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Birth-Quarter Distribution and Medal Outcomes at the Asian Youth Table Tennis Championships, 2022–2026

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Research Article

Keywords: relative age effect, youth table tennis, birth quarter, medal attainment, medal rank, generalized estimating equations

Posted Date: November 25th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11265242/v1

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Additional Declarations: No competing interests reported.

Abstract

Background: Relative age effects in youth sport often manifest as an over-representation of athletes born earlier in the calendar year at high competitive levels. However, greater representation does not necessarily imply a higher probability of winning a medal. In Asian youth table tennis, it remains unclear whether birth quarter is associated with medal-winning probability among participants or with medal rank among medalists.

Objective: To describe birth-quarter representation among confirmed U15 and U19 championship participants and test whether birth quarter was associated with medal attainment or, among medalists, highest medal rank.

Methods: Official participation, roster, birth-date, and result records were linked retrospectively. The unit was athlete × championship year × age category. Team medals required official roster membership and confirmed participation in the same year and category. Exploratory appearance-level tests compared birth-quarter distributions with a uniform reference. Binary and ordinal logistic GEE models clustered by athlete ID adjusted for sex, age category, and year.

Results: The sample comprised 1,172 appearances from 718 athletes, including 341 medal-winning appearances from 221 athletes. The participant distribution differed from the uniform reference, with Q1 accounting for 29.4% of appearances and Q4 for 22.1% ($\chi^2(3) = 13.788$, $p = 0.003$; $w = 0.108$). Medal-winning rates were 25.2%, 28.6%, 31.3%, and 32.4% across Q1–Q4. However, the adjusted models detected no statistically significant birth-quarter association with medal attainment (global $p = 0.462$) or highest medal rank among medalists (global $p = 0.402$). The adjusted Q1 versus Q4 OR for medal attainment was 0.74 (95% CI 0.47–1.15); all quarter-specific confidence intervals included 1 in both models.

Conclusion: Earlier-year births were more frequent among participant appearances, but no statistically significant birth-quarter association with medal attainment or conditional medal rank was detected. These findings do not establish equivalent outcomes across quarters. Birth-quarter representation and success among selected competitors should be evaluated separately.

1 Introduction

Youth sport competitions commonly use fixed annual eligibility cut-off dates to organise athletes into age categories. Within a single birth-year cohort, athletes born early and late in the eligibility year can therefore differ in chronological age by almost 12 months.[1,2] The relative age effect (RAE) refers to systematic differences in participation, selection, and attainment associated with an athlete's age relative to peers within the same age-grouping system.[3,4] During childhood and adolescence, relatively older athletes may benefit from differences in physical development and accumulated sport experience that influence current performance and selection opportunities.[1,3,5] These potential advantages can be reinforced by the expectations and decisions of parents and coaches, together with athletes' own perceptions of their abilities.[6,7] Preferential access to coaching, training, and competition may then allow initial advantages to accumulate, contributing to the over-representation of athletes born earlier in the eligibility year within selected sporting populations.[3,6] The emergence of RAE nevertheless depends on the interaction between individual development, sporting demands, and the competitive environment.[1] Understanding these processes is relevant to both equitable access to high-level youth competition and the interpretation of subsequent performance and long-term athlete development.[1,3,8]

Evidence from racket sports indicates that birth-quarter patterns vary across sporting and developmental contexts.[9–11] In a nationwide study of active Turkish players, Bilgiç and Güvenç identified an over-representation of relatively older participants in badminton, table tennis, and tennis, with more pronounced patterns in younger age categories.[12] However, the relationship between relative age and performance within selected youth populations is less consistent. In a four-year study of French top-100 youth table tennis players, Faber et al. found a statistically significant association between birth quarter and performance trajectories only among U18 males, with no significant associations in the female subsamples.[13] These findings suggest that birth-quarter representation and subsequent performance should be examined as distinct outcomes. In youth table tennis, the potential influence of physical development must also be considered alongside technical proficiency, tactical decision-making, and the opportunities available within particular competition systems.[1,13,14] Evidence from one national pathway or age category therefore cannot be assumed to apply uniformly to other settings, supporting the need to examine both sexes and different age groups within Asian youth competition.[15,16]

A central methodological distinction concerns the denominator used to evaluate competitive success.[17] A birth-quarter distribution calculated exclusively among medalists describes who is represented on the podium, but does not estimate the probability of winning a medal among those who competed. For example, a larger number of Q1 medalists could arise simply because more Q1 athletes entered the competition, even if their medal-winning rate was similar to or lower than that of Q4 athletes. Evaluating medal attainment therefore requires the number of medal-winning appearances to be related to all confirmed participant appearances within the corresponding birth quarter. Furthermore, the distribution of birth quarters within gold, silver, or bronze medal groups does not directly establish whether birth quarter is associated with achieving a higher medal rank. Distinguishing participant representation, medal attainment, and medal rank is consequently necessary to avoid interpreting an unequal distribution of successful athletes as evidence of a competitive advantage.

The Asian Youth Table Tennis Championships provide a setting in which these questions can be examined within the same competition framework. Linking confirmed participation records with official medal results permits the inclusion of both medalists and non-medalists, and thus supports a two-stage evaluation of competitive success: medal attainment among all participants and medal rank among those who won a medal. Analysing several championship editions also increases coverage across age groups and sexes, although some athletes contribute observations in more than one year or age category. Such observations cannot be treated as entirely independent. Generalized estimating equations (GEE), with athlete identity specified as the clustering unit, provide a means of estimating population-averaged associations while accounting for repeated appearances.[18] This approach extends the description of birth-quarter representation to an evaluation of whether birth quarter is associated with competition outcomes among athletes who have already reached continental youth competition.

Accordingly, this study examined U15 and U19 participants in the Asian Youth Table Tennis Championships from 2022 to 2026. The primary question was whether birth quarter was associated with winning at least one medal among confirmed participants. The secondary question concerned highest medal rank among those who won a medal. Birth-quarter distributions among all participants and within medalist subgroups were described to provide context for these outcome analyses. Although earlier-year births were expected to be more frequent among participants on theoretical grounds, an association with medal attainment or higher medal rank was tested separately and was not assumed.

2. Participants and Methods

2.1 Study Design

This retrospective observational study examined publicly available records from the 2022–2026 Asian Youth Table Tennis Championships in the U15 and U19 age categories. Official entry lists, match results, team rosters, and athlete profiles were linked to describe participant birth-quarter distributions and examine their associations with medal attainment and medal rank. The study used secondary competition data and involved no participant recruitment, direct contact, or intervention. The observation unit was an athlete's confirmed appearance within a particular championship year and age category, rather than an individual match, event entry, or medal. Analyses distinguished this appearance-level denominator from the number of unique athletes represented in the dataset.

2.2 Participants and Data Collection

The participant dataset was assembled from official championship records available through the International Table Tennis Federation (ITTF) results system, with athlete dates of birth and sex obtained from the linked official records and profiles.[19] Entry-list membership alone was insufficient for inclusion: participation required non-zero recorded game scores in a singles match or individual team submatch, or identification on the official roster of a doubles pair with recorded play, within the corresponding year and age category. A walkover, bye, or unplayed team line-up alone was insufficient. The extracted variables comprised ITTF athlete ID, name, date of birth, sex, age category, championship year, participation evidence, medal-winning status, and highest medal rank. Source URLs were retained for verification, and complete dates of birth were available for all included athletes without imputation. Two inconsistent team results were reconciled against Japan Table Tennis Association reports: China defeated Hong Kong in the 2026 U19 girls' team semi-final, and Korea defeated Japan in the 2025 U15 girls' team final.[20,21] Medal-winning team rosters were then linked to confirmed participation records before assigning each athlete's highest medal.

