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Title:

Relative age effects across and within female sport contexts: A systematic review and meta-analysis

By

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Relative age effects across and within female sport contexts: A systematic review and meta-analysis**Abstract**

Background: Subtle differences in chronological age within sport (bi-) annual-age groupings can contribute to immediate participation and long-term attainment discrepancies; known as the Relative Age Effect (RAE). Voluminous studies have examined RAEs in male sport; however, their prevalence and context-specific magnitude in female sport remain undetermined. *Study Objective:* To determine the prevalence and magnitude of RAEs in female sport via examination of published data spanning 1984-2016. *Methods:* Registered with PROSPERO (No: 42016053497) and using PRISMA systematic search guidelines, 57 studies were identified, containing 308 independent samples across 25 sports. Distribution data was synthesised using odds ratio meta-analyses, applying an invariance random-effects model. Follow-up subgroup category analyses examined whether RAE magnitudes were moderated by age-group, competition level, sport type, sport context and study quality. *Results:* When comparing the relatively oldest (Q1) v youngest (Q4) across all female sport contexts, the overall pooled estimate identified a significant but small RAE (OR 1.25; 95% CI = 1.21-1.30; $p = 0.01$; OR adjusted = 1.21). Subgroup analyses revealed RAE magnitude was higher in pre-adolescent (≤ 11 years) and adolescent (12-14 years) age groups and at higher competition levels. RAE magnitudes were higher in team-based and individual sport contexts associated with high physiological demands. *Conclusion:* Findings highlight RAEs are prevalent across the female sport contexts examined. RAE magnitude is moderated by interactions between developmental stages, competition level and sport context demands. Modifications to sport policy, organisational and athlete development system structure and practitioner intervention are recommended to prevent RAE-related participation and longer-term attainment inequalities.

Key points:

- Relative age effects (RAEs) have a small, but consistent influence on female sport.
- RAE magnitudes are moderated (i.e., increased or reduced) by the factors of participant age, competition level, sport type and sport context under examination.
- Modifications to the organisational structure of sport and athlete development systems are recommended to prevent RAE-related inequalities.

61 **Relative age effects across and within female sport contexts: A systematic review and meta-analysis**

62

63 **1 Introduction**

64 Whether considered from an athlete development or public health perspective, the dynamic factors that
65 influence sport participation and achievement are of key interest to researchers, policy-makers, sport
66 organisations and their practitioners. In terms of athlete development, Baker and Horton [1] highlight how the
67 path to expertise is a complex process, reflecting an interplay of direct (e.g., genetic makeup; quantity and
68 quality of training) and indirect factors (e.g., coaching knowledge and expertise; social-cultural milieu [2]). In
69 this process, one indirect factor - relative age - has emerged as a consistent influence on both immediate sport
70 participation and longer-term attainment [3-5].

71 With the goal of grouping children and adolescents according to similar developmental stages, one or
72 two-year chronological age groupings are common in youth sport. However, variations in age remain, leading to
73 participation and attainment (dis)advantages. Relative age effects (RAEs) [6-8] refer to those (dis)advantages
74 and outcomes that fundamentally result from an interaction between one's birthdate and the dates used to
75 logistically organise participants [9]. Sporting RAE's in junior and youth athlete participants are commonly
76 reflected by an over-representation of the relatively older. The relatively older are advantaged in terms of
77 athletic selection and achievement [10], but may also be at greater risk of injury due to the increased sport
78 exposure associated with higher competitive levels, such as an increased number of games/matches and training
79 time [11]. While RAEs and selection biases can lag into adult sports, recent evidence suggests that in the long-
80 term the relatively older are less likely, in proportion to those selected in athlete development programs, to go
81 on to attain elite sporting echelons [4, 12, 13]. Thus, both perceived advantages and disadvantages of RAEs are
82 undesirable for athlete development [14].

83 **1.1 Brief background on RAEs**

84 RAEs were initially recognized in the education system [15-17] and only identified in sport some
85 several decades later. Grondin, Deschaies and Nault [18] first reported an unequal distribution of birthdates
86 among Canadian ice hockey players. Across various skill levels, those born in the first quartile¹ of a same-age
87 group were over-represented relative to those born in the last quartile. At a similar time, Barnsley and colleagues
88 observed comparable relative age inequalities in 'top tier' minor hockey teams (i.e., 11 years and older) [19],

¹ The first quartile corresponds to the first three months following the sport-designated cut-off date used to group participants by age. For instance, the first quartile in a system using August 1st as a cut-off would correspond to August, September and October.

89 Canadian elite developmental and National Hockey League [6] players. Since these early studies, RAEs have
 90 been identified across a variety of team sport and cultural contexts including North American and European ice
 91 hockey [20-22] as well as soccer [23, 24] and rugby worldwide [10, 25, 26]. RAEs are also documented in
 92 individual sports such as swimming [27, 28], tennis [27, 29, 30] and Alpine skiing [31, 32]. That said, RAEs are
 93 not ubiquitous as the effect has not been consistently observed in adult senior professional sport [33, 34] and is
 94 absent in sports dependent on technique or skill rather than physical attributes *per se* (e.g., golf [35]; shooting
 95 sports [36]).

96 In a prior meta-analysis of research evidence (spanning studies published from 1984-2008), the relative
 97 age distribution of 130,108 (predominantly male) sport participants from 253 independent samples contained
 98 within 38 studies from 16 countries and 14 sports were examined [37]. Consistent overall RAEs were identified
 99 with a small-moderate effect size (Quartile 1 (Q1) vs Q4 odds ratio (OR)² = 1.65, 95%CI 1.54-1.77). Further,
 100 subgroup analyses revealed that age, competition level and sport context moderated RAE magnitude.
 101 Specifically, RAE risk increased with age from child (> 11 years; OR estimate = 1.22) to adolescent (15-18
 102 years; OR = 2.36) age categories, before declining at senior levels (\geq 19 years OR = 1.44). RAEs increased from
 103 recreational (OR = 1.12) to pre-elite (OR = 2.77) competition levels; though with a lower risk in adult elite
 104 contexts (OR = 1.42). Five team sports exhibited consistent Q1 v Q4 over-representations with the highest
 105 magnitudes associated with basketball (OR = 2.66), soccer (OR = 2.01) and ice-hockey (OR = 1.62). Findings
 106 from this review subsequently contributed to the focus and emphasis of onward RAE studies, including
 107 recommendations for examining female sport contexts.

108 **1.2 Explanations for RAEs**

109 In their narrative review, Musch and Grondin [7] proposed that the underlying causes of RAEs were
 110 potentially multi-factorial, referring to a combination of physical, cognitive, emotional, motivational and social
 111 factors. Whilst acknowledging this possibility, the most common data-driven explanations have been associated
 112 with two interacting processes, notably maturation and selection (i.e., the 'maturation-selection' hypothesis) [9,
 113 24, 37, 38]. The hypothesis suggests that greater chronological age is accompanied by favourable
 114 anthropometric (e.g., stature) and physical (e.g., muscular strength) characteristics, which may provide sporting
 115 performance advantages (e.g., soccer) [24]. While recognizing that maturational processes can deviate

² An odds ratio (OR) represents the odds, or likelihood, that an event will occur in one group compared to another. In this instance, the OR represents the odds that an athlete will be born in the first quartile (i.e., following a sport cut-off date) compared to the fourth quartile. An OR of one (1.00) would indicate that the outcome under investigation is equal in both groups, while an OR of two (2.00) would indicate the event is twice as likely to be observed in one compared to the other.

116 substantially between individuals, it is conceivable that a relatively older individual may experience puberty-
117 associated transformations (e.g., generally 12-14 years in girls and 13-15 years in boys [37, 39-42]) prior to
118 relatively younger peers. From this point and until maturation termination, the anthropometric and physical
119 variations between similar age-peers may be exacerbated further. During this time, the relatively older and/or
120 early maturing individual may appear more talented as a result of anthropometric/physical advances rather than
121 skill level, and be selected for representative levels of sport. With selection, additional benefits may occur such
122 as access to higher quality training and coaching expertise [38]; which translate into further advantages in terms
123 of sport-specific skills and experience. For the relatively younger and later maturing, overcoming the physical
124 and performance advantages may be extremely challenging in sports system structure incorporate stable and
125 fixed (bia-)annual age grouping policies and accompanying selection and competition calendars [43, 44].

126 Due to maturation-selection processes, RAEs are highlighted as discriminating against the relatively
127 younger and later maturing [45], and are implicated in eliminating athletic potential before having the
128 (equitable) opportunity to develop sport expertise [37, 39]. In fact, it has been proposed that the relatively
129 younger are more likely to encounter negative sport experiences and terminate sport participation earlier [46];
130 particularly at stages when selection and representative tiers of participation are introduced in athlete
131 development systems [14]. Such discrepancies are not surprising when social-cultural values emphasise elitism,
132 which may continue to drive selection and talent identification processes despite negative outcomes (e.g., injury
133 and burnout [47, 48]) and the low predictability of success even at the pre-elite level [49, 50].

134 Though with a lesser volume of supporting evidence, psychological [51] and socio-cultural
135 explanations [7] have also been highlighted [22, 52, 53]. For instance, the 'depth of competition' hypothesis
136 describes how the ratio of players available for playing rosters and positions could influence an individual's
137 likelihood of participating or being selected for team membership. If a significant imbalance is present (i.e., a
138 high number of athletes are competing for a small number of playing opportunities), the level of competition
139 experienced by players striving to obtain a position is inflated, potentially magnifying the influence of relative
140 age within a cohort. Therefore, the interest (or popularity) and availability (resource) imbalance in a sport
141 system could account for RAE magnification [7, 52, 54, 55]. Parental influence may also attenuate trends at the
142 time of initial sport involvement [9]. Some evidence suggests parents may be hesitant to register a later-born
143 (potentially physically smaller) child in the early years of participation, as reflected in lower registration
144 numbers of relatively younger participants [20, 56]. Selection processes are also notably absent at these early

145 levels, and emphasis is placed on participation and beginner skill development. Thus, the contributing
146 mechanisms outlined in the ‘maturation-selection’ hypothesis should be negligible.

147 **1.3 Rationale for a meta-analysis**

148 It has frequently been reported that RAE magnitudes are greater in male than female samples [39],
149 even when participation numbers are equal [52]. This may be a reasonable conclusion when the breadth of sport
150 differences between the sexes is considered (e.g., media attention, sport-specific funding, cultural acceptance of
151 athletes, level of physicality etc.), in addition to the proposed influences from maturation. Yet in Cobley et al.’s
152 meta-analysis [37], findings suggested little evidence of overall sex difference in pooled odds ratio estimates;
153 though only 2% of participants (24 samples) had been tested for RAEs in female sport in 2008. What therefore
154 remains unknown is whether RAEs are prevalent across and within female sport contexts; their effect
155 magnitude; contexts associated with higher and lower RAE risk; and akin to male sport contexts, whether
156 developmental time points are associated with higher RAE effect sizes. There has been a surge in female
157 samples in published literature and a review of female RAE studies is therefore timely and necessary to answer
158 these questions.

159 **1.4 Study objective**

160 The purpose of this systematic review and meta-analysis was to determine RAE prevalence and
161 magnitudes across and within female sport participation. To achieve the objective, published literature (1984-
162 2016) examining relative age (quartile) distributions in female sports were synthesised using odds ratio analyses.
163 To identify moderators of RAE magnitude, identified samples were analysed in subgroups according to age,
164 competition level, sport type and sport context categories. Based on existing literature, it was hypothesised that
165 RAEs were prevalent across female sport; and, that the highest RAE risks in female sport contexts would be
166 observed immediately prior to and during adolescence (i.e., 12-14 years of age) in comparison to early
167 childhood and post-maturation/adult samples. RAEs were also expected to increase with selection across
168 representative (competitive) tiers of sport participation. RAE magnitudes were expected to then progressively
169 minimise following maturation (i.e., beyond 15 years of age) and remain low in recreational sport. At higher
170 competition levels, it was expected that RAEs would persist through pre-elite levels though reducing with age
171 and entry into professional contexts.

172

173 **2 Methods**

174 Procedural steps employed in completing the systematic and meta-analytical review adhered to both the
175 Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines [57] and
176 PROSPERO guidelines (Registration No: 42016053497).

177 **2.1 Inclusion & exclusion criteria**

178 Inclusion criteria stipulated that only peer-reviewed studies examining RAEs in female sport contexts
179 would be included. Studies could be in any language and assess any age range, level or form of participation
180 (e.g., elite or recreational). Studies examining associated topics (e.g., maturation or sport dropout) were included
181 if they explicitly reported relative age distributions or reported RAE trends. Studies were excluded if they: (1)
182 exclusively examined male athletes or sex was not identified; (2) failed to report relative age distribution on
183 their participants; (3) examined RAEs in school sport or physical education; (4) examined other outcomes (e.g.,
184 fitness, fundamental movement skills, physical activity); (5) examined RAE interventions or solutions; (6)
185 included older (Master) athletes where participation distributions were confounded by ageing processes; (7)
186 examined other developmental or behavioural outcomes (e.g., leadership, anxiety); (8) examined cognitive
187 performance (e.g., chess).

