1.22	0.99	0.65–1.51	0.83	0.54–1.27
	18 years old	177	0.21	0.24	0.24	0.31	3.72	0.293	0.08	Small	0.69	0.38–1.24	0.76	0.43–1.36	0.76	0.43–1.36
400 m Freestyle	12 years old	40	0.45	0.30	0.18	0.08	12.60	0.006*	0.32	large	6.00	1.33–27.00*	4.00	0.86–18.64	2.33	0.47–11.69
	13 years old	260	0.35	0.31	0.15	0.19	27.42	0.000*	0.19	Medium	1.86	1.14–3.03*	1.63	1.00–2.68*	0.82	0.48–1.40
	14 years old	294	0.27	0.29	0.21	0.24	3.99	0.263	0.07	Small	1.10	0.70–1.73	1.18	0.75–1.86	0.86	0.54–1.38
	15 years old	348	0.22	0.27	0.20	0.32	12.62	0.006*,a	0.11	Small	0.68	0.45–1.04	0.86	0.58–1.29	0.62	0.40–0.94a
	16 years old	287	0.20	0.29	0.22	0.29	8.54	0.036*,a	0.10	Small	0.68	0.42–1.08	1.00	0.64–1.56	0.74	0.46–1.17
	17 years old	136	0.20	0.29	0.16	0.35	11.71	0.008*,a	0.17	Small	0.57	0.29–1.12	0.85	0.45–1.61	0.47	0.23–0.94a
	18 years old	64	0.13	0.25	0.23	0.39	9.13	0.028*,a	0.22	Medium	0.32	0.11–0.92a	0.64	0.25–1.63	0.60	0.23–1.54
100 m Breaststroke	12 years old	132	0.47	0.30	0.16	0.08	46.97	0.000*	0.34	large	6.20	2.72–14.13*	3.90	1.67–9.09*	2.10	0.86–5.14
	13 years old	405	0.34	0.32	0.19	0.16	39.69	0.000*	0.18	Medium	2.14	1.43–3.21*	2.00	1.33–3.01*	1.19	0.77–1.83
	14 years old	541	0.30	0.28	0.19	0.23	15.86	0.001*	0.10	Small	1.30	0.93–1.81	1.23	0.88–1.73	0.83	0.58–1.18
	15 years old	535	0.25	0.26	0.23	0.26	1.44	0.696	0.03	no	0.97	0.69–1.36	0.98	0.70–1.37	0.87	0.62–1.23
	16 years old	559	0.35	0.21	0.19	0.25	35.98	0.000*	0.15	Small	1.41	1.01–1.97*	0.84	0.59–1.20	0.74	0.53–1.05
	17 years old	239	0.24	0.23	0.24	0.29	1.92	0.589	0.05	no	0.83	0.50–1.36	0.81	0.49–1.34	0.83	0.50–1.36
	18 years old	87	0.22	0.28	0.14	0.37	9.78	0.021*,a	0.19	Medium	0.59	0.26–1.35	0.75	0.34–1.66	0.38	0.15–0.91a
200 m Breaststroke	12 years old	95	0.47	0.36	0.12	0.05	45.08	0.000*	0.40	large	9.00	3.04–26.63*	6.80	2.27–20.38*	2.20	0.66–7.31
	13 years old	313	0.37	0.31	0.18	0.14	45.58	0.000*	0.22	Medium	2.66	1.67–4.24*	2.20	1.37–3.54*	1.25	0.75–2.07
	14 years old	420	0.30	0.28	0.21	0.21	9.54	0.023*	0.09	Small	1.39	0.95–2.04	1.29	0.88–1.90	0.99	0.66–1.47
	15 years old	429	0.24	0.24	0.24	0.27	1.24	0.744	0.03	no	0.90	0.62–1.31	0.90	0.62–1.31	0.87	0.60–1.27
	16 years old	374	0.23	0.26	0.21	0.30	6.86	0.077	0.08	Small	0.75	0.50–1.12	0.85	0.57–1.26	0.71	0.47–1.06
	17 years old	187	0.20	0.27	0.22	0.31	5.45	0.142	0.10	Small	0.64	0.36–1.14	0.86	0.50–1.50	0.72	0.41–1.28
	18 years old	67	0.30	0.24	0.12	0.34	7.57	0.05*,a	0.19	Medium	0.87	0.35–2.15	0.70	0.27–1.76	0.35	0.12–1.01

Notes: Q1–Q4 = Quartile 1–4; Q1–Q4% = Quartile 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; 95%CI = 95% Confidence Intervals.

* Significance $p < 0.05$.

a Inverse RAEs (Q4 > Q1).