Records were consolidated using championship year × age category × ITTF ID as the unique key. Multiple event entries within the same year and age category were counted once, whereas appearances across different years or age categories were retained because they represented separate competition opportunities. Thus, an athlete competing in both U15 and U19 in the same edition could contribute one observation to each category. The ITTF ID was retained across observations to identify repeated athletes for clustered analyses. Medal records from singles, doubles, mixed doubles, and team events were linked to the corresponding participation record; when more than one medal was obtained within a year and age category, only the highest medal was retained for the ordinal outcome.

2.3 Birth-Quarter Classification

Birth quarters were assigned from each athlete's recorded birth month: Q1, January–March; Q2, April–June; Q3, July–September; and Q4, October–December. This classification described relative age within the calendar birth year, with Q1 representing earlier and Q4 later births. The 2025 official prospectus specified eligibility from 1 January 2006 for U19 and 1 January 2010 for U15, documenting a calendar-year boundary for that edition.[22] Because U15 and U19 categories can include athletes from several birth years, birth quarter did not indicate an athlete's absolute age relative to every other competitor in the category. The present analyses therefore addressed within-year birth-quarter patterns and did not separately estimate between-birth-year effects. Birth-

quarter classification was also distinguished from biological maturation, which was not measured in the competition records.

2.4 Outcome Variables

The primary outcome was medal-winning status, coded as 1 when an athlete obtained at least one gold, silver, or bronze medal in the corresponding championship year and age category, and 0 otherwise. For team events, all members on the official roster of a medal-winning team were classified as medalists if actual participation in that same year and age category had been confirmed. Medal attribution did not require the athlete to appear in the final or semi-final team line-up. This definition was applied consistently in the overall participant comparison, the binary GEE models, and the medalist-only analyses. Medal-winning rates were calculated by dividing medal-winning appearances by all confirmed participant appearances within each birth quarter; these rates described success conditional on participation in the championship.

The secondary outcome was the highest medal rank achieved within the corresponding year and age category, coded as bronze = 1, silver = 2, and gold = 3. This outcome was analysed only among medal-winning appearances. If an athlete won medals in several events, the highest-ranked medal determined the ordinal outcome, with gold taking precedence over silver and bronze. Medal rank consequently represented the athlete's best championship result within an age category, rather than the total number of medals or the outcome of an individual match. Associations estimated for this outcome were interpreted conditional on having won at least one medal and were not treated as estimates of the probability of winning gold among all participants.

2.5 Statistical Analysis

Participant characteristics and birth-quarter distributions were summarised using frequencies and percentages. Pearson chi-square goodness-of-fit tests compared the observed distribution with a theoretical uniform reference of 25% per quarter, with Cohen's w calculated as the square root of χ^2/n. This reference was not assumed to represent the actual birth distribution of the source populations.[23] Q1/Q4 representation ratios were calculated as the Q1 count divided by the Q4 count, with approximate log-scale 95% confidence intervals. A 4 × 2 contingency table compared birth quarter with medal-winning status, accompanied by quarter-specific medal-winning rates and Cramér's V. Medalist-only distributions were described overall and by age category, sex within age category, and highest medal rank. These appearance-level chi-square tests were treated as exploratory because repeated athletes could contribute more than one observation; models accounting for athlete clustering provided the principal inference concerning competitive success.

Binary logistic GEE models estimated the association between birth quarter and medal-winning status using a binomial distribution, logit link, exchangeable working correlation, and robust sandwich standard errors. ITTF ID defined the clusters, thereby accounting for repeated appearances across years and age categories. Model 1 included birth quarter alone, whereas Model 2 additionally included sex, age category, and championship year as categorical covariates. Q4, female sex, U15, and 2022 were the reference categories. Odds ratios (ORs) and 95% confidence intervals were reported for each contrast; an OR above 1 indicated higher odds of winning at least one medal. A joint three-degree-of-freedom Wald test assessed the overall association with birth quarter. These ORs were interpreted as associations with medal-winning odds and not as risk ratios or causal effects.[18]

Among medalists, ordinal logistic GEE models analysed the ordered outcome bronze < silver < gold using a cumulative logit formulation, a global odds ratio working association, ITTF ID clusters, and robust standard

errors. The model estimated common covariate effects across the thresholds separating silver/gold from bronze and gold from bronze/silver. An OR above 1 therefore indicated higher odds of achieving a higher medal category. The unadjusted and adjusted models used the same predictors and reference categories as the binary analysis, and the overall birth-quarter association was evaluated using a joint Wald test. Exploratory birth quarter × age category and birth quarter × sex interactions were assessed in separate adjusted ordinal models using joint three-degree-of-freedom Wald tests; individual subgroup significance patterns were not used as evidence of interaction.[24]

Direct comparisons of birth-quarter distributions between groups used chi-square tests of independence and Cramér's V. The proportional-odds specification was examined using an approximate diagnostic that stacked the two binary thresholds and estimated threshold-specific intercepts and slopes in a working-independence GEE model. An athlete-clustered robust Wald test jointly assessed equality of the nine covariate slopes across thresholds. Coefficient tests were two-sided, and chi-square and joint Wald tests used the corresponding upper-tail probabilities. All p values were unadjusted, with 0.05 used as the nominal significance threshold; subgroup and interaction findings were interpreted as exploratory in view of multiple comparisons. No sensitivity analyses were conducted. Analyses were performed in Python 3.12.14 using SciPy 1.16.2 and statsmodels 0.14.5. Athlete clustering addressed within-athlete repetition but did not account for dependence between different athletes sharing team or doubles outcomes.

3 Results

3.1 Participant Characteristics

The official rosters contained 1,191 athlete–year–age-category records from 731 unique athletes. Nineteen records were excluded because actual participation in the corresponding year and age category could not be confirmed. The final sample therefore comprised 1,172 confirmed appearances from 718 athletes (Table 1; Fig. 1). U15 accounted for 555 appearances (47.4%) and U19 for 617 (52.6%); 622 appearances (53.1%) were male and 550 (46.9%) were female. Annual counts ranged from 179 in 2022 to 258 in 2025. At least one medal was recorded in 341 appearances (29.1%) from 221 athletes, whereas 831 appearances (70.9%) involved no medal. Among medal-winning appearances, the highest medal was gold in 103, silver in 78, and bronze in 160. Thus, medal attainment was analysed in all 1,172 appearances, while medal rank was analysed in the 341 medal-winning appearances.

Table 1
Characteristics of confirmed championship participants according to medal-winning status

Variable	Category	All participants, n (%)	Medalists, n (%)	Non-medalists, n (%)
Total	—	1,172 (100.0)	341 (100.0)	831 (100.0)
Age group	U15	555 (47.4)	148 (43.4)	407 (49.0)
Age group	U19	617 (52.6)	193 (56.6)	424 (51.0)
Sex	Male	622 (53.1)	174 (51.0)	448 (53.9)
Sex	Female	550 (46.9)	167 (49.0)	383 (46.1)
Year	2022	179 (15.3)	62 (18.2)	117 (14.1)
Year	2023	237 (20.2)	60 (17.6)	177 (21.3)
Year	2024	246 (21.0)	72 (21.1)	174 (20.9)
Year	2025	258 (22.0)	73 (21.4)	185 (22.3)
Year	2026	252 (21.5)	74 (21.7)	178 (21.4)

Note. The unit is one confirmed athlete appearance per championship year × age category × ITTF ID; multiple events within this key are counted once. The sample comprises 1,172 appearances from 718 unique athletes: 341 medal-winning and 831 non-medal-winning appearances. The medal-winning subset includes 221 unique athletes. Percentages use the total of the corresponding column.

