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Relative age effect in male and female elite international amateur boxing

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ABSTRACT
This study aimed to determine whether the Relative Age Effect (RAE) was present in different sexes and age categories in 12 elite-level international amateur boxing competitions. A total of 4813 athletes competing between 2013 and 2022 were analysed. Athletes were split into four quartiles according to their birth date and compared to the expected (equal) birth date distribution using chi-squared goodness of fit. The results revealed greater RAE prevalence in youth compared to the senior group. RAE was more prominent in males compared to females, with the female group showing an inverse RAE trend. Odds ratio (OR) showed an overrepresentation of male boxers born in Q1 compared to Q4 (OR > 1.19-1.33), while senior female boxers presented an inverse trend (OR < 0.95). Odds Ratios for medallists within the youth group were greater than 1.07 (except Q3 × Q4 = 0.93) highlighting an overrepresentation of boxers born earlier in the year. A shift in strategy to reduce the RAE in young boxers whereby coaches focus less on the short-term pursuit of sporting success is encouraged. Organisations and coaches should increase awareness and provide systematic education around RAE, whilst creating equal competitive opportunities for all young boxers to reduce the extent of RAE in boxing.

Introduction

Age grouping is a commonly employed practice in youth sports, aimed at minimising developmental discrepancies (Cobley et al., 2009). The main objective is to ensure equal competition for all involved; however, the approach can lead to considerable age gaps (up to 12 months) between children belonging to the same annual age category (Musch & Grondin, 2001). For example, considering a cut-off date of 1 January (the most common cut-off date in major youth sports competitions worldwide), a child born on that day would be placed in the same sporting group as children born on 31 December (Delorme et al., 2011). Consequently, this child may possess a mental and physical development advantage compared to other children in the same age bracket. The imbalance of birth dates as a distribution where there is a significant dominance of older athletes compared to the ones born later in the year is referred to as the Relative Age Effect (RAE; Barnsley & Thompson, 1988).

Within the past 30 years, the number of RAE studies in sport has increased demonstrating the presence in both team (Costa et al., 2009; Cote et al., 2006; Delorme & Raspaud, 2009; Delorme et al., 2009; Oliveira et al., 2017; Romann & Fuchslocher, 2013, 2014; Schorer et al., 2009) and individual sports (Albuquerque et al., 2014; Bjerke et al., 2017; Delorme & Raspaud, 2009; Edgar & O'Donoghue, 2005; Fukuda et al., 2023; Medic et al., 2009; Romann & Fuchslocher, 2014). Furthermore, Cobley et al. (2009) collated 38 studies from 1984 to 2007 across 14 sports and 16 countries indicating a consistent presence of RAE (i.e., quartile 1 [Q1] = 31.2%; quartile 2 [Q2] = 26.1%; quartile 3 [Q3] = 22.3%; quartile 4 [Q4] = 20.6%). A more recent meta-analysis by Babić et al. (2022) examined 25 sports from research

published between 2017 and 2021. The overall results suggested the greatest impact of RAE among young males in the U18 category (81.9%), while the RAE was greatest for females within individual sports.

Combat sports such as boxing, wrestling, judo, and taekwondo tend to group participants by birth date and weight category, which according to Musch and Grondin (2001) and Cobley et al. (2009) may provide a partial solution to the RAE phenomenon. Albuquerque et al. (2012) investigated the presence of RAE in elite Taekwondo during three Olympic Games and Albuquerque et al. (2014) further investigated 3938 Olympic freestyle and Greco-Roman wrestlers, identifying the presence of RAE in all styles overall. RAE in freestyle medallists was only observed in male categories which mirrored the World Championship analysis by Fukuda et al. (2017). Albuquerque et al. (2015) assessed Olympic Judo athletes between 1964 and 2012 identifying significant RAE in heavy-weight male athletes and male medallists. Fukuda et al. (2023) later researched whether RAE was present in different age groups, weight classes, sexes and across different time frames in elite judo competitions (1993–2020). RAE was more evident in the male groups compared to female, as well as Junior/Cadet groups compared to the senior group. Fukuda et al. (2023) highlighted that RAE was more prevalent in recent years (2009–2021) for senior male competitors. Albuquerque et al. (2016) conducted a meta-analysis aiming to examine whether the utilisation of weight categories in combat sports can effectively mitigate RAE among the athletes. The paper concluded that RAE can be observed in all the examined combat sports (boxing, taekwondo, judo, and wrestling) and was mostly present in the male senior category. Conversely, Campideli et al. (2018)

examined RAE among combat competitors within the 2012 and 2016 Olympics. RAE was heavily observed in female judo competitors, which partially mirrored Fukuda et al. (2023); however, a clear overrepresentation of athletes born in the second half of the year was identified in female boxing, suggesting an inverse RAE.