188 **2.2 Systematic search**

189 Published RAE studies were identified via systematic searching of electronic databases, scanning the
190 reference lists of identified papers and existing meta-analyses [37, 58], and reviewing email alerts from research
191 databases. Six electronic databases were searched: CINAHL, Medline via OVID, Scopus, Sports Discus, Web of
192 Science, and PsycINFO (APAPsycNET) with no restriction on publication date. Search terms were categorised
193 into three groups: (i) Relative age (relative age OR relative age effect* OR age effect* OR birthdate/birth date
194 effect* OR season of birth OR RAE OR age position); AND (ii) Female (e.g., female* OR girl* OR wom?n);
195 AND (iii) Sport (sports/sport* OR game* OR league*). Results were then limited to (i) humans, and (ii) female.
196 The search process was completed between January-March 2017. Following the search, the first author (KS)
197 removed duplicates and screened titles/abstracts. If there was uncertainty as to whether inclusion criteria were
198 met, study eligibility was determined by KS and SC. The majority of these studies were published in English;
199 though two were found in Spanish; and one each in Chinese and French respectively. The Spanish papers were
200 translated using Google Translate©. The Chinese study was reviewed by a native speaker, while the French was
201 reviewed by a bilingual Canadian. Refer to Figure 1 for a summary of study screening and selection.

202 *(Insert Figure 1 about here)*

203 **2.3 Data extraction**

204 The systematic search yielded 57 studies spanning 1984-2016 and specific information was then
 205 extracted, including: Author(s), year of publication, location, sample characteristics (e.g., age, nationality,
 206 number of participants), sport setting (e.g., type of sport, level of competition), competition year, method of
 207 grouping athletes, relative age distributions (e.g., quartiles) and the distributions used for comparison purposes
 208 (e.g., 25% per quartile, population birth rates etc.). Corresponding authors were contacted when any information
 209 was not provided or where further clarity was needed (e.g., age or competition level)³. In total, 22 authors were
 210 contacted. Nine provided requested information; seven were unable to provide required information (e.g., data
 211 no longer accessible); four failed to respond, and two could not be located. Data from 44 of the 57 studies were
 212 used where possible in overall meta and subgroup analyses. In cases where participant numbers were not
 213 reported, but presented in tables or figures, estimates were extracted⁴. Samples that could not be utilized due to
 214 missing information were still assessed for methodological quality and reported in review summary tables.

215 **2.4 Study quality assessment**

216 An adapted version of the Strengthening the Reporting of Observational Studies in Epidemiology
 217 (STROBE) checklist [59] determined the quality of study reporting. The checklist included 14 items grouped
 218 into five categories: Abstract, Introduction, Methods, Results, and Discussion. A score of '0' for "absent or
 219 insufficient information provided" or '1' "item is explicitly described" was assigned to items. An overall score
 220 of 5-9 was considered 'lower quality;' 10-11 'medium quality;' and 12-14 'high quality' [60]. Two independent
 221 reviewers (KT and MR) completed study quality assessment. Rating disagreements were resolved by KS and
 222 inter-rater reliability calculated.

223 **2.5 Meta-analyses: Data inclusion & exclusion**

224 Data identified from the systematic search was included in meta-analyses. Inclusion criteria specified
 225 that with the exception of elite national levels, samples had to have examined ≥ 50 participants in a given age
 226 category or competition level, to help avoid artificially inflating RAE estimates. Where samples of < 50
 227 participants were apparent, but multiple independent samples in the sport context were reported (e.g., age
 228 categories - Under 14, 15 and 16), these were collapsed in alignment with sport-designated age categories. Data

³ Identification of sample age and/or an age-group breakdown were the most common sources of missing information.

⁴ Participant numbers were estimated from tables (i.e., overall sample numbers and percentage of participants per quartile were provided, but raw numbers per quartile were not available) by calculating an estimation of the number per quartile using the available values and rounding to the nearest whole number if required. Participant numbers were estimated from figures (i.e., presented in a graph but raw numbers per quartile not provided) by extrapolating from the graph using a ruler and rounding to the nearest whole number if required. Estimated samples within studies are coded and highlighted in Table 3.

229 from two studies were modified this way [25, 61]. Sport contexts where a participant may have been present in
 230 several samples, due to multiple event entries (e.g., Breaststroke and Freestyle in swimming) were included as
 231 this was reflective of the organisational structures employed in the respective sport. However, studies that
 232 examined RAEs in multi-sport samples and a broader overall athlete population (e.g., Youth Olympic Games)
 233 were excluded due to inherent variability and small sample size. Further, to keep the analysis relevant to modern
 234 participant trends, samples derived from archival data prior to 1981 were excluded. This competition year
 235 coincided with the first documented evidence of RAEs in sport [18], and corresponded to birthdates from the
 236 early 1960s onward. When applied, criteria yielded 308 independent samples from 44 studies. Retained samples
 237 examined 25 different sport contexts in at least 17 countries⁵. A range of junior-adult ages and a variety of
 238 competition levels (i.e., local community recreational - adult elite professional) were included.

239 2.6 Meta-analyses

240 All data extracted were analysed using Comprehensive Meta-Analysis software (Biostat, Inc. 2005).
 241 An Odds Ratio (OR) estimate, along with log odds ratio and standard error were calculated for each independent
 242 sample. For each sample, the relative age distributions observed (i.e., n Quartile 1 v n Quartile 4 participants)
 243 were compared relative to an expected frequency assuming equal distributions (e.g., $N = 100$, expected quartile
 244 count = $100/4 = 25$). When comparing relative age quartiles in analyses, Quartile 4 (i.e. relatively youngest)
 245 acted as the reference. Overall summary estimates were calculated using an invariance random-effects model
 246 [62], with the assumption that samples across studies were drawn from divergent populations across different
 247 sport contexts. Thus, an exact effect size was not expected to exist across samples.

248 Pooled OR estimates along with accompanying 95% confidence intervals indicated whether overall
 249 effects existed in a given analysis. Accompanying Z and p values tested the null hypothesis that OR estimates
 250 between relatively older and younger distributions (i.e., Q1-Q3 v Q4 comparisons) were not statistically
 251 different. The Cochran Q statistic⁶ [63] (with df and p) tested whether all studies shared a common effect size. I^2
 252 identified the proportion of observed variance reflecting differences in true effect sizes as opposed to sampling
 253 error. Moderate (> 50%) to high values (> 75%) were used to indicate value in subgroup analyses and to account
 254 for potential heterogeneity sources. T^2 provided the estimate of between-study variance in true effects, and T

⁵ Seventeen different countries were named in the literature. However, the total number represented may be larger as some studies reported “international” samples or participants from “across Europe.”

⁶ The Cochran Q test [63] assesses true heterogeneity in a meta-analysis. In essence, Q is a measure of dispersion of all effect sizes (individual studies) about the mean effect size (overall pooled effect) on a standardised scale.

255 estimated the between-study standard deviation in true effects. When heterogeneity was detected, sources were
 256 explored using sub-stratification analysis with specific application to Q1 v Q4 data.

257 To determine the presence of publication bias, funnel plot asymmetry⁷ was assessed with Log OR
 258 estimates plotted against corresponding standard error. The Egger test [64] confirmed asymmetry; as a result,
 259 Duval & Tweedie's 'trim and fill' procedure⁸ [65] was applied to determine whether estimates required
 260 adjustment based on missing studies. Asymmetry assessments and adjustments for all comparisons (i.e., Q1-Q3
 261 v Q4) are reported.

262 **2.7 Sub-stratification (subgroup) analyses**

263 To determine whether age moderated Q1 v Q4 pooled OR estimates, samples were categorised as pre-
 264 adolescent (≤ 11 years), adolescent (12-14 years [37, 39-42]), post-adolescent (15-19 years) and adult (> 19
 265 years of age⁹). Samples where ages spanned across categories were excluded from the analysis. To determine
 266 whether competition level moderated OR estimates, all samples were categorised based on an adaptation from
 267 Cogley et al. [37]: recreational (i.e., typified by an absence of selection or official competition), competitive
 268 (i.e., local community level with structured competition), representative (i.e., regional or provincial
 269 representative levels based on selection) and elite (i.e., competition at an international level or a career athlete).
 270 Elite was further subdivided into adolescent, post-adolescent, adult and combination categories; following age
 271 divisions outlined above. If competition level was unclear, data was added to a 'not codable' subgroup for
 272 analysis. To determine if the type of sport context moderated OR estimates, samples were categorised into team
 273 and individual types. Consistent with prior work [67], team sports were those often played with multiple team
 274 members (i.e., more than one participant per team), and individual sports were those involving a single
 275 participant in a given event or in direct competition against another. Individual sports were further subdivided
 276 into those deemed physically demanding (i.e., predominantly determined by strength or endurance for example
 277 [68, 69]); technique or skill-based sports, typically identified by judging of movement criteria [68, 69]; and
 278 contexts utilising weight-classifications or categories [70]. To determine whether particular sport contexts

⁷ A funnel plot is a scatter plot of treatment effect (e.g., odds ratio) set against a measure of study size (e.g., standard error). It provides an initial visual aid to detect bias or systematic heterogeneity. In the absence of heterogeneity, 95% of the studies should lie within the funnel defined by the two diagonal lines. Publication bias is suggested when there is asymmetry in the plot.

⁸ 'Trim and fill' uses an iterative procedure to remove the most extreme (small) studies from the positive side of the funnel plot, re-computing the effect size at each iteration until the funnel plot is symmetric about the (new) effect size. In theory, this yields an unbiased estimate of the effect size. While trimming yields the adjusted effect size, it also reduces the variance of the effects, yielding a (too) narrow confidence interval. Therefore, the algorithm then adds the original studies back into the analysis and imputes a mirror image for each [65].

⁹ The 90th percentile female attains adult stature at 20 years old when a criterion of four successive six-month increments < 0.5 cm is utilized [66].

279 moderated RAEs, data related to each sport context (e.g., volleyball, swimming etc.) were combined and pooled
 280 estimates generated. Finally, to determine if study quality moderated pooled estimates, samples were
 281 categorised into three groups (i.e., lower quality, scores 5-9 = 13 studies; medium, scores 10-11 = 23 studies;
 282 and, higher, scores 12-14 = 21 studies) based on a tertile division of the overall scores obtained on the study
 283 quality assessment criteria, as outlined in sub-section 2.4.

284

285 **3 Results**

286 **3.1 Studies systematically identified**

287 Figure 1 summarises the systematic search and study selection process. Initial database searches
 288 identified 1,806 studies with 12 studies identified through other sources. Following title and abstract screening,
 289 89 full-text articles were selected for further review. Twenty-one of these were removed as they examined male
 290 sport contexts (not reported in abstracts); while 11 were removed as they did not report relative age (quartile)
 291 comparisons (see Figure 1). Overall, 57 studies met inclusion and reporting criteria¹⁰.

292

(Insert Figure 1 about here)

293 **3.2 Study quality**

294 Table 1 summarises study quality ratings assessments. Twenty-one of 57 (36.8%) were considered
 295 'higher quality' according to the RAE-modified STROBE checklist [59]. Twenty-three (40.4%) were deemed
 296 'medium quality.' Thirteen studies (22.8%) were considered 'lower quality;' due to limited reporting of
 297 methodological and analysis details. Criteria commonly absent in reporting were related to the handling of
 298 missing data and/or duplicate entries for an individual athlete (i.e., when multiple competition years are assessed
 299 from the same sport context and an athlete may be represented on multiple rosters); an absence of post-hoc
 300 comparisons between quartiles; reporting of effect size; and, not identifying study limitations/biases. The inter-
 301 rater correlation between KS and independent reviewers was 0.92 and 0.88 respectively.

302

(Insert Table 1 about here)

303 **3.3 Summary of sample distributions**

304 With consideration of the annual cut-off dates employed in each respective sport context (e.g., August
 305 1st, January 1st etc.), the descriptive relative age distributions for the total sample of 646,383 female sport
 306 participants (former or present) in 308 independent samples identified an uneven distribution (i.e., Q1 =

¹⁰ Fifty-seven studies met inclusion criteria for the systematic review; 44 had useable data that could be included in the overall meta and subgroup analyses.

307 25.97%; Q2 = 26.32%; Q3 = 25.13%; Q4 = 22.58%). Table 2 provides a summary of unadjusted odds ratio
 308 estimates for each independent sample within each study.