For team events, medalists are official members of medal-winning teams who had confirmed actual participation in the same championship year and age category, whether or not they appeared in the final or semi-final line-up.

3.2 Birth-Quarter Representation among Participants

Q1 contributed the largest share of confirmed participant appearances: 345 (29.4%), compared with 287 (24.5%) in Q2, 281 (24.0%) in Q3, and 259 (22.1%) in Q4 (Table 2; Fig. 2A). The overall four-quarter distribution differed from the theoretical reference of 25% per quarter ($\chi^2(3) = 13.788$, $p = 0.003$), although the effect size was small (Cohen's $w = 0.108$). The Q1/Q4 representation ratio was 1.33 (95% CI 1.13–1.56), indicating approximately one-third more Q1 than Q4 appearances. Q1 was also the largest quarter in each age category, but the age-specific four-quarter tests were not statistically significant (U15, $p = 0.053$; U19, $p = 0.098$). A direct comparison likewise detected no age-category difference in the distributions ($\chi^2(3) = 0.195$, $p = 0.978$, Cramér's $V = 0.013$). These tests concern the composition of the participant sample, rather than differences in medal attainment.

Table 2

Birth-quarter distribution among confirmed participants at the Asian Youth Table Tennis Championships

Group	n	Q1 n (%)	Q2 n (%)	Q3 n (%)	Q4 n (%)	χ^2	p	Cohen's w	Q1/Q4 ratio (95% CI)
Total	1172	345 (29.4)	287 (24.5)	281 (24.0)	259 (22.1)	13.788	0.003	0.108	1.33 (1.13–1.56)
U15	555	165 (29.7)	138 (24.9)	131 (23.6)	121 (21.8)	7.674	0.053	0.118	1.36 (1.08–1.72)
U19	617	180 (29.2)	149 (24.1)	150 (24.3)	138 (22.4)	6.306	0.098	0.101	1.30 (1.04–1.63)
Male	622	184 (29.6)	147 (23.6)	149 (24.0)	142 (22.8)	7.132	0.068	0.107	1.30 (1.04–1.61)
Female	550	161 (29.3)	140 (25.5)	132 (24.0)	117 (21.3)	7.338	0.062	0.116	1.38 (1.08–1.75)
Male U15	288	89 (30.9)	66 (22.9)	73 (25.3)	60 (20.8)	6.528	0.089	0.151	1.48 (1.07–2.06)
Female U15	267	76 (28.5)	72 (27.0)	58 (21.7)	61 (22.8)	3.337	0.343	0.112	1.25 (0.89–1.75)
Male U19	334	95 (28.4)	81 (24.3)	76 (22.8)	82 (24.6)	2.359	0.501	0.084	1.16 (0.86–1.56)
Female U19	283	85 (30.0)	68 (24.0)	74 (26.1)	56 (19.8)	6.201	0.102	0.148	1.52 (1.08–2.13)

Note. The unit is one confirmed athlete appearance per championship year × age category × ITTF ID; multiple events within this key are counted once. Total: 1,172 appearances from 718 unique athletes. Percentages are within rows. Q1 = January–March; Q2 = April–June; Q3 = July–September; Q4 = October–December.

Pearson goodness-of-fit χ^2 tests (df = 3) use a theoretical 25% per quarter; Cohen's w = $\sqrt{(\chi^2/n)}$. This reference is not a population birth distribution. Q1/Q4 is the count-based representation ratio with an approximate log-Wald 95% CI; it is not a medal-winning odds ratio. These χ^2 tests and ratio CIs treat appearances as independent, although some athletes appear repeatedly. P values are nominal, unadjusted and exploratory.

3.3 Birth Quarter and Medal Attainment

The number of medal-winning appearances was similar across quarters, but the number of participant appearances differed. The medal-winning rates were 87/345 (25.2%) for Q1, 82/287 (28.6%) for Q2, 88/281 (31.3%) for Q3, and 84/259 (32.4%) for Q4 (Table 3; Fig. 2B). Thus, the greater number of Q1 participant appearances was not accompanied by a higher observed medal-winning rate. The overall 4 × 2 comparison of birth quarter and medal-winning status was not statistically significant ($\chi^2(3) = 4.623$, $p = 0.202$, Cramér's $V = 0.063$). The increasing percentages from Q1 to Q4 describe the observed sample; this exploratory comparison did not establish a birth-quarter association with medal attainment.

Table 3
Birth-quarter distribution and medal-winning status among confirmed participants

Birth quarter	All participants, n (%)	Medalists, n (%)	Non-medalists, n (%)	Medal-winning rate, %
Q1	345 (29.4)	87 (25.5)	258 (31.0)	25.2
Q2	287 (24.5)	82 (24.0)	205 (24.7)	28.6
Q3	281 (24.0)	88 (25.8)	193 (23.2)	31.3
Q4	259 (22.1)	84 (24.6)	175 (21.1)	32.4
Total	1,172 (100.0)	341 (100.0)	831 (100.0)	29.1

Note. The unit is one confirmed athlete appearance per championship year × age category × ITTF ID; multiple events within this key are counted once. Total: 1,172 appearances from 718 unique athletes; medalists: 341 medal-winning appearances from 221 unique athletes; non-medalists: 831 appearances. Quarter percentages in the first three numeric columns use their respective column totals. The medal-winning rate is medal-winning appearances divided by all participant appearances in the same quarter, multiplied by 100.

For team events, medalists are official members of medal-winning teams who had confirmed actual participation in the same championship year and age category, whether or not they appeared in the final or semi-final line-up.

Birth quarter × medal-winning status: Pearson $\chi^2(3) = 4.623$, $p = 0.202$, Cramér's $V = 0.063$. This is one overall 4 × 2 test. The test assumes independent appearances; the nominal p value is exploratory. Athlete-clustered GEE estimates are reported in Table 4.

The athlete-clustered binary GEE model also detected no statistically significant birth-quarter association with medal attainment after adjustment for sex, age category, and championship year (global Wald $\chi^2(3) = 2.576$, $p = 0.462$; Table 4; Fig. 3A). With Q4 as the reference, the adjusted ORs were 0.74 for Q1 (95% CI 0.47–1.15, $p = 0.177$), 0.85 for Q2 (95% CI 0.54–1.34, $p = 0.485$), and 1.00 for Q3 (95% CI 0.64–1.56, $p = 0.990$). The unadjusted GEE global test was also nonsignificant ($p = 0.430$). Each confidence interval included 1, so none of the quarter-specific comparisons identified statistically significant higher or lower medal-winning odds. The intervals also allowed potentially meaningful differences; the models did not demonstrate equivalent odds across quarters.