Edginton et al. (2014) represents one of the two distinct studies that have focused on the amateur boxing demographic. The study explored the distribution of 388 male medal-winning boxers and revealed a significant ($p < 0.001$) difference between the expected equal distribution and the observed distribution of birth dates when analysed by year half, quartile, and month, thus confirming a heavy presence of RAE (Edginton et al., 2014). While this study provides an initial overview of RAE in amateur international boxing, there are several limitations. The study represents only medal-winning male boxers and not the wider male or female amateur boxing demographic; therefore, it remains to be determined whether RAE exists in the sport beyond medallists. As medallist represents the top level of the sport in the respective competition, it would appear useful to ascertain whether this group has a RAE advantage in comparison to the wider non-medallist population. Similarly, the study did not focus any of their analysis on age category groupings (e.g., Senior, Youth). This is an important consideration based on the findings by Fukuda et al. (2023) which highlighted that there was a greater prevalence of RAE in younger compared to the senior age group categories in the combat sport of judo.

The second distinct study to focus upon boxing alone was Delorme (2014) which investigated whether weight categories prevent young athletes from being exposed to RAE in amateur boxing. The result showed an absence of RAE in both amateur and professional boxers, with an inverse RAE observed in the senior amateur male category. Delorme (2014) suggests the strategic adjustment made by relatively younger children who transition from other sports to boxing, with incorporated weight categories, ensures fair competition. The study concluded that implementing a weight category system may serve as a potential solution to address the RAE phenomenon.

Female amateur boxing was not incorporated into the Olympic programme until London 2012, and therefore, the female cohort of the sport may have received limited attention from a 1) widening participation perspective and 2) funding perspective (sponsors, government, and national governing body organisations) within their respective countries due to the sports absence from the Olympic competition spotlight. The increased awareness, funding (although only speculated for a large proportion of competing nations), and the wider knowledge and understanding of male RAE (including the potential strategies to limit impact upon selection processes) highlight the need to gain a foundational understanding of female competition. Second, extending the longitudinal knowledge of male competition to the wider population (i.e., not just medallist) in more recent times, alongside their female counterparts, due to the increase in research and knowledge surrounding the RAE phenomenon is warranted. Therefore, the aim of this study was to investigate the presence of RAE in various age groups (senior and youth) and within sexes (male and female) in elite-level international amateur boxing competitions between 2013 and 2022.

Methods

Participants and data collection

The participants were 4813 amateur boxers (2871 males and 1942 females) competing in 12 international boxing competitions (Eleven World Championships and Rio 2016 Olympic Games) across senior and youth (U19) age groups between 2013 and 2022. The Mean (± SD) of the two age categories were senior male (24.07 ± 3.78), senior female (25.29 ± 4.45), youth male (16.95 ± 0.68) and youth female (16.85 ± 0.72). Athletes' data including names, birthdates, competitive result, and weight class were collected from an open-access database of the IBA website. Several studies have utilised open-access data in the previous research on relative age effect, and this was therefore deemed appropriate for the aims of the study (Albuquerque et al., 2012; Cote et al., 2006; Fukuda et al., 2017; Medic et al., 2009). Ethical approval was gained from a university's ethics committee.

Procedures

The participant group was categorised into several sub-groups for each competition. This included participants (full list of amateur boxers that participated in a particular competition) and medallists (all medal-winning boxers in that competition). In cases where the competition included both sexes, both participants and medallists were sub-categorised into groups by sex accordingly. Following previous research on RAE that utilised samples from international competitions (Albuquerque et al., 2012, 2015; Cote et al., 2006; Fukuda et al., 2017, 2023) a traditional approach into investigating RAE was implemented. Athletes' birthdate distributions were grouped into four calendar-based quartiles which were Q1 (January, February, and March), Q2 (April, May, and June), Q3 (July, August, and September), and Q4 (October, November, and December) and manually recorded in Microsoft Excel for further analysis.

Statistical analysis

To assess the significance of deviations from the expected number of births in each quartile, comparisons were performed among the four quartiles within each competition. Condon and Scaglion (1982) demonstrated the distribution of births throughout the year is not uniform and can be influenced by environmental and cultural factors. However, like other RAE studies (Cote et al., 2006; Edgar & O'Donoghue, 2005), the sample included international pool of athletes; therefore, the expected values were determined by assuming an equal distribution of births across each quartile of the year. A chi-square (χ^2) goodness-of-fit test was used to compare whether the number of participants and medallists born in each quartile of the year was significantly different from the expected distribution (i.e., 25% in Q1, Q2, Q3 and Q4). Following the recommendations of O'Donoghue (2012), to determine whether a significant difference between the observed and expected frequency distribution was present, statistical significance was set at $p < 0.05$. Odds Ratios (ORs) were calculated to compare the distribution of the first three quartiles to the last quartile and observed against uniformed values. OR is used effectively

when exploring inequalities in participation numbers along with probabilities of RAE occurrence (Cobley et al., 2009). All data collation, analyses, and calculations were performed using Microsoft Excel.