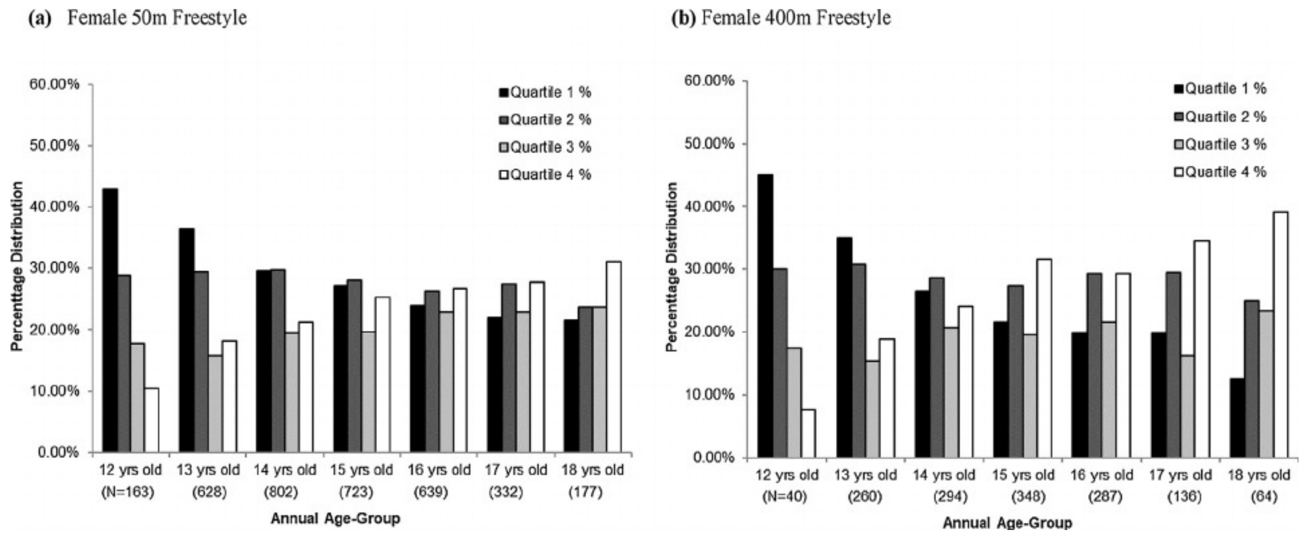

Fig. 1. (a & b) A graphical summary of female participants competing in the 50 m (a) & 400 m (b) Freestyle at the National Swimming Championships (2000–2014 inclusive) according to annual age group and quartile.

males and females. As maturation occurs chronologically earlier in females, transient RAEs did appear to initiate and reverse earlier than males (i.e., 1 year); and inverse RAEs observed in females appear more sustained and advanced at 17–18 years. The exception relates to 50 m Freestyle where physical strength and power demands may still associate with relative age and/or earlier maturing advantages.

Present findings support recent studies highlighting how relatively younger and later maturing athletes actually may be more likely to go onto to attain senior adult success. The dissipation of RAEs and emergence of over representations of the relatively younger toward the latter years of junior age Championships (i.e., 17–18 years of age) coheres with studies examining who attained professional contracts beyond 18 years of age[27,28] and who experienced relatively more career success beyond draft selections.[25] While the exact processes and mechanisms accounting for these changes remain speculative, we suspect that multiple interacting factors are involved. Adhering to the maturation-selection hypothesis, the equalisingof RAEs at 15–16 years aligns with attainment (or passing) of peak height velocity in maturation as well as increased anthropometric and physical development in the later maturing. Anthropometric and physical disadvantages in the relatively younger, possibly offset by high technical competency, may be nullified (or overtaken) leading to performance advantages at later time points. In parallel, psychological perceptions and beliefs may change. Growing competence and confidence may occur with biological transiency; while similar constructs may be undermined in the relatively older and/or early maturing, due to comparatively lesser performance development over a similar time period. Whatever the processes involved, (ir)rational biases in coaching selection were notresponsible[25] in this context, as participation at the Championships was determined by individual performance qualification times.

Finally, in addition to transient RAEs patterns, transient participation patterns were also apparent at the Championships. Whilst acknowledging that small performance variations (and many other factors; e.g., injury) can account for (non-)participation at the national age-championships, our data highlighted that regardless of sex in a given stroke event, the composition of relative age groups (Q1 & Q4) also changed with age-group. Put another way and to exemplify, of the relatively older or younger swimmers present at a Championship at 13 years old, only 50–60% participated at the same event the following year. These figures then linearly diminished each year to 5–8% four years later. Correspondingly, of those participating at 18 years of age, 60–70% participated the previous year, reducing to 12–26% four years earlier. From a sport system and athlete development perspective, these observations further question the significance of earlier age-groups particularly when confounded by growth and maturation, and their potential relationship with detrimental outcomes (e.g., dropout and sport withdrawal). Findings point toward greater relevance of later age-groups with closer proximity to senior adult transition. Considered together, transient RAEs and transient participation in National level junior swimmers highlight several implications for sport systems, athlete development programmes and their practitioners.

5. Conclusion

As highlighted by RAEs across and within junior age swimming, performance advantages from relative age and thereby growth and potentially maturation are transient. Regardless of sex or stroke (and distance) examined, typical RAEs were highly prevalent with large-medium effects sizes in earlier age-groups (e.g., 12–14 years old). RAE magnitude reduced with age group, and predominantly were diminished by 16 years of age. By 17–18 years of age descriptive and significant inverse RAEs were apparent. Greater consideration of RAEs as well as growth and maturation is necessary to minimise their impact on participation and athlete development systems.

Practical implications

- The influence of relative age in representative swimming is transient. While relatively older are more likely to achieve National swimming qualification standards and participate in National Championships in junior developmental years, the relatively younger are equally or more likely to attain similar outcomes after 16 years of age.
- Athlete development systems, youth competition structures and models of coaching in swimming (and other sport contexts) need to consider and account for the relatively younger and later development trajectories of youth athletes.
- To help remove RAEs and prevent growth and development from influencing local-National level participation sports organizations are encouraged to revise the purpose and emphasis of their programmes according to developmental stages; consid-

ering strategies to delay athlete selection and differentiation to improve validity.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jsams.2017.12.008.

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