Table 4
Association between birth quarter and medal-winning status among confirmed participants

Predictor	OR	95% CI	p
Model 1 Birth quarter only			
Q1 vs Q4	0.73	0.47–1.14	0.166
Q2 vs Q4	0.86	0.55–1.35	0.515
Q3 vs Q4	1.01	0.64–1.58	0.970
Birth quarter, global test	—	—	0.430
Model 2 Adjusted main model			
Q1 vs Q4	0.74	0.47–1.15	0.177
Q2 vs Q4	0.85	0.54–1.34	0.485
Q3 vs Q4	1.00	0.64–1.56	0.990
U19 vs U15	1.16	0.92–1.46	0.219
Male vs female	0.91	0.67–1.25	0.569
2023 vs 2022	0.75	0.51–1.08	0.125
2024 vs 2022	0.84	0.58–1.24	0.388
2025 vs 2022	0.98	0.66–1.46	0.927
2026 vs 2022	1.07	0.72–1.59	0.746
Birth quarter, global test	—	—	0.462

Note. The unit is one confirmed athlete appearance per championship year × age category × ITTF ID; multiple events within this key are counted once. Binary logistic GEE uses 1,172 appearances from 718 unique athletes, with ITTF ID clusters, an exchangeable working correlation and robust sandwich standard errors. The outcome is at least one medal (1) versus no medal (0); OR > 1 indicates higher medal-winning odds.

Model 1 includes birth quarter only. Model 2 adjusts for sex, age category and championship year as categorical variables. Reference categories are Q4, female sex, U15 and 2022. Global birth-quarter p values are joint three-df Wald tests. CI = confidence interval. Coefficient p values are two-sided; all p values are unadjusted.

For team events, medalists are official members of medal-winning teams who had confirmed actual participation in the same championship year and age category, whether or not they appeared in the final or semi-final line-up. Clustering accounts for repeated athletes, but not dependence between different athletes sharing team or doubles outcomes.

3.4 Exploratory Birth-Quarter Distributions among Medalists

Within the 341 medal-winning appearances, the observed quarter shares were similar: Q1, 87 (25.5%); Q2, 82 (24.0%); Q3, 88 (25.8%); and Q4, 84 (24.6%) (Table 5). The distribution did not differ significantly from the uniform reference ($\chi^2(3) = 0.267$, $p = 0.966$, Cohen's $w = 0.028$), and the Q1/Q4 representation ratio was 1.04 (95% CI 0.77–1.40). These percentages use all medal-winning appearances as the denominator. They describe the

composition of the medalist group and should be distinguished from the quarter-specific medal-winning rates in Table 3, which use all confirmed participant appearances within each quarter as the denominator.

Table 5
Overall birth-quarter distribution among medal-winning athlete appearances

Group	n	Q1 n (%)	Q2 n (%)	Q3 n (%)	Q4 n (%)	Expected share	χ^2	p	Cohen's w	Q1/Q4 ratio (95% CI)
Total medal-winning athlete appearances	341	87 (25.5)	82 (24.0)	88 (25.8)	84 (24.6)	25% each quarter	0.267	0.966	0.028	1.04 (0.77–1.40)

Note. The unit is one confirmed athlete appearance per championship year × age category × ITTF ID; multiple events within this key are counted once. The medalist sample comprises 341 medal-winning appearances from 221 unique athletes. For team events, medalists are official members of medal-winning teams who had confirmed actual participation in the same championship year and age category, whether or not they appeared in the final or semi-final line-up. Q1 = January–March; Q2 = April–June; Q3 = July–September; Q4 = October–December.

Pearson goodness-of-fit χ^2 tests (df = 3) use a theoretical 25% per quarter; Cohen's w = $\sqrt{(\chi^2/n)}$. This reference is not a population birth distribution. Q1/Q4 is the count-based representation ratio with an approximate log-Wald 95% CI; it is not a medal-winning odds ratio. These χ^2 tests and ratio CIs treat appearances as independent, although some athletes appear repeatedly. P values are nominal, unadjusted and exploratory.

The medalist sample included 148 U15 and 193 U19 appearances (Table 6). Q1 was the largest quarter in U15 (29.7%), whereas Q3 was the largest in U19 (30.1%). Neither four-quarter distribution differed significantly from the uniform reference (U15: $\chi^2(3) = 2.865$, p = 0.413, w = 0.139; U19: $\chi^2(3) = 3.124$, p = 0.373, w = 0.127). The direct U15–U19 comparison was also nonsignificant ($\chi^2(3) = 5.608$, p = 0.132, Cramér's V = 0.128). Accordingly, the different largest quarters did not establish an age-category difference in the overall medalist distribution.

Table 6
Birth-quarter distribution by age group among medal-winning athlete appearances

Age group	n	Q1 n (%)	Q2 n (%)	Q3 n (%)	Q4 n (%)	χ^2	p	Cohen's w	Q1/Q4 ratio (95% CI)
U15	148	44 (29.7)	39 (26.4)	30 (20.3)	35 (23.6)	2.865	0.413	0.139	1.26 (0.81–1.96)
U19	193	43 (22.3)	43 (22.3)	58 (30.1)	49 (25.4)	3.124	0.373	0.127	0.88 (0.58–1.32)

Note. The unit is one confirmed athlete appearance per championship year × age category × ITTF ID; multiple events within this key are counted once. Analyses include 341 medal-winning appearances from 221 unique athletes; percentages are within age-category rows. Q1 = January–March; Q2 = April–June; Q3 = July–September; Q4 = October–December.

Pearson goodness-of-fit χ^2 tests (df = 3) use a theoretical 25% per quarter; Cohen's w = $\sqrt{(\chi^2/n)}$. This reference is not a population birth distribution. Q1/Q4 is the count-based representation ratio with an approximate log-Wald 95% CI; it is not a medal-winning odds ratio. These χ^2 tests and ratio CIs treat appearances as independent, although some athletes appear repeatedly. P values are nominal, unadjusted and exploratory.

Among the four sex-by-age medalist subgroups, only the U19 female distribution departed from uniformity at the nominal significance threshold ($\chi^2(3) = 9.703$, p = 0.021, w = 0.327); Q3 was the largest quarter, with 35 of 91 appearances (38.5%) (Table 7). The remaining subgroup goodness-of-fit tests were nonsignificant (p = 0.112–0.694). Direct distribution comparisons identified nominal differences between sexes within U15 (p = 0.035) and between age categories among females (p = 0.011), but not between sexes within U19 (p = 0.058) or between age categories among males (p = 0.517). These tests compared birth-quarter distributions within the medalist sample. They did not test whether sex or age modified the probability of winning a medal among all participants; formal interactions for medal rank are reported in Section 3.5.

Table 7
Birth-quarter distribution by sex and age group among medal-winning athlete appearances

Sex	Age group	n	Q1 n (%)	Q2 n (%)	Q3 n (%)	Q4 n (%)	χ^2	p	Cohen's w	Q1/Q4 ratio (95% CI)
Male	U15	72	26 (36.1)	12 (16.7)	18 (25.0)	16 (22.2)	5.778	0.123	0.283	1.62 (0.87–3.03)
Female	U15	76	18 (23.7)	27 (35.5)	12 (15.8)	19 (25.0)	6.000	0.112	0.281	0.95 (0.50–1.81)
Male	U19	102	28 (27.5)	22 (21.6)	23 (22.5)	29 (28.4)	1.451	0.694	0.119	0.97 (0.57–1.62)
Female	U19	91	15 (16.5)	21 (23.1)	35 (38.5)	20 (22.0)	9.703	0.021	0.327	0.75 (0.38–1.46)

Note. The unit is one confirmed athlete appearance per championship year × age category × ITTF ID; multiple events within this key are counted once. Analyses include 341 medal-winning appearances from 221 unique athletes; percentages are within sex × age-category rows. Q1 = January–March; Q2 = April–June; Q3 = July–September; Q4 = October–December.