309 *(Insert Table 2 about here)*

310 Table 3 summarises the distribution of total sample numbers according to subgroup categories.
 311 Samples were fairly evenly distributed across age categories, with adult (> 19 years; 5.58%) and post-
 312 adolescence (15-19 years; 30.53%) containing the lowest and highest numbers respectively; with 13% approx.
 313 not readily age-categorised (i.e., sample age crossed the designated age groupings for subgroup analyses). In
 314 terms of competition level, 57.12% contained recreational level participants, with considerably smaller
 315 competitive (7.32%), representative (1.87%), elite adolescent (12-14 years; 0.08%), elite post-adolescent (15-19
 316 years; 0.83%), elite adult (> 19 years; 0.34%) and elite combination (i.e., not codable by age; 2.43%)
 317 involvement. Thirty percent of sample numbers could not be clearly coded into a competition level category,
 318 mainly due to limited contextual information provided in study reporting. For sport type, samples were evenly
 319 distributed (154) between team and individual sport contexts. Within the individual subcategories, more samples
 320 (28.57%) and participant numbers (51.42%) were engaged in physically demanding contexts. Meanwhile,
 321 technique/skill-based and weight-categorised contexts contained 3.93% and 0.37% of total participants
 322 respectively. The sport contexts with the largest sample sizes represented (in order) were: Alpine skiing (31.2%
 323 of athletes), basketball (16.9%), ice hockey (12.4%), soccer (11.5%), tennis (9.63%) and track and field
 324 (9.56%).

325 *(Insert Table 3 about here)*

326 **3.4 Meta-analyses**

327 Based on 44 studies containing 308 independent samples, overall pooled data comparing participation
 328 distributions of the relatively oldest (Q1) v relatively youngest (Q4) identified a significant, but small, OR
 329 estimate = 1.25 (95%CI = 1.21-1.30; $Z = 13.74$, $p = 0.0001$), suggesting the relatively older were 25% more
 330 likely to be represented. The Q statistic of 2135.50 ($df = 307$, $p = 0.001$) highlighted the true effect size was not
 331 similar across samples. $I^2 = 85.62$ indicating approximately 85% of variance in the observed effects were due to
 332 true effects, while T^2 and T were 0.04 and 0.21 (in log units) respectively. A similar RAE magnitude was
 333 identified for Q2 v Q4 (i.e., OR = 1.24; 95%CI = 1.21-1.27, $Z = 15.75$, $p < 0.01$) before reducing for Q3 v Q4
 334 (OR = 1.13; 95%CI = 1.11-1.15, $Z = 14.18$, $p < 0.01$) respectively. Akin to the Q1 v Q4 findings, heterogeneity
 335 was apparent (Q2 v Q4 $Q = 1335.29$, $df = 307$, $p < 0.01$, $I^2 = 77.02$; Q3 v Q4 $Q = 513.2$, $df = 307$, $p < 0.01$, $I^2 =$
 336 40.24). Descriptive Q2 total participation numbers were marginally higher than Q1; thus, a Q1 v Q2 comparison

337 was also conducted. No overall pooled OR differences were identified 0.99 (95%CI = 0.97-1.01; $Z = -1.21$, $p =$
 338 0.23). As evidence for heterogeneity was consistent, follow-up subgroup stratification analyses examined their
 339 potential sources using Q1 v Q4 data.

340 The asymmetry of funnel plots suggested publication bias was apparent. Inspection of Figure 2
 341 revealed that estimates with larger samples and more precise comparative estimates between Q1 and Q4
 342 frequencies were distributed about the overall estimate. Further, there was a comparative absence to the 'left' of
 343 the pooled estimate in terms of less precise studies with more conservative estimates for Q1 v Q4 proportions.
 344 Asymmetry potentially may also have occurred as smaller powered published samples may have inflated pooled
 345 effect size estimates, resulting in a slight overestimation of the actual trend. Studies containing the largest
 346 samples were clustered symmetrically around overall effect size estimates. The Egger test for Q1 v Q4
 347 confirmed asymmetry (intercept = 0.91, SE = 0.20, $p < 0.01$). Duval and Tweedie's "trim and fill" procedure
 348 provided an adjusted pooled estimate = 1.21 (95%CI 1.15-1.25; $n = 39$ imputed samples). Nonetheless, the
 349 adjusted estimate remained significant and close to the original. Similar results were evident for Q2 v Q4
 350 (adjusted OR = 1.19, 95%CI = 1.16-1.22; $n = 34$) and Q3 v Q4 (adjusted OR = 1.11, 95%CI = 1.09-1.13; $n =$
 351 38). The follow-up Q1 v Q2 comparison did not suggest asymmetry was apparent ($p < 0.10$).

352 **3.5 Sub-stratification (subgroup) analyses**

353 For a summary of Q1 v Q4 subgroup analyses according to moderating factors, refer to Table 4.

354 *(Insert Table 4 about here)*

355 **3.5.1 Age**

356 When stratified according to defined age categories (i.e., pre-adolescent to adult), significant pooled
 357 OR estimates were apparent in all categories, except adults (> 19 years). Q1 v Q4 OR estimates were similar in
 358 pre-adolescent (≤ 11 years) and adolescent (12-14 years) categories (OR = 1.33 and 1.28), before reducing by
 359 14% in post-adolescence (15-19 years) and becoming insignificant in adulthood. The between groups Q statistic
 360 and p -value suggested changes were significant. Total within-age subgroup variance and heterogeneity estimates
 361 identified subgroups did not share a common effect size and substantial dispersion was apparent within pre-
 362 adolescent, adolescent and post-adolescent categories. When studies containing samples that traversed the
 363 designated age groupings were independently assessed, a similar estimate ($n = 79$, OR = 1.37, 95%CI = 1.29-
 364 1.46) to the overall pooled estimate was evident, and a common effect size was not apparent.

365 **3.5.2 Competition level**

366 When stratified according to competition level (i.e., recreational to elite combined), significant OR
 367 estimates were consistently apparent with OR's ranging from 1.08 (recreational level; $n = 76$ samples) – 2.70
 368 (elite adolescent; $n = 5$). OR estimates increased with competition level, prior to an OR reduction at the elite
 369 adult stage. In samples traversing competition categories ($n = 56$), the OR = 1.19 was similar to the recreational
 370 level. Changes identified across subgroup categories were regarded as systematic ($Q = 77.09$; $p = 0.0001$). Total
 371 within subgroup variance and heterogeneity estimates identified high dispersion was apparent (or a high
 372 proportion of variance remained unexplained) in the recreational and 'not-codable' categories ($I^2 = 92.71$ and
 373 84.62). Moderate-high heterogeneity was apparent in competitive, representative, elite post-adolescent and 'elite
 374 combined' subgroup categories. Whilst acknowledging fewer samples in elite adolescent and elite adult
 375 categories, a more common effect size was estimated as lower/no evidence of estimate dispersion was apparent.

376 3.5.3 Sport type

377 When samples were stratified according to individual v team sports, subgroup differences were
 378 apparent ($p = 0.001$), as team sports were associated with higher RAE estimates (OR = 1.33 v 1.18). A large
 379 proportion of variance within the subgroups was unexplained ($I^2 = 88.70$ and 77.79), and when individual sports
 380 were further analysed, significant estimates remained for physically demanding sports (OR = 1.23). Meanwhile,
 381 technique/skill-based (OR = 1.06) and weight-categorised (OR = 1.18) sport types were generally not associated
 382 with RAEs. The proportion of variance still unexplained was reduced for technique/skill and weight-categorised
 383 ($I^2 = 51.77$ and 19.81, respectively), but remained high for physically demanding sports ($I^2 = 92.82$).

384 3.5.4 Sport context

385 Table 5 summarises Q1 v Q4 subgroup analyses according to more specific sport contexts. Of the 25
 386 sports examined to date, 15 had ≥ 6 independent samples available for analysis. Nine of these had pooled OR
 387 estimates exceeding the overall pooled OR estimate (1.25). Those most notable with higher Q1 representations
 388 were volleyball (OR = 1.81), swimming (OR = 1.67), handball (OR = 1.41) and ice-hockey (OR = 1.39). In
 389 contrast, contexts associated with no RAEs included table tennis (OR = 0.85), gymnastics (OR = 1.06), rugby
 390 (OR = 1.07), shooting (OR = 1.07) and snowboarding (OR = 1.16).

391 *(Insert Table 5 about here)*

392 3.5.5 Study quality

393 When stratified according to study quality, effect sizes again differed ($p = 0.001$). Lower quality rated
 394 studies ($n = 38$ samples from 13 studies, OR = 1.63) had significantly higher OR estimates than medium (n
 395 samples = 92 from 23 studies, OR = 1.29) and higher quality rated studies (n samples = 178 from 21 studies; OR

396 = 1.19). The finding suggests that studies with lower rated methodological and reporting qualities were more
397 likely to be associated with higher RAE Q1 v Q4 OR estimates. Again, across studies categorised as medium
398 and higher quality, a large proportion of variance remained unexplained (refer to Table 4).

399

400 **4 Discussion**

401 **4.1 Overview of main findings**

402 The present study represents the most comprehensive systematic review and meta-analysis of RAEs
403 amongst female sport participants and athletes to date. The primary objective was to determine RAE prevalence
404 and magnitude across and within female sport. The secondary objective was to determine whether moderator
405 variables affected RAE magnitude. Based on data available, findings identified RAEs are consistently prevalent
406 in female sport contexts, with 25% (21% adjusted) more relatively older (Q1) participants than relatively
407 younger (Q4). Compared to males, and generally speaking, findings identified a smaller overall RAE
408 magnitude. Nonetheless, the factors of age, competition level, sport type and context significantly moderated
409 overall RAE magnitude estimates; generally confirming original hypotheses, with some novel additions. Unlike
410 males, greater RAE (Q1 v Q4) magnitude was associated with both the pre-adolescent (≤ 11 years old) and
411 adolescent (12-14 years old) age categories. RAEs then reduced afterwards coinciding with completion of
412 biological maturation. As expected, RAEs were lower at the recreational level and increased with higher
413 competition, particularly in the elite adolescent (12-14 years) to post-adolescent years (15-19 years) where
414 anthropometric and physical variability may have affected performance and selection processes. RAE risk did
415 reduce in the adult elite category; remaining significant but with smaller effect sizes in adult/professional
416 athletes. Collectively, findings now provide female-specific estimates that have only previously been speculated
417 upon.

418 **4.2 Summary of subgroup analyses**

419 Related to the age subgroup analyses, the highest level of RAE risk was associated with the youngest
420 age category (≤ 11 years; OR = 1.33); a finding partially contradicting the prior meta-analysis [37] where the
421 highest risk was associated with adolescence. This may be explained by the large proportion of male samples in
422 previous work (i.e., females comprised only 2% of participants in Cobley et al. [37]), and genuinely different
423 RAE patterns could be evident in females. If accurate, the earlier emergence of RAEs pre-maturation implicates
424 the influences of both normative biological growth disparities (pre-maturation) within age-grouped peers and
425 other psycho-social processes. For instance, growth charts tracking stature and body mass across chronological

426 age highlight the potential for important relative (within age-group) differences in a given year [71, 72]. These
427 may also relate to motor coordination, control and physical (e.g., muscular force) characteristic development
428 advantages that assist sport-related performance (e.g., soccer). Interacting with age-related biological
429 differences, parental and young participants' choices may also account for increased RAE magnitude. As part of
430 initial recreation and participation experiences, the identification of an appropriate 'sporting fit' relative to
431 physical characteristics of similarly aged girls (and possibly boys - in early age mixed sport contexts; e.g.,
432 soccer) may occur.

433 Age findings also partially resonate with the general findings of prior literature. After the adolescent
434 age category (12-14 years; OR = 1.28), RAE magnitudes reduced with age; possibly suggestive of a declining
435 influence of growth and maturational processes on sporting involvement. To acknowledge however, the overall
436 adolescent age estimates could have been confounded by competition level as approximately two-thirds of
437 adolescents were recreational level participants. This may explain why RAE magnitude estimates in adolescence
438 were potentially smaller than expected when compared to prior reviews and given existing explanatory
439 mechanisms. Finally, there were many samples (79) that could not be coded into subgroup categories; likely for
440 several reasons including the analyses of samples in original studies that were collapsed across multiple age
441 groups. Future studies will need to be mindful of such collapsing, as they may be potentially missing important
442 changes in RAE estimates.

443 Competition level also moderated RAE risk, with increasing magnitude at higher competition levels.
444 The interaction of elite competition level with ages coinciding with adolescence (12-14 years) and post-
445 adolescence (15-19 years) was associated with the greatest RAE risk (i.e., OR = 2.70 & 1.65). These findings
446 corroborate previous studies examining representative athletes in talent identification and development systems,
447 and the maturation-selection hypothesis [9, 24, 37, 38]. As higher tiers of representation necessitate the
448 requirement for higher performance levels at a given age or developmental stage, selection is likely to favour
449 those with more favourable anthropometric and physical characteristics; and thereby relatively older in a given
450 junior/youth grouping process [38]. Distinct trends within epidemiological (national) data samples support the
451 hypothesis in accounting for RAE perpetuation. For instance, Romann and Fuchslocher [61] provided data at
452 recreational levels and sport organisation-imposed age categories in Alpine skiing, tennis and track/field. At
453 recreational levels, significant RAEs existed in these contexts until approximately 15 years of age (i.e., post-
454 *peak height velocity* for females [42]). RAEs then continued in competitive tiers where selection processes were
455 present, perpetuating early growth and physical advantages. Furthermore, a slow reversal of recreational-level

456 RAE trends at post-15 years was observed, possibly indicating the relatively older were either participating at
457 higher levels of competition or had ceased participation.