Results

Overall participant group

The mean age (and SD) of the senior male group was 24.1 ± 3.8 years, whilst the female group was slightly higher at 25.3 ± 4.4 years. The birth distribution for the overall combined group of participants (Table 1) was significantly different compared to the expected equal distribution between four quarters ($\chi^2 = 19.058$; $p < 0.001$). The overall male sub-group (all ages) showed significant difference ($\chi^2 = 28.972$; $p < 0.001$) in birth distribution, and there were further differences identified in youth boxers overall ($\chi^2 = 21.997$; $p < 0.001$), youth male boxers ($\chi^2 = 20.763$; $p < 0.001$) and senior male boxers ($\chi^2 = 7.942$; $p < 0.05$). The observed birth distribution was not significantly different from expected for any of the female participant groups. The combined senior group showed no significant distribution difference.

The observed difference was also compared in every separate competition, sub-categorising participants into males and females where applicable. Out of 12 separate competitions (16 sub-groups) only two sub-groups (2016 Youth Male Championship [$\chi^2 = 8.673$; $p = 0.034$] and 2021 Youth Male Championship [$\chi^2 = 7.869$; $p = 0.048$]) showed small, but significant differences. The 2016 Male Championship displayed a gradual decrease in birth dates from Q1 to Q4. A small overrepresentation of athletes born in Q1 compared to Q4 (OR > 1.01–1.33) can be seen in all overall groups (Table 1) apart from senior female participants where athletes born in Q4 prevail over athletes born in all other quarters (OR < 0.95).

Medallists

The mean age (and SD) of the senior male medallists' group was 24.1 ± 3.2 years, whilst the senior female medallist group was 25.8 ± 4.4 years. The birth distribution difference was not significant in any of the overall groups (Table 2). In the yearly (competition) sub-groups, only 2014 Youth Male Championship showed a significant difference ($\chi^2 = 11.718$; $p = 0.008$). Odds Ratios were above 1 for the overall combined and overall male groups, highlighting an overrepresentation of athletes in the earlier quartiles of the year; however, the overall female group had OR < 0.97 (Table 2). Within the youth group, all OR except Q3 × Q4(0.93) were greater than 1.07 highlighting an overrepresentation of athletes. The senior group demonstrated contrasting findings between the male (OR > 1.12, overrepresentation) and female (OR < 0.74, underrepresentation) subgroup. Chi-square (χ^2) analysis was additionally calculated for every competition sub-category among the medallists, where birth distribution difference in participants was significant; however, no statistically significant differences in birth distribution among the medal-winners were observed.

Discussion

Comparing overall sub-groups by age, a clear trend can be observed where RAE is more prevalent in Youth (17–18 years old) compared to senior groups. This finding corelates with the results presented in some previous RAE studies (Cobley et al., 2009; Fukuda et al., 2023). Considering that RAE presence in sports is often attributed to the physical maturation and size differences among individuals within the same age group (i.e., the maturation-selection hypothesis), it is reasonable to expect that the phenomenon becomes more pronounced during the early stages of physical development when the relative age differences within a cohort are greater. When athletes are

Table 1. All participant group quartile birth date distribution categorised as competitor level (overall, youth or senior) and by sex.

Demographic	Sex	Q1 n	Q1 %	Q2 n	Q2 %	Q3 n	Q3 %	Q4 n	Q4 %	Total n	Total %	χ^2	p	OR Q1 x Q4	OR Q2 x Q4	OR Q3 x Q4
Overall	Combined	1292	26.84	1232	25.60	1206	25.06	1084	22.50	4813	100.00	19.058	<0.001	1.19	1.14	1.11
	Male	809	28.18	725	25.25	730	25.43	607	21.14	2871	100.00	28.972	<0.001	1.33	1.19	1.20
	Female	483	24.87	507	26.11	476	24.51	477	24.56	1942	100.00	1.300	0.729	1.01	1.06	1.00
Youth	Combined	578	27.12	586	27.50	515	24.17	452	21.21	2131	100.00	21.997	<0.001	1.28	1.30	1.14
	Male	412	28.18	399	27.29	349	23.87	302	20.66	1462	100.00	20.763	<0.001	1.36	1.32	1.16
	Female	166	24.81	187	27.95	166	24.81	150	22.42	669	100.00	4.130	0.248	1.11	1.25	1.11
Senior	Combined	562	25.76	516	23.65	568	26.03	537	24.61	2182	100.00	3.155	0.368	1.05	0.96	1.06
	Male	284	26.82	240	22.66	291	27.48	244	23.04	1059	100.00	7.942	0.047	1.16	0.98	1.19
	Female	278	24.76	276	24.58	277	24.67	293	26.09	1123	100.00	0.692	0.875	0.95	0.94	0.95