Pearson goodness-of-fit χ^2 tests (df = 3) use a theoretical 25% per quarter; Cohen's w = $\sqrt{(\chi^2/n)}$. This reference is not a population birth distribution. Q1/Q4 is the count-based representation ratio with an approximate log-Wald 95% CI; it is not a medal-winning odds ratio. These χ^2 tests and ratio CIs treat appearances as independent, although some athletes appear repeatedly. P values are nominal, unadjusted and exploratory. Differences in subgroup significance do not establish between-group differences; direct comparisons use χ^2 independence tests and Cramér's V.

Of the six highest-medal-by-age strata, only the U19 gold distribution departed from uniformity at the nominal significance threshold ($\chi^2(3) = 14.695$, $p = 0.002$, $w = 0.499$). Q3 contributed 27 of the 59 U19 gold appearances (45.8%) (Table 8). The other five strata showed no significant departure (all $p \geq 0.372$). A separate, direct comparison of birth quarter and highest medal category was nominally significant within U19 ($\chi^2(6) = 14.380$, $p = 0.026$), but not within U15 ($p = 0.765$). These unadjusted appearance-level findings were exploratory. The next analysis used an ordinal model to assess higher medal rank across quarters, with covariate adjustment and clustering for repeated athletes.

Table 8
Birth-quarter distribution by highest medal category and age group

Medal category	Age group	n	Q1 n (%)	Q2 n (%)	Q3 n (%)	Q4 n (%)	χ^2	p	Cohen's w	Q1/Q4 ratio (95% CI)
Gold	U15	44	15 (34.1)	11 (25.0)	7 (15.9)	11 (25.0)	2.909	0.406	0.257	1.36 (0.63–2.97)
Silver	U15	36	9 (25.0)	11 (30.6)	10 (27.8)	6 (16.7)	1.556	0.670	0.208	1.50 (0.53–4.21)
Bronze	U15	68	20 (29.4)	17 (25.0)	13 (19.1)	18 (26.5)	1.529	0.675	0.150	1.11 (0.59–2.10)
Gold	U19	59	14 (23.7)	9 (15.3)	27 (45.8)	9 (15.3)	14.695	0.002	0.499	1.56 (0.67–3.59)
Silver	U19	42	12 (28.6)	11 (26.2)	8 (19.0)	11 (26.2)	0.857	0.836	0.143	1.09 (0.48–2.47)
Bronze	U19	92	17 (18.5)	23 (25.0)	23 (25.0)	29 (31.5)	3.130	0.372	0.184	0.59 (0.32–1.07)

Note. The unit is one confirmed athlete appearance per championship year × age category × ITTF ID; multiple events within this key are counted once. Analyses include 341 medal-winning appearances from 221 unique athletes. The highest medal per appearance is retained (gold > silver > bronze); percentages are within medal-category × age-category rows. Q1 = January–March; Q2 = April–June; Q3 = July–September; Q4 = October–December.

Pearson goodness-of-fit χ^2 tests (df = 3) use a theoretical 25% per quarter; Cohen's $w = \sqrt{(\chi^2/n)}$. This reference is not a population birth distribution. Q1/Q4 is the count-based representation ratio with an approximate log-Wald 95% CI; it is not a medal-winning odds ratio. These χ^2 tests and ratio CIs treat appearances as independent, although some athletes appear repeatedly. P values are nominal, unadjusted and exploratory. Direct comparisons of birth-quarter distributions between medal categories use χ^2 independence tests and Cramér's V.

3.5 Birth Quarter and Highest Medal Rank among Medalists

Among the 341 medal-winning appearances from 221 athletes, the ordinal GEE model assessed whether birth quarter was associated with a higher position in the ordered outcome bronze < silver < gold (Table 9; Fig. 3B). No statistically significant overall association was detected in the unadjusted model (global p = 0.369) or after adjustment for sex, age category, and championship year (global Wald $\chi^2(3) = 2.936$, p = 0.402). Relative to Q4, the adjusted ORs for higher medal rank were 1.46 for Q1 (95% CI 0.75–2.85, p = 0.270), 1.16 for Q2 (95% CI 0.60–2.24, p = 0.653), and 1.70 for Q3 (95% CI 0.87–3.33, p = 0.119). Although all point estimates exceeded 1, each confidence interval included 1. The model therefore did not identify a statistically significant quarter-specific difference in medal rank. These estimates apply to medalists and do not estimate gold-medal probability among all participants.

Table 9
Birth quarter and highest medal rank among medal-winning athlete appearances

Predictor	OR / ratio of ORs	95% CI	p
Model 1 Birth quarter only			
Q1 vs Q4	1.50	0.77–2.92	0.228
Q2 vs Q4	1.20	0.63–2.31	0.577
Q3 vs Q4	1.74	0.89–3.40	0.103
Birth quarter, global test	—	—	0.369
Model 2 Adjusted main model			
Q1 vs Q4	1.46	0.75–2.85	0.270
Q2 vs Q4	1.16	0.60–2.24	0.653
Q3 vs Q4	1.70	0.87–3.33	0.119
U19 vs U15	0.90	0.63–1.28	0.549
Male vs female	1.00	0.63–1.57	0.992
2023 vs 2022	0.84	0.46–1.55	0.578
2024 vs 2022	0.67	0.37–1.21	0.185
2025 vs 2022	0.74	0.40–1.35	0.325
2026 vs 2022	0.92	0.50–1.71	0.797
Birth quarter, global test	—	—	0.402
Model 3a Quarter × age group			
Q1 × U19	1.38	0.52–3.70	0.518
Q2 × U19	0.86	0.32–2.34	0.764
Q3 × U19	2.06	0.72–5.94	0.180
Interaction, global test	—	—	0.318
Model 3b Quarter × sex			
Q1 × male	2.27	0.60–8.61	0.230
Q2 × male	1.30	0.35–4.80	0.691
Q3 × male	1.04	0.27–4.00	0.952
Interaction, global test	—	—	0.581

Note. The unit is one confirmed athlete appearance per championship year × age category × ITTF ID; multiple events within this key are counted once. Ordinal logistic GEE uses 341 medal-winning appearances from 221 unique athletes, with ITTF ID clusters, a global odds ratio working association and robust sandwich standard errors. Medal rank is coded bronze = 1, silver = 2 and gold = 3. Main-effect OR > 1 indicates higher odds of a higher medal category (silver/gold versus bronze and gold versus bronze/silver), conditional on medal attainment.

Model 1 includes birth quarter only; Model 2 adjusts for sex, age category and championship year. Reference categories are Q4, female sex, U15 and 2022. Models 3a and 3b separately add birth quarter × age category and birth quarter × sex interactions to Model 2. Only interaction terms are displayed for these two models; all lower-order terms remain in the fitted models.

For Models 3a and 3b, exp(β) is a ratio of ORs: the quarter-versus-Q4 OR in U19 relative to U15, or in males relative to females, respectively. Global birth-quarter and interaction p values are joint three-df Wald tests. CI = confidence interval. Coefficient p values are two-sided; all p values are unadjusted; interaction analyses are exploratory. Athlete clustering does not model dependence between different athletes sharing team or doubles outcomes.