458 At elite representative levels, significant pooled RAEs remained, although they did decrease with age
459 (e.g., elite adult; OR = 1.27). Prior study findings have also been inconsistent at the elite adult (i.e., professional
460 athlete) level, suggesting potential variability in RAE risk which may be associated with context-specific
461 conditions and performance demands. The definitive explanations for why RAEs reduce and even reverse at the
462 elite adult stage remain somewhat speculative and deserving of further attention. Initial explanations from male
463 contexts suggest later ages benefit from anthropometric and physical development [4, 13] ‘equalisation’ and
464 delayed, less intensive sporting involvement with training specialisation occurring later in development [73-75].
465 One alternative, referred to as the ‘underdog’ hypothesis [76], suggests that challenges (e.g., non-selection;
466 physical dominance by relatively older players) encountered at younger ages may ultimately facilitate longer-
467 term athlete development [77] through a combination of needing to develop greater resiliency and coping skills
468 in such psycho-social conditions, along with enhanced or alternative skill development to circumvent the
469 performance hurdles. Such successful transitions may partially account for the greater presence of the relatively
470 younger in adult professional sport [12, 55, 76].

471 Related to sport type, the highest RAE risk was associated with team-based sports (OR = 1.33)
472 whereby the nature of the field of play and performance emphasizes the requirement for anthropometric and
473 physical capabilities to outcompete opponents [78]. Accordingly, and coinciding with individual study samples,
474 higher RAEs were apparent in elite level basketball [79, 80] and representative volleyball [18, 81]. The
475 examination of other team sports with ≥ 6 samples available highlighted notably higher RAE magnitudes than
476 the overall estimate in handball, swimming, ice-hockey and soccer (see Table 4). Overall, these findings adhere
477 to those found in the predominantly male meta-analytical review [37]. Perhaps most surprising, given game
478 physicality requirements, was that rugby [10, 25] did not show significant RAEs (OR = 1.06, 95% CI 0.95-1.18)
479 despite estimates being based on 27 samples from three countries (Canada, New Zealand, UK). However, it
480 should be noted that both rugby union and rugby league samples were combined, and independent RAE
481 estimates were significant at pre-adolescent (≤ 11 years) levels in rugby union when sample size was more
482 robust [25]. There were no pre-adolescent rugby league samples available for comparison.

483 Individual sport types were initially examined holistically, identifying an RAE below the pooled
484 estimate (i.e., Q1 v Q4 OR = 1.18 v 1.25) with a high level of within-group heterogeneity. To follow-up,
485 individual sports were re-categorised with consideration of predominant sport demands (i.e.,

486 physical/endurance, technique/skill) as well as those implementing weight-categorisation instead of age-based
487 cohort grouping. Findings identified variable RAE risk. Individual sports associated with strength and/or
488 endurance requirements illustrated some of the highest RAEs at particular age and competition levels. For
489 instance, Alpine skiing OR's ranged between 2.00-2.51 between 11-14 years at competitive/representative levels
490 [61, 82]. In track and field, Romann and Fuchslocher [61] reported OR's of 2.30-2.6 in competitive 15-16-year-
491 olds; while Costa et al. [28] identified OR's exceeding 4.00 in a sample of junior representative swimmers.
492 Overall, these findings are novel for individual sport contexts, and efficacy for these estimates can be derived
493 from the multiple large samples spanning age groups and competition settings.

494 Based on the 59 samples containing varying age and competition levels, skill/technique-based sports
495 (e.g., table tennis, OR = 0.85; gymnastics, OR = 1.06) were not associated with any RAE risk (OR = 1.06, 95%
496 CI=0.97-1.16); a finding consistent with suggestions in previous studies [35]. Such a contrast between pooled
497 estimates of individual skill/technique-based sports and those with physical/endurance requirements again points
498 toward the importance of physical and maturation disparities driving RAEs, and to a lesser extent selection
499 processes. Likewise, when weight-categorised sports were examined, RAE magnitude was lower. However, this
500 finding should be interpreted with caution due to limited samples available and the absence of samples at lower
501 competition levels. Further assessment in weight-categorised sport (e.g., martial arts) is warranted as such
502 processes attempt to mitigate and neutralise the effect of anthropometric and physical discrepancies from
503 impacting competition.

504 With reference to study quality, findings highlighted that higher study quality was associated with a
505 lower RAE estimate and vice versa. Though no prior RAE reviews have identified such a trend; the finding is
506 aligned with meta-analytical reviews in other sport science [83] areas. This finding highlights the importance of
507 detailed reporting on the sport context (e.g., characteristics of competition and selection across age groups),
508 sufficient sampling of participants and reporting of participant characteristics (e.g., quartile distributions, ages,
509 one-year age groupings, levels of competition etc.) and implementation of appropriate data analysis steps (i.e.,
510 techniques for comparison; effect size) [84] to enable valid estimates of true RAE sizes. The adapted reporting
511 checklist used in this review may be useful to help enable appropriate sampling and reporting in future RAE
512 studies.

513 **4.3 Unexpected findings**

514 One unexpected finding, even though OR comparisons showed no differences, was that Q2 representation
515 was either similar or descriptively higher than Q1. Marginal Q2 over-representation has previously been

516 reported, primarily in Canadian ice-hockey [20, 84, 85] but also in adult female soccer [52, 56]. Canadian ice-
517 hockey samples provided 12.63% of relative weight to present analyses, and so their influence may be apparent.
518 Further examination in this context also identifies subtle but pervasive shifts in Q1+Q2 over-representation
519 according to age and competition categories. Specifically, Q1 over-representations are apparent at pre-
520 adolescent (≤ 11 years) competitive levels, while Q2 over-representation is evident at age equivalent
521 recreational levels. By adolescence (12-14 years) however, Q2's were over-represented at both recreational and
522 competitive levels in the same sport system. These transitions potentially suggest adverse effects from
523 intensified involvement at a younger age (where RAE OR's are highest), and possible interactions with growth
524 and maturational processes. Rather than an accumulated advantage as suggested by the 'maturation-selection'
525 hypothesis, intensified involvement in pre-adolescence and during adolescence (maturation) in Canadian ice-
526 hockey may be associated with greater risks of injury, burnout and sport withdrawal [11, 86, 87]. By contrast, a
527 lower intensity-level involvement until adolescence (or post-peak growth) may be more protective and
528 conducive to long-term participation. Nonetheless, caution is necessary for recognising the specificity of Q2
529 trends and in attempting to account for them accurately.

530 **4.4 Limitations**

531 Several limitations can be acknowledged in the present study. First, it is plausible that despite
532 comprehensive searches, some published literature may not have been identified even though systematic steps
533 were taken (as reported) to avoid such possibilities. Second, the sporting landscape has changed in past decades
534 and it was not possible to assess whether the intensification of competitive youth sport was associated with
535 increased RAE magnitude. Third, within identified studies, inconsistency and variability in data reporting were
536 apparent, and therefore multiple authors had to be contacted for data verification and further extraction to enable
537 present analyses. In conducting subgroup meta-analyses, pooled estimates may have been affected by 'non-
538 codable' data that traversed categories (e.g., age). Such data was still examined to determine if data dispersions
539 were apparent. Further, and as was often the case, multiple data samples still remained generating likely valid
540 pooled subgroup estimates. Finally, in subgroup analyses, a large amount of heterogeneity often remained
541 unaccounted for, suggesting other variables (not examinable) may still moderate RAEs. It also highlights the
542 potential for multi-factorial explanations of RAEs across and within sport contexts.

543 **4.5 Implications: RAE intervention and removal**

544 Relative age research is fundamentally concerned with participation and development inequalities.
545 Present findings are therefore concerning with respect to the relatively younger, who are more likely to refrain

546 from engagement in the early years (e.g., 6-11 years) of recreational sport and/or withdraw, possibly due to less
 547 favourable participation experiences and conditions. With the inequality continuing into the (post-) adolescent
 548 years, and being exacerbated by forms of selection and representation, the need for organisational policy, athlete
 549 development system structure and practitioner intervention can be recommended. Previous recommendations
 550 have suggested changes to age-grouping policies, such as rotating cut-off dates [6]; creating smaller age bands
 551 (e.g., 9-month rotating bands) [88] and increasing RAE awareness via education for sport-system practitioners
 552 (e.g., coaches, scouts) [37, 46]. However, despite increasing RAE awareness, few prior recommendations have
 553 been implemented organisation wide and in the long-term. Meanwhile, a cultural performance emphasis in
 554 many junior/youth sports systems has grown with the development of RAEs [5, 89].

555 Considerate of emerging literature and sport organisation trends, Cobley [90] recently summarised a
 556 range of feasible organisational and practitioner strategies for national sporting organisations. At an organisation
 557 level, these included a general recommendation to delay age time-points for structured competition and to delay
 558 tiers of selective representation (e.g., post-maturation). These strategies would help enable inclusive
 559 participation and dissociate with an early-age performance emphasis (and RAE bias [39, 91]). Potentially more
 560 relevant for individual sport contexts (e.g., sprinting, track and field), the application of corrective performance
 561 adjustments could potentially remove performance differences related to growth and development [9]. For team
 562 sports (e.g., soccer, ice-hockey), body mass or biological maturity banding at particular development time-
 563 points (e.g., maturation years) could help dissipate performance inequalities and improve participation
 564 experiences [7, 92, 93]. With organisational alignment and support, recommended practitioner strategies
 565 included the development of psycho-social climates that emphasised 'personal learning and development' in
 566 junior/youth sport as opposed to inter-individual/team competition *per se*; explicit cueing of relative age or
 567 biological maturity differences (e.g., ordered shirt number) in player evaluation/selection [89]); and, the benefit
 568 of longer-term athlete tracking on various indicators (i.e., physiological and skill-based) [94, 95].
 569 Notwithstanding these strategies, there is still further developmental work required in identifying effective and
 570 feasible interventions for female sport.

571 **4.6 Future research**

572 Based on current evidence and findings, future research should seek to further examine female sport
 573 contexts where minimal samples and data are available (as highlighted). Sampling across and within these
 574 contexts will help establish a better understanding for how growth and biological development interacts with
 575 sport development systems and their psycho-social climate to affect sporting experience and behaviour. Further,

576 moving beyond reporting RAEs in female sport to better isolate and confirm underlying causes will prove
577 beneficial. Such work will likely inform the necessary interventions that attempt to remove RAEs and/or
578 organisation/practitioner strategies mitigating their effects. To this end, a shift in research methodologies may
579 also prove valuable, including qualitative investigations with sport stakeholders (e.g., athletes, coaches, parents,
580 administrators) [20, 21, 96] to consider the influence of sport organisation processes and practitioner behaviours.
581 Qualitative idiographic investigations examining child/athlete experiences within sporting structures at early and
582 onward stages of participation would also strengthen understanding of how RAEs manifest and operate in the
583 pre-maturational years.

584 Connected to early sporting experiences, the examination of dropout may also provide additional
585 perspective. Growth and particularly maturation (puberty onset and duration) may contribute differentially to
586 dropout in each sex. The relatively younger (Q4) males may disengage in greater numbers than Q1 peers, due to
587 the early emphasis on physical dominance and performance which becomes exacerbated in the maturational
588 years [46, 97]. Preliminary work in female athletes has been inconclusive, and the relevant factors involved may
589 be different [46, 98]. For females, entering maturation may be associated with negative outcomes (e.g.,
590 increased body mass to height ratio, wider hips [41]) impacting performance in particular contexts; and other
591 psycho-social concerns at play (e.g., body image). Thus, longitudinal and multivariate studies of RAEs in terms
592 of sport participation, dropout, and positive and negative experiences are likely to be insightful. Recently,
593 Sabiston and Pila [99] asked female adolescent sport participants to complete a questionnaire targeting their
594 emotions and sport experience over three years. They identified that across tracking, 14% withdrew from all
595 sporting participation and 58% disengaged from at least one sport. Negative body image emotions - derived
596 from interactions with parents, coaches and peers - increased over the three years and were associated with
597 lower commitment and enjoyment levels of their sport. Such work demonstrates how interactions between
598 several biological, sport context/system and psycho-social factors are likely to affect individual sporting
599 behaviour, whether in terms of early-age initiation, continued participation or continued progressive
600 involvement across athlete development and professional stages.

601

602 **5 Conclusions**

603 Overall, RAEs have a consistent but likely small-moderate influence on female sport participation.
604 Findings highlight the impact of interactions between athlete developmental stages, competition level, sport
605 context demands and sociocultural factors on RAE prevalence and effect magnitudes across and within female

606 contexts. To reduce and eliminate RAE-related inequalities in female athletic development, direct policy,
607 organisational and practitioner intervention are required.

608

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613

614 **7 Declaration of Interest**

615 Kristy Smith, Patricia Weir, Kevin Till, Michael Romann and Stephen Copley declare that they have no
616 conflict of interest relevant to the content of this paper.