Table 2. Medallist participant group quartile birth date distribution categorised as competitor level (overall, youth or senior) and by sex.

Demographic	Sex	Q1 n	Q1 %	Q2 n	Q2 %	Q3 n	Q3 %	Q4 n	Q4 %	Total n	Total %	χ^2	p	OR Q1 x Q4	OR Q2 x Q4	OR Q3 x Q4
Overall	Combined	187	25.76	181	24.93	177	24.38	172	23.69	726	100.00	0.777	0.855	1.09	1.05	1.03
	Male	95	26.84	87	24.58	88	24.86	75	21.19	354	100.00	2.565	0.463	1.27	1.16	1.17
	Female	92	24.73	94	25.27	89	23.92	97	26.08	372	100.00	0.366	0.947	0.95	0.97	0.92
Youth	Combined	90	29.03	80	25.81	73	23.55	68	21.94	310	100.00	3.523	0.318	1.32	1.18	1.07
	Male	48	28.24	44	25.88	38	22.35	41	24.12	170	100.00	1.294	0.731	1.17	1.07	0.93
	Female	42	30.00	36	25.71	35	25.00	27	19.29	140	100.00	3.257	0.354	1.56	1.33	1.30
Senior	Combined	70	22.44	72	23.08	76	24.36	84	26.92	312	100.00	1.795	0.616	0.83	0.86	0.90
	Male	33	25.00	29	21.97	34	25.76	26	19.70	132	100.00	2.000	0.572	1.27	1.12	1.31
	Female	37	20.56	43	23.89	42	23.33	58	32.22	180	100.00	5.467	0.141	0.64	0.74	0.72

younger and still experiencing significant growth and development, a nearly 12-month age difference represents a relatively larger proportion of their total age, which means that the physical advantages or disadvantages associated with being relatively older or younger within the same age group can have a more pronounced effect. The higher prevalence of the RAE observed in the youth categories than at senior level may lead to a conclusion that athletic success in the early development stages is not a strong predictor of a successful future career (Boccia et al., 2017; Brustio et al., 2018). Additionally, despite weight classes being utilised to control for boxer size and physicality, the presence of RAE suggests that boxers born in Q1 might also possess a cognitive or game intelligence advantage over their peers which is more difficult to control for. Athletes born later in the year may therefore not reach the world-class level until they enter the senior category, at which point the influence of the RAE tends to diminish. This can be further validated by the medal-winning analysis herein where a lack of RAE was observed, except in the case of 1 individual youth male competition.

Interestingly, when comparing with Edginton et al. (2014), a noticeable difference in the results can be seen. While Edginton et al. (2014) also examined the presence of RAE among the elite level senior IBA World Championships' and Olympic Games' boxing medallists (year 2000 to 2012), the research confirmed a significant presence of RAE. Whilst the research design was very similar, there are several factors that might have contributed to such a difference. Firstly, the difference in the size of the sample ($n = 388$ versus $n = 132$ senior males) which is likely due to the lack of data of several senior male competitions between 2013 and 2022, as well as cancellations, re-scheduling, and a smaller number of participants in competitions during and after the COVID-19 lockdowns might have reduced/influenced our findings. Secondly, it is possible that the increased amount of RAE-related research within the last decade has led to an improved awareness among boxing coaches, trainers, and talent development programmes, which has resulted in the implementation of strategies and countermeasures to mitigate its influence. This might have included adjusting selection processes, providing equal opportunities for athletes of different birth dates, and focusing more on the long-term skill development of all young boxers rather than on immediate talent, physical attributes, and age-based criteria. Unfortunately, this is speculated as details of any organisational changes may not be commonplace knowledge. Additionally, increased competitiveness and overall skill level might have been an important factor. Boxing has been an Olympic sport for over 119 years; however, the last decade has seen an increase in popularity of the sport particularly through the introduction of female boxing into the Olympic schedule.