The ordinal models detected no statistically significant birth quarter × age-category interaction (global Wald $\chi^2(3) = 3.525$, $p = 0.318$) or birth quarter × sex interaction ($\chi^2(3) = 1.957$, $p = 0.581$). The interaction estimates in Table 9 are ratios of quarter-specific ORs; they did not establish that the quarter–rank association differed by age category or sex. These interaction tests concern medal rank among medalists only. The approximate threshold-specific diagnostic did not detect a departure from common slopes in the adjusted main-effects model (Wald $\chi^2(9) = 3.024$, $p = 0.963$), although this result does not prove that the proportional-odds assumption holds exactly.

4 Discussion

4.1 Principal Findings

The central finding was that neither the primary analysis of medal attainment nor the secondary analysis of medal rank detected a statistically significant birth-quarter association after adjustment for sex, age category, and championship year. This finding occurred alongside a small birth-quarter imbalance among participant appearances, with Q1 contributing more appearances than Q4. The two results are not contradictory: the distribution describes who reached the championship, whereas the outcome models compare success among athletes who competed. Greater representation of early-year births was therefore not accompanied by clear evidence of better medal outcomes within this selected population. However, the confidence intervals included potentially meaningful differences as well as no association. The study consequently provides an uncertain estimate of the quarter–outcome relationships at this competitive level, rather than evidence that relative age is irrelevant or that all quarters have equivalent prospects.[25,26]

4.2 Comparison with Previous Research

Previous racket-sport studies have not consistently linked birth quarter to performance.[13,27] In French top-100 youth table tennis players, Faber et al. found an association with performance trajectories only among U18 males; the other male age groups and all female groups showed no statistically significant associations.[13] Germič et al. similarly reported no significant quarter differences in ranking position or points across the age-by-sex groups of their Slovenian tennis sample, despite a birth-distribution imbalance among U18 males.[27] The present nonsignificant medal-outcome estimates are compatible with those findings in showing that an uneven birth distribution need not be accompanied by a detectable performance difference. Nevertheless, ranking position, longitudinal rating trajectories, and winning a championship medal are different outcomes. These studies provide contextual comparisons, rather than direct replications of the present analysis.

A stronger early-birth concentration has also been reported at higher ranking levels. Aku and Yang found a stronger concentration of early-year births in the year-end top-30 groups of Chinese junior male tennis players.[28] That finding concerns the composition of ranking groups and does not provide the same estimate as an adjusted model of medal attainment among confirmed championship participants. Likewise, the earlier-birth over-representation reported in the Turkish racket-sport study describes participation rather than medal success.[12] Differences in sampling level, sex and age composition, national selection systems, and the definition of performance may therefore help explain why the literature does not yield a uniform pattern.[10,15,16] The present results specifically concern success after entry into continental youth competition; they neither refute a possible association with earlier selection nor establish that associations found for ranking outcomes should extend to medals.

4.3 Possible Explanations for the Medal-Attainment Findings

One plausible explanation is selection before the championship. Athletes from every birth quarter had already progressed far enough to enter a continental event, so this sample excludes those not nominated or no longer participating. Selection may narrow differences in some performance-related characteristics and alter the relationship between birth quarter and success within the remaining group.[1,29,30] Relevant evidence comes from German junior tennis: Ulbricht et al. observed stronger early-birth over-representation at higher competitive levels, but no systematic quarter differences in maturity, anthropometry, or fitness among regional squad players.[31] This illustrates how a birth-quarter imbalance can coexist with no consistent detected quarter differences in measured physical characteristics within a selected group. It does not demonstrate that selection explains the present findings. Without data on the athletes who did not reach the championship, the study cannot determine whether a quarter-related advantage existed earlier, diminished during development, or was altered by selection.

A second possibility is that birth quarter provides only indirect information about the abilities required for medal success. In a nine-year follow-up of 39 young table tennis players, Faber et al. linked early ball-control skills, including eye–hand coordination and aiming at a target, with subsequent competition performance.[32] This supports considering sport-specific skill development when interpreting medal outcomes.[14] Within an already selected championship group, variation in technical proficiency, tactical decisions, training experience, and competition experience could make birth quarter alone a weak marker of the characteristics that distinguish winners from non-winners. However, none of these explanatory variables was measured in the present study, and their importance relative to birth quarter was not tested. This remains a hypothesis for further investigation; the nonsignificant results do not show that later-born players developed compensatory skills or that physical development no longer matters.

4.4 Possible Explanations for the Medal-Rank Findings

The absence of a statistically significant association with medal rank may also reflect the way this outcome was defined and the population in which it was analysed. The ordinal model included only athletes who had already won a medal, imposing an additional condition beyond championship participation. Within this group, the outcome distinguished three broad categories and retained only the highest medal per appearance. It does not capture match-level performance, all results across events, or total medal counts. Moreover, individual, doubles, and team medals were combined. A team member’s highest medal partly reflects the performance of teammates, and an athlete’s birth quarter need not correspond closely to that shared result. These features could make a birth-quarter relationship harder to detect or change its interpretation. They are possible measurement

and selection explanations, not evidence that a stronger association would necessarily emerge with a different outcome.

Limited estimation precision is another explanation that must be considered, particularly for medal rank. The adjusted Q3 versus Q4 OR was 1.70, but its 95% confidence interval ranged from 0.87 to 3.33. Thus, the data were compatible with no association and with a potentially substantial increase in the odds of a higher medal rank.[26] The 341 medal-winning appearances arose from 221 athletes, so the number of appearances should not be interpreted as an equal number of independent individuals. Pooled estimates may also combine heterogeneous competitive contexts, including different countries, events, and developmental stages. However, the available age and sex interaction tests did not establish such effect modification for medal rank. The appropriate interpretation is that the study did not resolve the association precisely, rather than that low precision or hidden subgroup effects have been proven to explain the nonsignificant result.

4.5 Interpreting the Exploratory Subgroup Findings

The Q3 concentrations among U19 female medalists and U19 gold medalists do not overturn the principal outcome findings. Their goodness-of-fit tests assessed whether particular medalist groups had uniform birth-quarter distributions; they did not directly estimate the probability that a Q3 participant would win a medal. The direct U19 quarter-by-medal-category comparison addressed a closer performance question, but remained an unadjusted appearance-level analysis that did not account for repeated athletes. By contrast, the main ordinal model adjusted for measured covariates and athlete clustering. The analyses therefore differ in their populations, questions, and treatment of dependence. Numerous exploratory comparisons also increase the possibility of chance findings.[26] In the absence of significant ordinal age or sex interactions, these subgroup patterns should be treated as observations for future confirmation, rather than evidence of a general Q3 advantage, a reversal of the RAE, or a developmental explanation for the nonsignificant overall associations.

4.6 Practical Implications

For talent identification, the practical implication is to separate access to high-level competition from success after selection. The greater representation of early-year births does not, by itself, justify expecting better medal outcomes from those athletes. Conversely, the present nonsignificant associations do not establish that selection opportunities or medal prospects are equal across birth quarters. Coaches and sporting organisations should interpret birth quarter alongside direct assessments of skills, training progress, and developmental context, rather than use it as a stand-alone indicator of medal potential.[14,33,34] Monitoring athletes before and after selection, including those who do not reach continental competition, would help distinguish possible selection-related imbalances from differences in subsequent performance.[8] Such follow-up is needed before recommending birth-quarter-based changes on the assumption that they will improve either competitive success or fairness.[35]

4.7 Limitations

Several limitations prevent a definitive explanation of the nonsignificant associations. The retrospective observational design cannot establish causal effects, and information on national selection policies, rankings, event exposure, training history, and technical proficiency was unavailable. These omissions limit the evaluation of the proposed selection and skill-related explanations and may introduce residual confounding. Birth quarter also does not measure biological maturity: research in male academy soccer players did not detect an

association between relative age and maturity status, illustrating why the two require separate assessment.[30,36,37] Furthermore, different birth years compete within U15 and U19, and adjustment for the broad age category does not control for those within-category age differences. Previous table tennis research has explicitly distinguished within-year and between-year effects.[38] Theoretical 25% quarter shares may differ from the relevant population birth distributions, and the calendar-quarter classification does not reconstruct athletes' earlier eligibility cut-offs.[17,23] Finally, the 19 excluded records represent participation unconfirmed in the available evidence, not necessarily absence from the championship.