617

618

References

- 619 1. Baker J, Horton S. A review of primary and secondary influences on sport expertise. *High Abil Stud.*
620 2004;15(2):211-28.
- 621 2. Stambulova N, Alfermann D, Statler T, Côté J. ISSP position stand: Career development and transitions of
622 athletes. *Int J of Sport Exe Psychol.* 2009;7(4):395-412.
- 623 3. Cogley S, Abraham C, Baker J. Relative age effects on physical education attainment and school sport
624 representation. *Phys Educ Sport Peda.* 2008;13(3):267-76.
- 625 4. Deaner RO, Lowen A, Cogley S. Born at the wrong time: Selection bias in the NHL draft. *PLoS ONE.*
626 2013;8(2):e57753.
- 627 5. Helsen WF, Baker J, Michiels S, Schorer J, Van Winckel J, Williams AM. The relative age effect in
628 European professional soccer: Did ten years of research make any difference? *J Sport Sci.* 2012;30(15):1665-71.
- 629 6. Barnsley RH, Thompson AH, Barnsley PE. Hockey success and birthdate: The relative age effect. *Can Assoc*
630 *Health Phys Educ Recreation J.* 1985;51:23-8.
- 631 7. Musch J, Grondin S. Unequal competition as an impediment to personal development: A review of the
632 relative age effect in sport. *Dev Rev.* 2001;21(2):147-67.
- 633 8. Wattie N, Cogley S, Baker J. Towards a unified understanding of relative age effects. *J Sport Sci.*
634 2008;26(13):1403-9.
- 635 9. Romann M, Cogley S. Relative age effects in athletic sprinting and corrective adjustments as a solution for
636 their removal. *PLoS ONE.* 2015;10(4):e0122988.
- 637 10. Till K, Cogley S, Wattie N, O'Hara J, Cooke C, Chapman C. The prevalence, influential factors and
638 mechanisms of relative age effects in UK Rugby League. *Scand J Med Sci Sport.* 2010;20(2):320-9.
- 639 11. Wattie N, Cogley S, Macpherson A, Howard A, Montelpare WJ, Baker J. Injuries in Canadian youth ice
640 hockey: The influence of relative age. *Pediatr.* 2007;120(1):142-8.
- 641 12. Baker J, Logan AJ. Developmental contexts and sporting success: Birth date and birthplace effects in
642 national hockey league draftees 2000–2005. *Brit J Sport Med.* 2007;41(8):515-7.
- 643 13. Till K, Cogley S, Morley D, O'Hara J, Chapman C, Cooke C. The influence of age, playing position,
644 anthropometry and fitness on career attainment outcomes in rugby league. *J Sport Sci.* 2016;34(13):1240-5.
- 645 14. Cogley SP, Till K. Participation trends according to relative age across youth UK Rugby League. *Int J*
646 *Sports Sci Coa.* 2017;12(3):339-43.

- 647 15. Armstrong H. A comparison of the performance of summer and autumn-born children at eleven and sixteen.
648 Brit J Educ Psychol. 1966;36(1):72-6.
- 649 16. Freyman R. Further evidence on the effect of date of birth on subsequent school performance. Educ
650 Research. 1965;8:58-64.
- 651 17. Jinks P. An investigation into the effect of date of birth on subsequent school performance. Educ Research.
652 1964;6:220-5.
- 653 18. Grondin S, Deshaies P, Nault L-P. Trimestre de naissance et participation au hockey et au volleyball. La
654 Revue Québécoise de l'Activité Physique. 1984;2:97-103.
- 655 19. Barnsley RH, Thompson AH. Birthdate and success in minor hockey: The key to the NHL. Can J Behav Sci.
656 1988;20(2):167-76.
- 657 20. Smith KL, Weir PL. An examination of the relative age effect in developmental girls' hockey in Ontario.
658 High Abil Stud. 2013;24(2):171-84.
- 659 21. Stenling A, Holmström S. Evidence of relative age effects in Swedish women's ice hockey. Talent Dev
660 Excell. 2014;6(2):31-40.
- 661 22. Wattie N, Baker J, Cogley S, Montelpare WJ. A historical examination of relative age effects in Canadian
662 hockey players. Int J Sport Psychol. 2007;38(2):178-86.
- 663 23. Helsen WF, Van Winckel J, Williams AM. The relative age effect in youth soccer across Europe. J Sport
664 Sci. 2005;23(6):629-36.
- 665 24. Lovell R, Towlson C, Parkin G, Portas M, Vaeyens R, Cogley S. Soccer player characteristics in English
666 lower-league development programmes: The relationships between relative age, maturation, anthropometry and
667 physical fitness. PLoS ONE. 2015;10(9):e0137238.
- 668 25. Lemez S, Macmahon C, Weir P. Relative age effects in women's rugby union from developmental leagues
669 to World Cup tournaments. Res Q Exerc Sport. 2016;87(1):59-67.
- 670 26. Cogley S, Hanratty M, O'Connor D, Cotton W. First club location and relative age as influences on being a
671 professional Australian Rugby League player. Int J Sports Sci Coa. 2014;9(2):335-46.
- 672 27. Baxter-Jones ADG. Growth and development of young athletes. Should competition levels be age related?
673 Sports Med. 1995;20(2):59-64.
- 674 28. Costa AM, Marques MC, Louro H, Ferreira SS, Marinho DA. The relative age effect among elite youth
675 competitive swimmers. Eur J Sport Sci. 2013;13(5):437-44.

- 676 29. Edgar S, O'Donoghue P. Season of birth distribution of elite tennis players. *J Sport Sci.* 2005;23(10):1013-
677 20.
- 678 30. Giacomini CP. Association of birthdate with success of nationally ranked junior tennis players in the United
679 States. *Percept Motor Skill.* 1999;89:381-6.
- 680 31. Romann M, Fuchslocher J. Survival and success of the relatively oldest in Swiss youth skiing competition.
681 *Int J Sports Sci Coa.* 2014;9(2):347-56.
- 682 32. Müller L, Müller E, Kornexl E, Raschner C. The relationship between physical motor skills, gender and
683 relative age effects in young Austrian alpine ski racers. *Int J Sports Sci Coa.* 2015;10(1):69-85.
- 684 33. Nakata H, Sakamoto K. Sex differences in relative age effects among Japanese athletes *Percept Motor Skill.*
685 2012;115(1):179-86.
- 686 34. Delorme N, Boiché J, Raspaud M. The relative age effect in elite sport: The French case. *Res Q Exerc Sport.*
687 2009;80(2):336-44.
- 688 35. Côté J, Macdonald DJ, Baker J, Abernethy B. When 'where' is more important than 'when': Birthplace and
689 birthdate effects on the achievement of sporting expertise. *J Sport Sci.* 2006;24(10):1065-73.
- 690 36. Delorme N, Raspaud M. Is there an influence of relative age on participation in non-physical sports
691 activities? The example of shooting sports. *J Sport Sci.* 2009;27(10):1035-42.
- 692 37. Cogley S, Baker J, Wattie N, McKenna J. Annual age-grouping and athlete development: A meta-analytical
693 review of relative age effects in sport. *Sports Med.* 2009;39(3):235-56.
- 694 38. Helsen WF, Starkes JL, Van Winckel J. The influence of relative age on success and dropout in male soccer
695 players. *Am J Human Biol.* 1998;10(6):791-8.
- 696 39. Baker J, Schorer J, Cogley S. Relative age effects. An inevitable consequence of elite sport? *Sportwiss.*
697 2010;40(1):26-30.
- 698 40. Haywood K, Getchell N. *Life Span Motor Development.* 5th ed. Champaign, Illinois: Human Kinetics
699 Publishers; 2009.
- 700 41. Malina RM. The young athlete: Biological growth and maturation in a biocultural context. *Children and*
701 *youth in sport: A biopsychosocial perspective.* Dubuque, Iowa: Brown & Benchmark; 1996.
- 702 42. Tanner J, Whitehouse R, Takaishi M. Standards from birth to maturity for height, weight, height velocity,
703 and weight velocity: British children, 1965. Part I. *Arch Dis Child.* 1966;41(219):454-71.
- 704 43. Cogley SP, Schorer J, Baker J. Relative age effects in professional German soccer: A historical analysis. *J*
705 *Sport Sci.* 2008;26(14):1531-8.

- 706 44. Till K, Cogley S, O'Hara J, Cooke C, Chapman C. Considering maturation status and relative age in the
707 longitudinal evaluation of junior rugby league players. *Scand J Med Sci Sport*. 2014;24(3):569-76.
- 708 45. Cogley S, Miller, P., Till, K., & McKenna, J. The good and bad of youth sport today: What about the
709 unforeseen ethical issues. In: Harvey SL, R. L., editor. *Ethics in youth sport: Policy and pedagogical applications*.
710 Oxfordshire: Routledge; 2013.
- 711 46. Delorme N, Chalabaev A, Raspud M. Relative age is associated with sport dropout: Evidence from youth
712 categories of French basketball. *Scand J Med Sci Sport*. 2011;21(1):120-8.
- 713 47. Bergeron MF, Mountjoy M, Armstrong N, Chia M, Côté J, Emery CA et al. International Olympic
714 Committee consensus statement on youth athletic development. *Br J Sports Med*. 2015;49(13):843-51.
- 715 48. Côté J, Abernethy B. A developmental approach to sport expertise. *The Oxford Handbook of Sport and*
716 *Performance Psychology*. 2012.
- 717 49. Koz D, Fraser-Thomas J, Baker J. Accuracy of professional sports drafts in predicting career potential.
718 *Scand J Med Sci Sport*. 2012;22(4):e64-e9.
- 719 50. Till K, Cogley S, O'Hara J, Morley D, Chapman C, Cooke C. Retrospective analysis of anthropometric and
720 fitness characteristics associated with long-term career progression in Rugby League. *J Sci Med Sport*.
721 2015;18(3):310-4.
- 722 51. Hancock DJ, Adler AL, Côté J. A proposed theoretical model to explain relative age effects in sport. *Eur J*
723 *Sport Sci*. 2013;13(6):630-7.
- 724 52. Baker J, Schorer J, Cogley S, Bräutigam H, Büsch D. Gender, depth of competition and relative age effects
725 in team sports. *AJESS*. 2009;6(1):1-7.
- 726 53. Schorer J, Cogley S, Bräutigam H, Loffing F, Hütter S, Büsch D et al. Developmental contexts, depth of
727 competition and relative age effects in sport: A database analysis and a quasi-experiment. *Psychol Test Assess*
728 *Model*. 2015;57(1):126-43.
- 729 54. Daniel T, Janssen C. More on the relative age effect. *Can Assoc Health Phys Educ Recreation J*. 1987;53:21-
730 4.
- 731 55. Schorer J, Cogley S, Büsch D, Bräutigam H, Baker J. Influences of competition level, gender, player
732 nationality, career stage and playing position on relative age effects. *Scand J Med Sci Sport*. 2009;19(5):720-30.
- 733 56. Delorme N, Boiché J, Raspud M. Relative age effect in female sport: A diachronic examination of soccer
734 players. *Scand J Med Sci Sport*. 2010;20(3):509-15.

- 735 57. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP et al. The PRISMA statement for
736 reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation
737 and elaboration. *PLoS medicine*. 2009;6(7):e1000100.
- 738 58. Albuquerque MF, Fukuda DH, Da Costa VT, Lopes MC, Franchini E. Do weight categories prevent athletes
739 from the relative age effect? A meta-analysis of combat sports. *Sport Sci Health*. 2016;12(2):133-9.
- 740 59. Vandembroucke JP, Von Elm E, Altman DG, Gøtzsche PC, Mulrow CD, Pocock SJ et al. Strengthening the
741 reporting of observational studies in epidemiology (STROBE): Explanation and elaboration. *Epidemiology*.
742 2007;18(6):805-35.
- 743 60. Tompsett C, Sanders R, Taylor C, Cobley S. Pedagogical approaches to and effects of fundamental
744 movement skill interventions on health outcomes: A systematic review. *Sports Med*. 2017;47(9):1795-819.
- 745 61. Romann M, Fuchslocher J. The need to consider relative age effects in women's talent development process.
746 *Percept Motor Skill*. 2014;118(3):651-62.
- 747 62. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials*. 1986;7(3):177-88.
- 748 63. Cochran WG. The combination of estimates from different experiments. *Biometrics*. 1954;10(1):101-29.
- 749 64. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test.
750 *BMJ*. 1997;315(7109):629-34.
- 751 65. Duval S, Tweedie R. Trim and fill: A simple funnel-plot-based method of testing and adjusting for
752 publication bias in meta-analysis. *Biometrics*. 2000;56(2):455-63.
- 753 66. Malina RM, Bouchard, C., & Bar-Or, O. Maturity-associated variation in growth and performance. 2nd ed.
754 *Growth, Maturation, and Physical Activity*. Champaign, Illinois: Human Kinetics Publishers; 2004.
- 755 67. Ward S, Bélanger, M., Donovan, D., Caissie, I., Goguen, J., & Vanasse, A. Association between school
756 policies and built environment, and youth's participation in various types of physical activities. *J School Health*.
757 2015;85(7):423-32.
- 758 68. Raschner C, Müller L, Hildebrandt C. The role of a relative age effect in the first winter Youth Olympic
759 Games in 2012. *Brit J Sport Med*. 2012;46(15):1038-43.
- 760 69. Müller L, Hildebrandt C, Schnitzer M, Raschner C. The role of a relative age effect in the 12th Winter
761 European Youth Olympic Festival in 2015. *Percept Motor Skill*. 2016;122(2):701-18.
- 762 70. Albuquerque MR, Franchini E, Lage GM, Da Costa VT, Costa IT, Malloy-Diniz LF. The relative age effect
763 in combat sports: An analysis of Olympic judo athletes, 1964-2012. *Percept Motor Skill*. 2015;121(1):300-8.