A complete absence of RAE was recorded in all female subgroups within both participants and medallists, supporting the findings of Delorme (2014). The fact that female boxing has only recently become more established with the introduction of the sport in the 2001 World Championship and the Olympic Games (2012) highlights the relative novelty of the sport. Women's boxing has been actively growing for the last decade evidenced by an increase in female boxers from 36 at the London and Rio Olympics to 100 during Tokyo 2020. Musch

and Grondin (2001) suggested that when a country records a high popularity for a particular sport strong evidence for the RAE is observed. The greater the number of elite female boxers participating at top-level competitions, the more monetary investment will be provided on a national level, ultimately increasing participation and the potential athlete pool which to select from. As participation increases, it might be speculated that a rise in the presence of the RAE in female boxing may become evident so should be continually monitored.

Secondly, the RAE prevalence in males might be attributed to the earlier maturation status in young females. According to Malina et al. (2004) young females tend to reach biological and physical maturity earlier than their male counterparts in the context of sport. This means that females may have gone through a large proportion of their maturation before the competitions investigated here, thus reducing the prevalence of the RAE. Additionally, there is less diversity or variation in the maturity status among girls compared to boys, which means the range of maturity levels within the female population may be narrower, with most girls experiencing similar rates of physical development at a given age (Smith et al., 2018).

Several additional factors related to delayed maturation can play a role in lower RAE rates (or its complete absence) in female sports. For example, younger female athletes might be valued more over older ones in some sports. Hancock et al. (2015) observed an over-representation of female gymnasts born in Q4 over those born in Q1 of the competitive year, stating that being physically less mature might possess a competitive advantage in gymnastics whereby aspects such as flexibility are key to performance. Fukuda et al. (2023) observed an inverse RAE in young (U18) judo athletes in the featherweight category (the lowest weight category in the research), suggesting that being naturally smaller in the lowest weight class might be advantageous. This can partially be attributed to the fact that the smallest athletes in judo do not need to cut weight for competition, while physically larger athletes that want to participate in the same featherweight division do. Additionally, Wattie et al. (2012) suggests that early pubertal maturation in relatively older female athletes may increase the risk of dropping out of school sport and competition, which can lead to more equal participant birth date distribution. In the current research, over-representation of female boxers born in Q4 was observed in several subgroups including overall senior female participants and medallists. However, the greatest example of such over-representation can be seen in the 2016 Rio Olympic Games, where the OR (Q1 × Q4 = 0.38) highlights that 2.50 times more female boxers were born in the last quarter of the competitive year (similar findings observed within medallists). However, it must be noted that both findings were statistically insignificant.

Future directions

A limitation of the current study, and one seen in studies with multi-national cohorts, is the absence of country-specific expected birth date distributions, i.e., the study did not account for the specific seasonal or cultural variations in birth date distributions that may exist within each

country. Taking into consideration the non-uniform distribution of births throughout the year might be an important adjustment in the RAE context. Future focus should be placed on examining the presence of RAE in international boxing in different weight classes. Poisson regression should be considered as a potential method to calculate RAE along with the chi-squared method. Poisson regression considers weekly birthdate trends throughout the year and has been recognised as a suitable approach for detecting the presence of the relative age effect (Brustio et al., 2018; Doyle et al., 2019). While this approach has been primarily utilised in team sport studies (Brustio et al., 2021), its application within combat sports research has also been proven useful. For example, when adapted by Fukuda et al. (2023) RAE was successfully identified. Furthermore, considering that amateur boxing popularity varies across countries and that high popularity can increase RAE presence, there is a need for studies that specifically examine countries where boxing is most popular or those who have won the greatest number of Olympic medals, such as USA, Cuba, and UK.

Conclusion

This is the first and only research that examines the presence of RAE according to sex and age group in elite-level international amateur boxing competitions from an overall and medallist perspective. The results indicate RAE is more prominent in younger amateur boxing groups, as well as highlighting a greater prevalence in male compared to the female group. Female amateur boxers, although statistically insignificant, have shown an inverse RAE trend, and this should be monitored closely as the sport popularity grows. Odds ratio showed an overrepresentation of male boxers born in Q1 compared to Q4 (OR > 1.19–1.33), while senior female boxers presented an inverse trend (OR < 0.95). Odds Ratios for medallists within the youth group highlighted an overrepresentation of boxers born earlier in the year. A shift in youth strategy to reduce the extent of RAE in young boxers is encouraged. However, as Figueiredo et al. (2022) suggests, if coaches feel the pressure to win at grassroot competitions, they are likely to favour bigger and stronger athletes who are usually relatively older than their peers. Consequently, the technical, tactical, and psychological aspects that are so important within elite-level performance tend to become secondary factors within selection and competitive opportunities.

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