The inferential limitations also require caution. Appearance-level chi-square tests and representation-ratio confidence intervals do not account for repeated athletes and were treated as exploratory. GEE accounted for repeated observations within ITTF IDs, but not additional dependence between teammates or doubles partners who shared medal outcomes; this may affect standard errors. The broad model confidence intervals do not establish equivalence across quarters, and the multiple subgroup comparisons were not adjusted for multiplicity.[25,26] The approximate proportional-odds diagnostic did not validate every interaction specification or prove model adequacy. Although retaining the highest medal avoided counting several event medals as separate athlete appearances, it discarded medal totals, unsuccessful event entries, and individual contributions to shared results. Larger linked datasets with pre-championship selection histories, direct skill and maturity measures, and event-level outcomes are needed to evaluate the proposed explanations and estimate birth-quarter associations more precisely.

5 Conclusion

At the 2022–2026 Asian Youth Table Tennis Championships, participant appearances showed a small birth-quarter imbalance, with Q1 more frequent than Q4. However, athlete-clustered models detected no statistically significant birth-quarter association with medal attainment or, among medalists, highest medal rank after adjustment for sex, age category, and championship year. These findings distinguish participant representation from success within a selected championship population. They do not demonstrate equivalent medal outcomes or establish why the associations were nonsignificant; selection, sport-specific abilities, outcome definition, and estimation precision remain possible explanations requiring further study.

Abbreviations

CI
confidence interval
GEE
generalized estimating equations
ID
identifier
ITTF
International Table Tennis Federation
OR
odds ratio
Q1–Q4
first to fourth birth quarters

RAE
relative age effect
U15
under-15 age category
U18
under-18 age category
U19
under-19 age category.

Declarations

Ethics approval and ethical standards: This retrospective observational study used publicly accessible official competition records and athlete information. No athletes were recruited or contacted, and no experimental intervention or prospective data collection was conducted. The study was conducted in accordance with the principles of the Declaration of Helsinki and the applicable institutional requirements of Beijing Sport University for research using publicly available archival data. The responsible institutional body was the Sports Science Experimental Ethics Committee of Beijing Sport University. The Committee determined that formal ethical review was not required because the study involved secondary analysis of publicly available archival data without direct recruitment, interaction, or intervention involving human participants.

Consent to participate declaration: Not applicable. This study involved secondary analysis of publicly available archival competition records and athlete information, with no direct recruitment, intervention, or contact with athletes.

Consent to publish declaration: Not applicable. No identifiable individual-level information is presented in this manuscript.

Clinical trial number: not applicable.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data Availability Statement: The datasets analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests: The authors declare that they have no competing interests.

Authors' contributions: H.L. is the first author, and Y.W. is the co-first author. H.L., Y.W., and J.N. jointly contributed to the conceptualization and design of the study, data collection and verification, data analysis and interpretation, and preparation of the manuscript. All authors contributed to drafting and critically revising the manuscript, approved the final version, and agreed to be accountable for all aspects of the work.

Acknowledgements: Not applicable.

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Figures

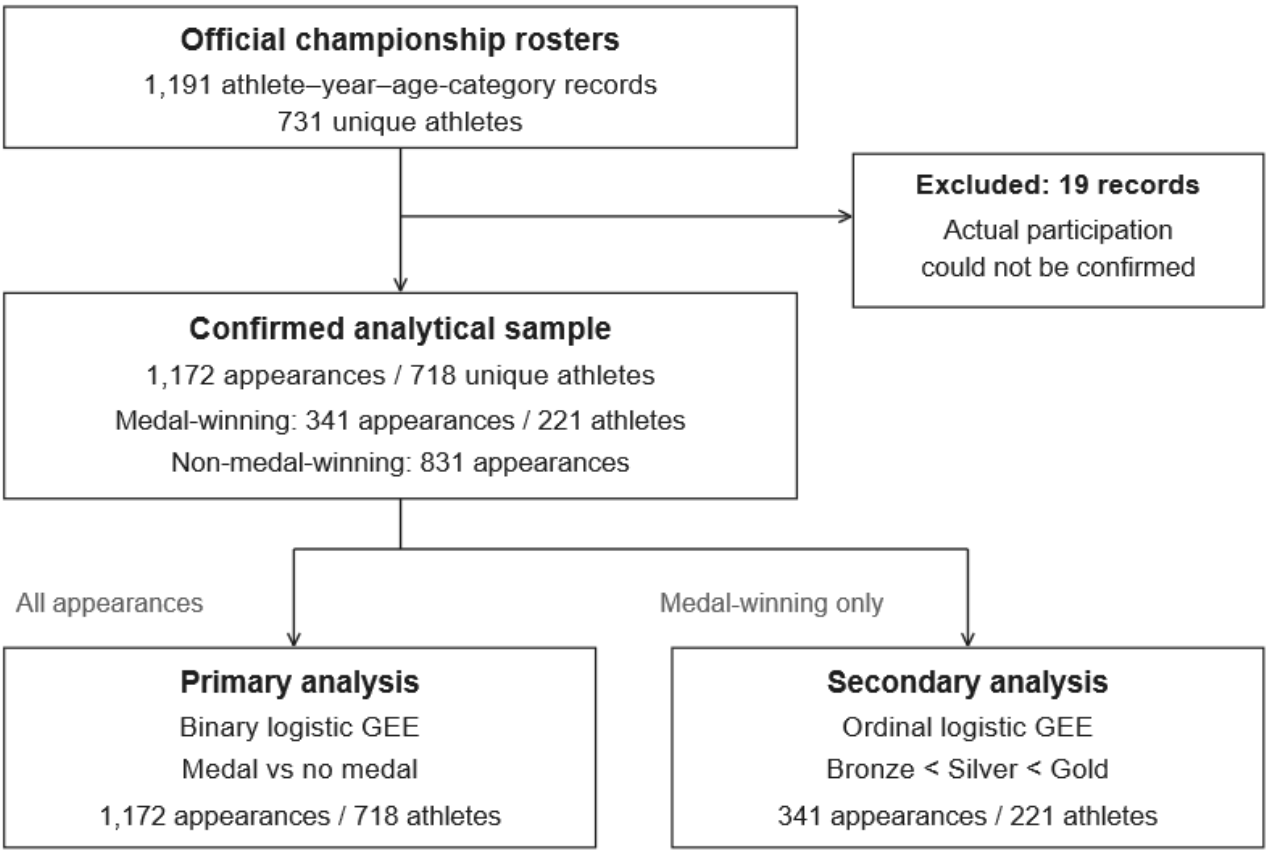

Figure 1

Flow diagram of participant identification, eligibility assessment, and analytical samples. An appearance denotes one athlete × championship year × age category. Multiple event entries within this key were counted once. Both GEE analyses were clustered by ITTF athlete ID; the ordinal analysis included only medal-winning appearances.