- 764 71. Tanner JM, Whitehouse RH. Clinical longitudinal standards for height, weight, height velocity, weight
765 velocity, and stages of puberty. *Arch Dis Child*. 1976;51(3):170-9.
- 766 72. Freeman JV, Cole TJ, Chinn S, Jones PR, White EM, Preece MA. Cross sectional stature and weight
767 reference curves for the UK, 1990. *Arch Dis Child*. 1995;73(1):17-24.
- 768 73. Güllich A, Emrich E. Considering long-term sustainability in the development of world class success. *Eur J*
769 *Sport Sci*. 2014;14(sup1):S383-S97.
- 770 74. Moesch K, Elbe A-M, Hauge M-LT, Wikman JM. Late specialization: The key to success in centimeters,
771 grams, or seconds (cgs) sports. *Scand J Med Sci Sport*. 2011;21(6):e282–e90.
- 772 75. Baker J, Cobley S, Fraser-Thomas J. What do we know about early sport specialization? Not much! *High*
773 *Abil Stud*. 2009;20(1):77-89.
- 774 76. Gibbs BG, Jarvis JA, Dufur MJ. The rise of the underdog? The relative age effect reversal among Canadian-
775 born NHL hockey players: A reply to Nolan and Howell. *Int Rev Sociol Sport*. 2011;47(5):644-9.
- 776 77. Collins D, MacNamara Á. The rocky road to the top. *Sports Med*. 2012;42(11):907-14.
- 777 78. Baker J, Janning C, Wong H, Cobley S, Schorer J. Variations in relative age effects in individual sports:
778 Skiing, figure skating and gymnastics. *Eur J Sport Sci*. 2014;14(suppl.1):S183-S90.
- 779 79. Saavedra-García M, Aguilar ÓG, Romero JJF, Lastra DF, Oliveira GE. Relative age effect in lower
780 categories of international basketball. *Int Rev Sociol Sport*. 2014;49(5):526-35.
- 781 80. Arrieta H, Torres-Unda J, Gil SM, Irazusta J. Relative age effect and performance in the U16, U18 and U20
782 European Basketball Championships. *J Sport Sci*. 2016;34(16):1530-4.
- 783 81. Okazaki FHA, Keller B, Fontana FE, Gallagher JD. The relative age effect among female Brazilian youth
784 volleyball players. *Res Q Exerc Sport*. 2011;82(1):135-9.
- 785 82. Müller L, Hildebrandt C, Raschner C. The relative age effect and the influence on performance in youth
786 alpine ski racing. *JSSM*. 2015;14(1):16-22.
- 787 83. Soomro N, Sanders R, Hackett D, Hubka T, Ebrahimi S, Freeston J et al. The efficacy of injury prevention
788 programs in adolescent team sports: A meta-analysis. *Am J Sport Med*. 2016;44(9):2415-24.
- 789 84. Hancock DJ, Seal K, Young BW, Weir PL, Ste-Marie DM. Examining mechanisms that contribute to
790 relative age effects in pre-pubescent female ice hockey players. *Talent Dev Excell*. 2013;5(2):59-66.
- 791 85. Weir PL, Smith KL, Paterson C, Horton S. Canadian women's ice hockey - Evidence of a relative age effect.
792 *Talent Dev Excell*. 2010;2(2):209-17.

- 793 86. Fraser-Thomas J, Côté J. Understanding adolescents' positive and negative developmental experiences in
794 sport. *Sport Psychol.* 2009;23(1):2-23.
- 795 87. Wall M, Côté J. Developmental activities that lead to dropout and investment in sport. *Phys Educ Sport*
796 *Peda.* 2007;12(1):77-87.
- 797 88. Boucher J, Halliwell W. The Novem System: A practical solution to age grouping. *Can Assoc Health Phys*
798 *Educ Recreation J.* 1991;57(1):16-20.
- 799 89. Mann DL, van Ginneken PJMA. Age-ordered shirt numbering reduces the selection bias associated with the
800 relative age effect. *J Sport Sci.* 2017;35(8):784-90.
- 801 90. Cogley S. Growth and maturation in athlete development: An educational resource for sporting
802 organisations. Canberra, Australia: Australian Institute of Sport.2016.
- 803 91. Cogley S. Talent identification and development in youth sport. In: Green K, Smith A, editors. *Routledge*
804 *Handbook of Youth Sport.* Abingdon: Routledge; 2016. p. 476-91.
- 805 92. Cumming SP, Lloyd RS, Oliver JL, Eisenmann JC, Malina RM. Bio-banding in sport: Applications to
806 competition, talent identification, and strength and conditioning of youth athletes. *Strength Cond J.*
807 2017;39(2):34-47.
- 808 93. Cumming SP, Lloyd RS, Oliver JL, Eisenmann JC, Malina RM. A renaissance in bio-banding: Applications
809 in competition, talent identification, and training. . *Strength and Conditioning Journal.* In press.
- 810 94. Till K, Cogley S, O'Hara J, Chapman C, Cooke C. An individualized longitudinal approach to monitoring
811 the dynamics of growth and fitness development in adolescent athletes. *J Strength Cond Res.* 2013;27(5):1313-
812 21.
- 813 95. Cogley S, Till K, O'Hara J, Cooke C, Chapman C. Variable and changing trajectories in youth athlete
814 development: Further verification in advocating a long-term inclusive tracking approach. *J Strength Cond Res.*
815 2014;28(7):1959-70.
- 816 96. Andronikos G, Elumaro AI, Westbury T, Martindale RJJ. Relative age effect: implications for effective
817 practice. *J Sport Sci.* 2016;34(12):1124-31.
- 818 97. Lemez S, Baker J, Horton S, Wattie N, Weir P. Examining the relationship between relative age,
819 competition level, and dropout rates in male youth ice-hockey players. *Scand J Med Sci Sport.* 2014;24(6):935-
820 42.
- 821 98. Wattie N, Tietjens M, Cogley S, Schorer J, Baker J, Kurz D. Relative age-related participation and dropout
822 trends in German youth sports clubs. *Eur J Sport Sci.* 2014;14(S1):S213-S20.

- 823 99. Sabiston C, Pila E, editors. Body-related emotional experiences in sport among adolescent girls:
824 Participation outcomes over time. Sport Canada Research Initiative Conference. Knowledge Transfer Papers.;
825 2017 September 19-20.
- 826 100. Albuquerque MR, Lage GM, Da Costa VT, Ferreira RM, Penna EM, De Albuquerque Moraes LCC et al.
827 Relative age effect In Olympic Taekwondo athletes. *Percept Motor Skill*. 2012;114(2):461-8.
- 828 101. Albuquerque MR, Da Costa VT, Faria LO, Lopes MC, Lage GM, Sledziewski D et al. Weight categories
829 do not prevent athletes from relative age effect: An analysis of Olympic Games wrestlers. *Arch Budo*.
830 2014;10:127-32.
- 831 102. Bidaurrezaga-Letona I, Badiola A, Granados C, Lekue JA, Amado M, Gil SM. Efecto relativo de la edad
832 en futbol: Estudio en un club Vasco profesional. / Relative age effect in soccer: A study in a professional
833 Basque club. *Retos: Nuevas Perspectivas de Educación Física, Deporte y Recreación*. 2014(25):95-9.
- 834 103. Brazo-Sayavera J, Martínez-Valencia MA, Müller L, Andronikos G, Martindale RJ. Identifying talented
835 track and field athletes: The impact of relative age effect on selection to the Spanish National Athletics
836 Federation training camps. *J Sport Sci*. 2017;35(22):2172-8.
- 837 104. Chittle L, Horton S, Dixon JC. Time out or fast break? The relative age effect in NCAA Division I
838 basketball. *J Sport Behav*. 2016;39(2):107-25.
- 839 105. Delorme N, Raspaud M. The relative age effect in young French basketball players: A study on the whole
840 population. *Scand J Med Sci Sport*. 2009;19(2):235-42.
- 841 106. Delorme N. Do weight categories prevent athletes from relative age effect? *JSSM*. 2014;32(1):16-21.
- 842 107. Dixon JC, Liburdi V, Horton S, Weir PL. An examination of the impact of relative age effects and
843 academic timing on intercollegiate athletics participation in women's softball. *J Intercol Sport*. 2013;6(2):147-
844 63.
- 845 108. Fukuda DH. Analysis of the relative age effect in elite youth judo athletes. *Int J Sport Physiol Perform*.
846 2015;10(8):1048-51.
- 847 109. Gorski T, Rosser T, Hoppeler H, Vogt M. Relative age effect in young Swiss alpine skiers from 2004 to
848 2011. *Int J Sport Physiol*. 2016;11(4):455-63.
- 849 110. Hancock DJ, Starkes JL, Ste-Marie DM. The relative age effect in female gymnastics: A flip-flop
850 phenomenon. *Int J Sport Psychol*. 2015;46(6):714-25.
- 851 111. Lidor R, Arnon M, Maayan Z, Gershon T, Côté J. Relative age effect and birthplace effect in Division 1
852 female ballgame players—The relevance of sport-specific factors. *Int J Sport Exerc Psychol*. 2014;12(1):19-33.

- 853 112. Liu W-m, Liu D. A research on the relative age effect among excellent youth female football players in
854 China. *J Beijing Sport Univ.* 2008;31(1):135-7.
- 855 113. Nagy N, Ökrös C, Sós C. Research on relative age in Hungarian swimming. *Phys Cult Sport Stud Res.*
856 2015;68(1):5-13.
- 857 114. O'Donoghue P. Relative age in elite tennis. *Stud Phys Cult Tourism.* 2009;16(4):379-88.
- 858 115. Romann M, Fuchslocher J. Influence of the selection level, age and playing position on relative age effects
859 in Swiss women's soccer. *Talent Dev Excell.* 2011;3(2):239-47.
- 860 116. Romann M, Fuchslocher J. Influences of player nationality, playing position, and height on relative age
861 effects at women's under-17 FIFA World Cup. *J Sport Sci.* 2013;31(1):32-40.
- 862 117. Saavedra García M, Gutiérrez Aguilar Ó, Galatti L, Fernández Romero JJ. Efecto de la edad relativa en los
863 mundiales de baloncesto FIBA en categorías inferiores (1979-2011). / Relative age effect in lower categories of
864 FIBA basketball world championships (1979-2011). *Cuadernos de Psicología del Deporte.* 2015;15(3):237-42.
- 865 118. Saavedra-García M, Gutiérrez-Aguilar Ó, Sa-Marques P, Fernández-Romero JJ. Efecto de la edad relativa
866 en el atletismo español. / Relative age effect in Spanish athletics. *Cuadernos de Psicología del Deporte.*
867 2016;16(1):275-85.
- 868 119. Schorer J, Baker, J., Büsch, D., Wilhelm, A, & Pabst, J. Relative age, talent identification and youth skill
869 development: Do relatively younger athletes have superior technical skills? *Talent Dev Excell.* 2009;1(1):45-56.
- 870 120. Schorer J, Baker J, Lotz S, Büsch D. Influence of early environmental constraints on achievement
871 motivation in talented young handball players. *Int J Sport Psychol.* 2010;41(1):42-58.
- 872 121. Schorer J, Wattie N, Baker JR. A new dimension to relative age effects: Constant year effects in German
873 youth handball. *PLoS ONE.* 2013;8(4):e60336.
- 874 122. Sedano S, Vaeyens R, Redondo JC. The relative age effect in Spanish female soccer players. Influence of
875 the competitive level and a playing position. *J Hum Kinet.* 2015;46(1):129-37.
- 876 123. van den Honert R. Evidence of the relative age effect in football in Australia. *J Sport Sci.*
877 2012;30(13):1365-74.
- 878 124. Vincent J, Glamser FD. Gender differences in the relative age effect among US Olympic Development
879 Program youth soccer players. *J Sport Sci.* 2006;24(4):405-13.
- 880 125. Werneck FZ, Coelho EF, de Oliveira HZ, Ribeiro Júnior DB, Almas SP, de Lima JRP et al. Relative age
881 effect in Olympic basketball athletes. *Sci Sport.* 2016;31(3):158-61.

- 882 126. Sutton AJ, Abrams KR, Jones DR, Jones DR, Sheldon TA, Song F. Methods for meta-analysis in medical
883 research. John Wiley & Sons, LTD; 2000.
884

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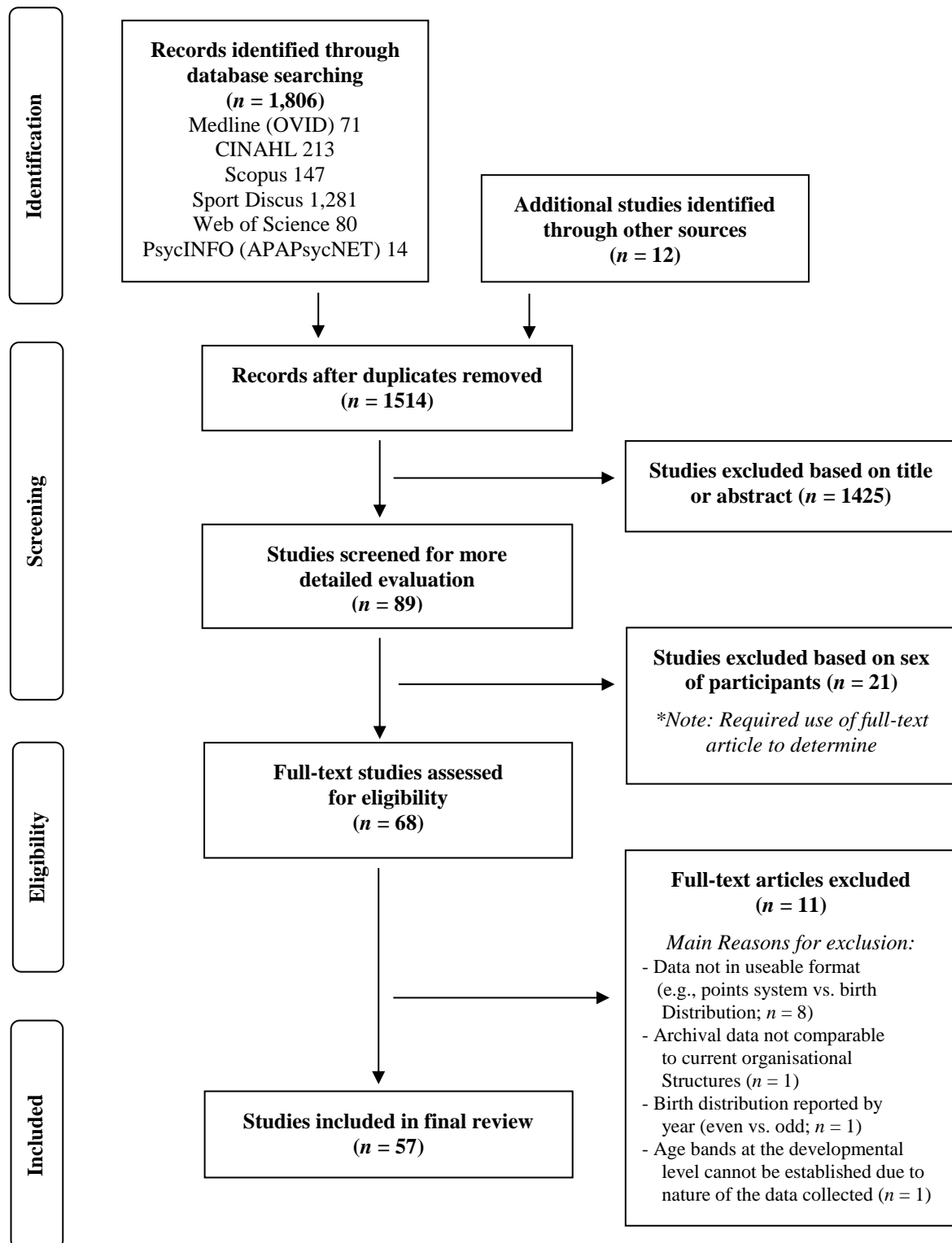
Figure 1: Flow diagram for screening and selection of studies according to PRISMA [57]

Figure 2: Funnel plot of standard error by log odds ratio (Q1 v Q4 OR analysis).

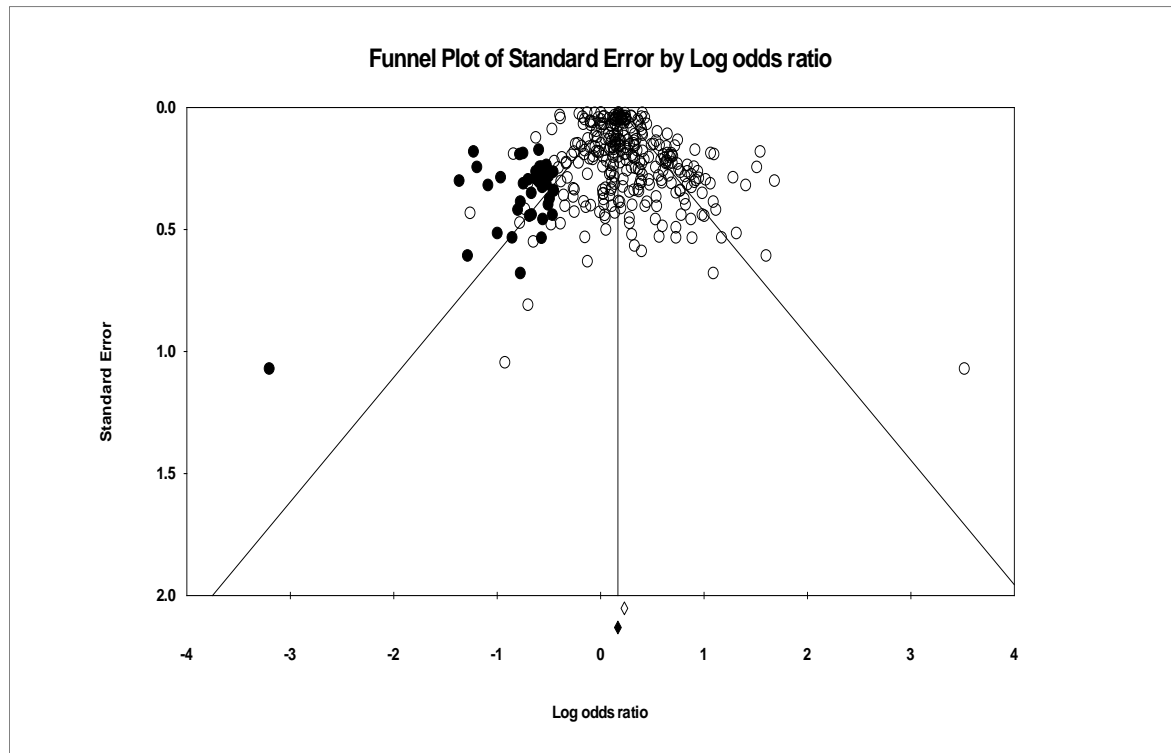


Figure Notes: In the absence of heterogeneity, 95% of the studies should fall within the funnel defined by the two diagonal lines. The plot assumes that those studies with higher precision (higher sample, lower estimates of error) will plot near the overall estimate (vertical line) and will cluster around the line evenly. Those studies with lower precision (lower on the graph) should also spread evenly on both sides, even though they have a smaller sample size and less precise estimates of error. Publication bias is suggested when there is asymmetry in the plot. The results displayed taking into account the Trim and Fill adjustment. Observed studies are shown as open circles, and the observed point estimate is an open diamond. The imputed studies are shown as filled circles, and the imputed point estimate in log units is shown as a filled diamond.

Table 1: Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [59]

Study	<p>#1. In the abstract an informative and balanced summary of what was done and what was found is provided.</p> <p>#2. Explain the scientific background and rationale for the investigation being reported.</p> <p>#3. State clear, specific objectives and/or any prespecified hypotheses.-</p> <p>#4. Describe the setting, locations, and relevant dates for data collection. This must include information on sport context, type, level of competition, and competition year(s) for data collected to be scored as a '1'.</p> <p>#5a. Give characteristics of study participants (must include: age, gender, skill level, overall number, and nationality).</p> <p>#5b. Describe the procedure for selecting and grouping athletes in the context under examination (e.g., by birthdate or weight) and how participants were categorised for study purposes (e.g., application of a cut-off date to determine birth quartile).</p> <p>#5c. Describe the source and procedure for obtaining the sample (e.g., obtained from an online roster, provided by a sport governing body, etc.).</p> <p>#6. Explain and report the reference baseline distribution (e.g., equal distribution vs. population birth rate).</p> <p>#7a. Clearly describe all statistical methods, including specific analytical methods used to examine subgroups.</p> <p>#7b. Explain how duplicates (if applicable) and missing data were addressed or incomplete data were handled.</p> <p>#8. Report the number or percentage of participants found in each quartile/semester (and subcategory if applicable).</p> <p>#9. Provide statistical estimate(s) and precision (e.g., 95% confidence interval) for each sample or subgroup group examined.</p> <p>#10a. Post-hoc comparisons between quartiles (e.g., Q1 vs. Q4) are provided when appropriate (i.e., overall test is significant).</p> <p>#10b. A measure of effect size is provided (e.g., Cramer's V, phi coefficient, Cohen's w, etc.).</p> <p>#11. A summary of key results with reference to study objectives is provided.</p> <p>#12. Discusses limitations of the study, taking into account sources of potential bias, confounding factors or imprecision.</p> <p>#13. A cautious overall interpretation of results considering objectives and relevant evidence.</p> <p>#14. Discusses the generalizability of the study results to similar or other contexts.</p>														Quality Score Total / 14			
	#1	#2	#3	#4	#5a	#5b	#5c	#6	#7a	#7b	#8	#9	#10a	#10b	#11	#12	#13	#14
Albuquerque et al., 2012 [100]	0	1	1	0		(0,1,1) 0	1	(1,0) 0	1	1	(0,0) 0	1	0	0	1	7		
Albuquerque et al., 2014 [101]	1	1	1	1		(0,1,1) 0	1	(1,0) 0	1	1	(0,0) 0	1	1	0	1	10		
Albuquerque et al., 2015 [70]	0	1	0	1		(0,1,1) 0	1	(1,0) 0	1	1	(0,1) 0	1	1	0	1	8		
Arrieta et al., 2016 [80]	0	0	1	1		(0,1,1) 0	1	(1,0) 0	1	1	(0,0) 0	1	0	0	1	7		
Baker et al., 2009 [52]	1	1	1	1		(1,1,0) 0	1	(1,0) 0	1	1	(0,1) 0	1	1	1	1	11		
Baker et al., 2014 [78]	1	1	1	1		(1,1,1) 1	1	(1,0) 0	1	1	(0,1) 0	1	1	1	1	12		
Bidaurrzaga-Letona et al., 2014 [102]	1	1	1	0		(1,1,1) 1	1	(1,1) 1	1	1	(0,0) 0	1	0	1	1	11		
Brazo-Sayavera et al., 2016 [103]	1	1	1	1		(1,1,1) 1	0	(1,0) 0	1	1	(1,1) 1	1	0	1	0	10		
Chittle et al., 2016 [104]	1	1	1	1		(1,1,1) 1	1	(1,1) 1	1	1	(1,1) 1	1	0	1	1	13		
Costa et al., 2013 [28]	1	1	1	1		(1,1,1) 1	0	(1,0) 0	1	1	(0,0) 0	1	1	1	1	11		