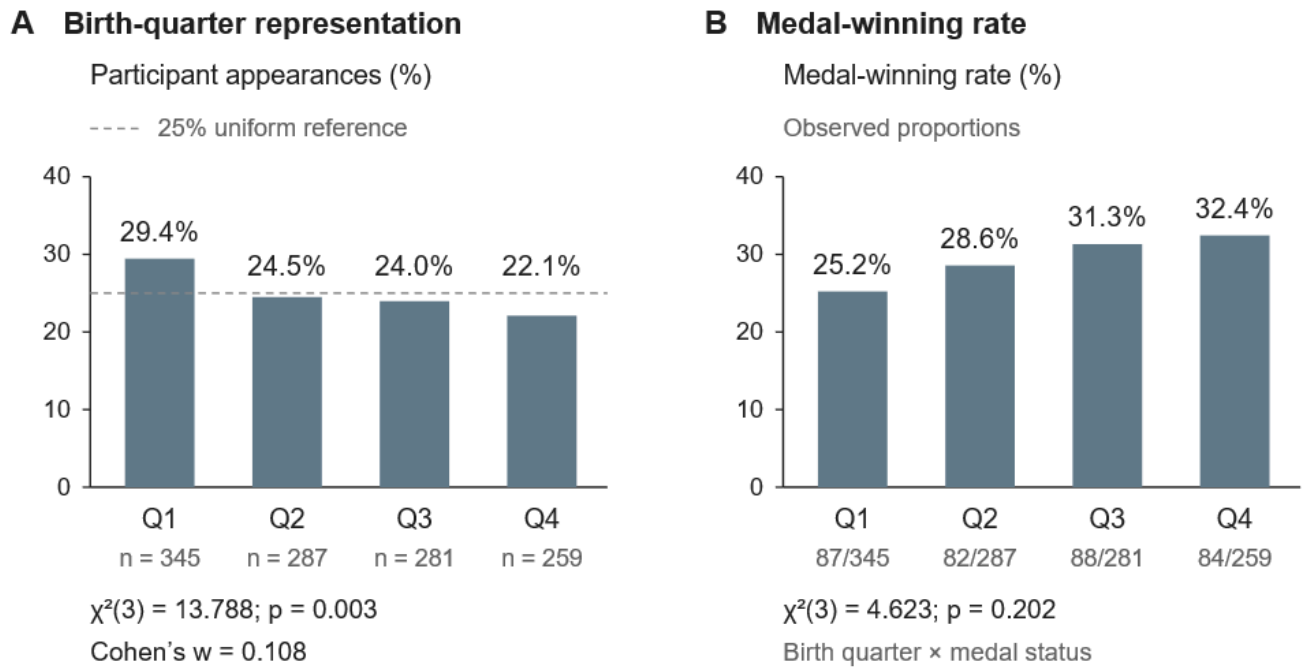

Figure 2

Birth-quarter representation and medal-winning rates among confirmed participants. (A) Distribution of 1,172 confirmed participant appearances across birth quarters; the dashed line denotes the theoretical uniform reference of 25% per quarter. (B) Observed medal-winning appearances divided by all participant appearances within each quarter, with numerators and denominators shown below the bars. Q1 = January–March; Q2 = April–June; Q3 = July–September; Q4 = October–December. The appearance-level χ^2 tests are exploratory and do not account for repeated athletes.

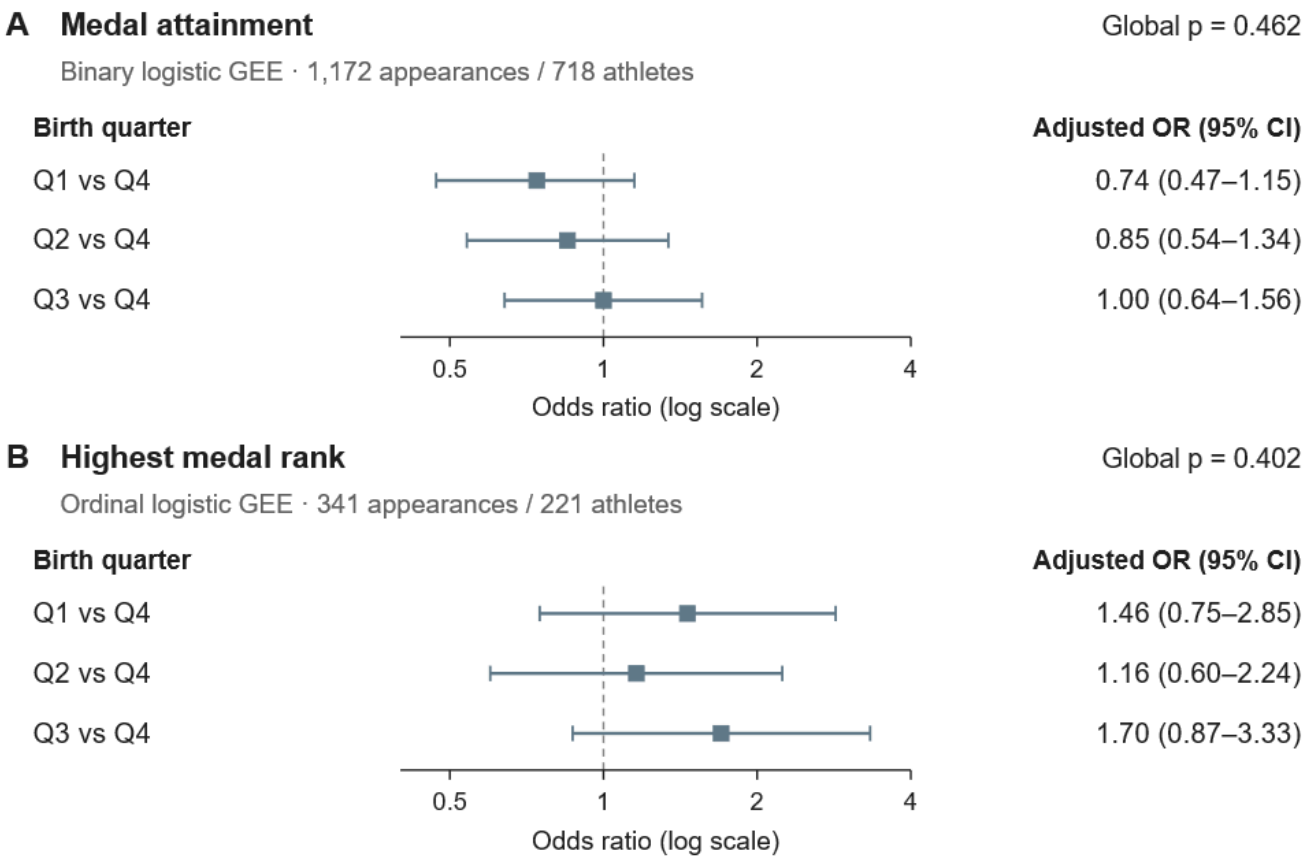

Figure 3

Adjusted associations of birth quarter with medal attainment and highest medal rank. (A) Binary logistic GEE among all confirmed participant appearances. (B) Ordinal logistic GEE among medal-winning appearances, with bronze < silver < gold. Squares and horizontal lines show adjusted odds ratios and 95% confidence intervals from Model 2 in Tables 4 and 9. Both models adjust for sex, age category, and championship year and use ITTF ID clusters with robust standard errors. Q4 is the reference; the dashed line denotes OR = 1. Global p values are joint three-df Wald tests of birth quarter.