Study	#1	#2	#3	#4	#5a,b,c	#6	#7a,b	#8	#9	#10a,b	#11	#12	#13	#14	Score /14
Delorme & Raspaud, 2009 [36]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(0,0) 0	0	0	1	1	11
Delorme & Raspaud, 2009 [105]	0	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(0,0) 0	0	0	1	1	10
Delorme et al., 2009 [34]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(0,0) 0	0	0	1	1	11
Delorme et al., 2010 [56]	1	1	1	1	(1,1,1) 1	1	(1,0) 0	1	1	(0,0) 0	1	0	1	1	11
Delorme, 2014 [106]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(1,0) 0	1	1	1	1	13
Dixon et al., 2013 [107]	0	1	1	1	(1,1,1) 1	1	(1,0) 0	1	1	(1,1) 1	1	1	1	1	12
Edgar & O'Donoghue, 2005 [29]	1	1	1	1	(0,1,1) 0	1	(1,0) 0	1	1	(0,0) 0	1	1	1	1	11
Fukuda, 2015 [108]	1	1	1	1	(0,1,1) 0	0	(1,1) 1	1	1	(0,1) 0	1	1	1	1	11
Giacomini, 1999 [30]	1	1	1	1	(1,1,1) 1	1	(1,0) 0	1	1	(0,0) 0	1	1	0	0	10
Gorski et al., 2016 [109]	1	1	1	1	(1,1,1) 1	1	(1,0) 0	1	1	(1,1) 1	1	1	1	1	13
Grondin et al., 1984 [18]	1	1	1	1	(1,1,1) 1	1	(0,0) 0	0	1	(1,0) 0	1	1	1	1	11
Hancock et al., 2013 [84]	1	1	1	1	(1,1,1) 1	0	(1,0) 0	1	1	(0,1) 0	1	0	1	1	10
Hancock et al., 2015 [110]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(1,1) 1	1	1	1	1	14
Helsen et al., 2005 [23]	1	1	1	1	(1,1,0) 0	1	(1,0) 0	1	1	(0,0) 0	0	0	1	1	9
Lemez et al., 2016 [25]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(1,1) 1	1	1	1	1	14
Lidor et al., 2014 [111]	1	1	1	1	(1,1,1) 1	1	(1,0) 0	1	1	(0,1) 0	1	0	1	1	11
Liu & Liu, 2008 [112]	1	0	1	0	(0,0,0) 0	0	(0,0) 0	0	0	(0,0) 0	1	1	1	0	5
Muller et al., 2015 [32]	0	1	1	1	(0,1,1) 0	1	(1,0) 0	0	1	(1,0) 0	1	1	0	1	8
Muller et al., 2015 [82]	1	1	1	1	(0,1,1) 0	1	(1,0) 0	1	1	(0,1) 0	1	1	1	0	10
Muller et al., 2016 [69]	0	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(1,1) 1	1	1	1	1	13
Nagy et al., 2015 [113]	0	1	0	0	(1,0,1) 0	0	(0,0) 0	1	1	(0,0) 0	1	0	1	1	6
Nakata & Sakamoto, 2012 [33]	0	1	0	1	(0,1,0) 0	1	(0,1) 0	1	1	(0,1) 0	1	0	0	0	6
O'Donoghue, 2009 [114]	1	1	1	1	(0,1,1) 0	0	(1,0) 0	1	1	(0,1) 0	1	0	1	1	9
Okazaki et al., 2011 [81]	0	1	1	1	(1,1,1) 1	0	(1,0) 0	1	1	(0,0) 0	0	0	1	1	8
Raschner et al., 2012 [68]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(1,0) 0	1	1	1	1	13
Romann & Fuchslocher, 2011[115]	1	1	1	1	(1,1,0) 0	1	(1,0) 0	1	1	(1,1) 1	1	0	1	1	11
Romann & Fuchslocher, 2013 [116]	1	1	1	1	(1,1,1) 1	1	(1,0) 0	1	1	(1,1) 1	1	1	1	1	13
Romann & Fuchslocher, 2014 [61]	1	1	1	1	(1,1,1) 1	1	(1,0) 0	1	1	(1,1) 1	1	0	1	1	12
Romann & Fuchslocher, 2014[31]	1	1	1	1	(1,1,1) 1	1	(1,0) 0	1	1	(1,1) 1	1	0	1	1	12

Study	#1	#2	#3	#4	#5a,b,c	#6	#7a,b	#8	#9	#10a,b	#11	#12	#13	#14	Score /14
Saavedra-García et al., 2014 [79]	1	1	1	1	(1,0,1) 0	0	(1,0) 0	1	1	(1,1) 1	1	0	1	1	10
Saavedra-García et al., 2015 [117]	0	1	1	0	(1,0,1) 0	1	(1,0) 0	1	1	(0,1) 0	1	0	1	1	8
Saavedra-García et al., 2016 [118]	0	1	1	1	(0,1,1) 0	1	(1,0) 0	1	1	(1,1) 1	1	0	0	0	8
Schorer et al., 2009 [55]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(0,1) 0	1	0	1	1	12
Schorer et al., 2009 [119]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(0,1) 0	1	1	1	1	13
Schorer et al., 2010 [120]	0	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(0,1) 0	1	1	1	1	12
Schorer et al., 2013 [121]	0	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(0,1) 0	1	1	1	1	12
Schorer et al., 2015 [53]	1	1	1	1	(0,1,1) 0	1	(1,0) 0	1	1	(0,1) 0	1	1	1	1	11
Sedano et al., 2015 [122]	1	1	1	1	(1,1,1) 1	1	(1,0) 0	1	1	(1,1) 1	1	0	0	1	11
Smith & Weir, 2013 [20]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(1,1) 1	1	1	1	1	14
Stenling & Holmstrom, 2014 [21]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(1,1) 1	1	1	1	1	14
Till et al., 2010 [10]	1	1	1	1	(1,1,1) 1	1	(1,0) 0	1	1	(1,1) 1	1	1	1	1	13
van den Honert, 2012 [123]	0	1	0	0	(1,1,0) 0	1	(1,0) 0	1	1	(0,1) 0	1	0	1	0	6
Vincent & Glamser, 2006 [124]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(0,0) 0	0	0	1	1	11
Wattie et al., 2007 [22]	1	1	1	1	(0,1,1) 0	1	(1,1) 1	1	1	(0,0) 0	1	0	1	0	10
Wattie et al., 2014 [98]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(1,1) 1	1	1	1	1	14
Weir et al., 2010 [85]	1	1	1	1	(1,1,1) 1	1	(1,1) 1	1	1	(0,1) 0	1	0	1	1	12
Werneck et al., 2016 [125]	1	1	1	1	(1,0,1) 0	1	(0,0) 0	1	1	(0,0) 0	1	1	0	1	10

Tables Notes: 0 = Item criterion is absent or insufficiently information is provided; 1 = Item criterion is explicitly described and met.

Table 2: Unadjusted odds ratios for independent female samples examining RAEs in sports contexts.

Author(s)	Sample Age (Years)	Sport	Competition Level	(N)	Odds ratio comparisons – Quartile 1-4 (95% Confidence intervals)		
					Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4
Grondin, Deschaies, & Nault, 1984†† [18]	14-15	Volleyball	Provincial Cadet ^{Rp}	219	2.28 (1.30, 3.99)	2.13 (1.21, 3.73)	1.44 (0.80, 2.58)
	16-17	Volleyball	Provincial Juvenile ^{Rp}	188	1.26 (0.70, 2.25)	1.44 (0.81, 2.55)	1.13 (0.62, 2.04)
	17-19	Volleyball	Provincial Junior AA ^{Rp}	59	1.06 (0.39, 2.87)	0.81 (0.29, 2.27)	0.81 (0.29, 2.27)
Helsen, Van Winckel, & Williams, 2005†† [23]	U18	Soccer	Union des Associations Européennes de Football (UEFA) ^E	72	1.83 (0.70, 4.79)	2.17 (0.84, 5.58)	1.00 (0.36, 2.81)
Vincent & Glamser, 2006†† [124]	U19	Soccer	Olympic Development Program (ODP) State ^{Rp}	804	1.12 (0.85, 1.48)	1.15 (0.87, 1.51)	1.10 (0.83, 1.46)
	U19	Soccer	ODP Regional ^{Rp}	71	1.33 (0.52, 3.41)	1.53 (0.61, 3.87)	0.87 (0.32, 2.34)
	U19	Soccer	National team ^E	39	3.00 (0.78, 11.5)	1.40 (0.33, 5.97)	2.40 (0.61, 9.44)
Liu & Liu, 2008† [112]	12	Soccer	China Football Association ^{Rp}	73	3.75 (1.36, 10.3)	2.50 (0.88, 7.11)	1.88 (0.64, 5.50)
	13	Soccer		115	3.00 (1.39, 6.46)	1.56 (0.69, 3.52)	1.63 (0.72, 3.65)
	14	Soccer		163	2.33 (1.25, 4.36)	1.56 (0.81, 2.98)	1.15 (0.58, 2.25)
	15	Soccer		308	2.02 (1.28, 3.17)	1.35 (0.84, 2.15)	1.24 (0.77, 1.99)
	16	Soccer		1081	1.15 (0.91, 1.45)	0.93 (0.73, 1.18)	0.80 (0.62, 1.02)
Baker, Schorer, Cobley, Bräutigam, & Büsch, 2009† [52]	Adult	Handball	German 1 st League ^{Rp}	372	1.03 (0.69, 1.54)	0.94 (0.63, 1.41)	0.87 (0.57, 1.30)
	Adult	Handball	German 1 st League ^{Rp}	145	1.06 (0.55, 2.03)	0.97 (0.50, 1.88)	1.12 (0.58, 2.13)
	Adult	Handball	German 2 nd League ^{Rp}	345	1.07 (0.69, 1.65)	1.22 (0.79, 1.87)	1.38 (0.91, 2.11)
	Adult	Handball	German 1 st League ^{Rp}	100	0.88 (0.39, 1.98)	1.04 (0.47, 2.28)	1.27 (0.59, 2.74)
	Adult	Handball	German 2 nd League ^{Rp}	270	1.36 (0.83, 2.22)	1.29 (0.79, 2.10)	1.45 (0.89, 2.36)
	Adult	Handball	International players: German 1 st League ^{Rp}	110	1.04 (0.49, 2.20)	0.93 (0.43, 1.98)	1.11 (0.53, 2.34)
	Adult	Handball	German 1 st League ^{Rp}	50	1.40 (0.45, 4.33)	2.00 (0.67, 5.96)	0.60 (0.17, 2.16)
	Adult	Handball	German 2 nd League ^{Rp}	56	0.87 (0.30, 2.47)	0.87 (0.30, 2.47)	1.00 (0.36, 2.80)
	U15, U17, U18	Soccer*	National team ^E	207	4.17 (2.21, 7.87)	3.44 (1.81, 6.56)	2.50 (1.29, 4.84)
	U20, U23, Adult	Soccer*	National team ^E	573	1.15 (0.82, 1.62)	1.50 (1.08, 2.09)	1.35 (0.97, 1.89)
Delorme, Boiché, & Raspaud, 2009†† [34]	Adult	Soccer	Professional ^E	242	1.48 (0.88, 2.48)	1.41 (0.84, 2.37)	1.37 (0.81, 2.31)
	Adult	Basketball	Professional ^E	92	1.13 (0.51, 2.50)	1.04 (0.47, 2.33)	0.67 (0.28, 1.57)
	Adult	Handball	Professional ^E	154	1.25 (0.66, 2.38)	1.28 (0.67, 2.44)	1.28 (0.67, 2.44)

Author(s)	Sample Age (Years)	Sport	Competition Level	(N)	Odds ratio comparisons – Quartile 1-4 (95% Confidence intervals)		
					Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4
Delorme & Raspaud, 2009†† [36]	U11	Shooting	French Federation for Shooting Sports (FFT) Rc/C	284	1.11 (0.69, 1.77)	1.22 (0.76, 1.93)	1.05 (0.65, 1.68)
	11-12	Shooting		476	0.99 (0.69, 1.42)	1.00 (0.70, 1.43)	1.01 (0.70, 1.44)
	13-14	Shooting		510	1.05 (0.74, 1.49)	1.11 (0.79, 1.58)	1.02 (0.72, 1.44)
	15-16	Shooting		798	1.16 (0.89, 1.53)	0.94 (0.71, 1.25)	0.98 (0.74, 1.30)
	18-20	Shooting		584	1.14 (0.82, 1.58)	1.07 (0.77, 1.48)	1.06 (0.76, 1.47)
	Adult	Shooting		10171	1.04 (0.97, 1.13)	1.12 (1.03, 1.21)	1.09 (1.01, 1.18)
Delorme & Raspaud, 2009†† [105]	7	Basketball	Youth categories of the French Basketball Federation (FFBB) ^{Rc}	7590	1.21 (1.10, 1.32)	1.27 (1.16, 1.39)	1.16 (1.06, 1.27)
	8	Basketball		9518	1.18 (1.09, 1.28)	1.24 (1.14, 1.34)	1.10 (1.01, 1.19)
	9	Basketball		11613	1.21 (1.12, 1.30)	1.25 (1.16, 1.34)	1.13 (1.05, 1.22)
	10	Basketball	Youth categories of the FFBB ^{Rc/C}	12734	1.16 (1.08, 1.24)	1.20 (1.12, 1.29)	1.11 (1.04, 1.19)
	11	Basketball		11078	1.23 (1.14, 1.32)	1.28 (1.18, 1.38)	1.15 (1.07, 1.24)
	12	Basketball		10613	1.29 (1.19, 1.39)	1.32 (1.22, 1.42)	1.18 (1.09, 1.27)
	13	Basketball		10832	1.36 (1.26, 1.46)	1.28 (1.18, 1.38)	1.23 (1.13, 1.32)
	14	Basketball		10701	1.26 (1.16, 1.36)	1.28 (1.18, 1.38)	1.14 (1.06, 1.24)
	15	Basketball		8780	1.22 (1.12, 1.33)	1.32 (1.21, 1.44)	1.21 (1.11, 1.32)
	16	Basketball		7522	1.23 (1.12, 1.35)	1.32 (1.20, 1.44)	1.14 (1.04, 1.25)
17	Basketball	6123	1.29 (1.17, 1.43)	1.41 (1.27, 1.56)	1.19 (1.07, 1.32)		
O'Donoghue (2009) †††† [114]	13	Tennis	ITF Junior Tour (2003) ^E	59	2.44 (0.85, 7.05)	1.78 (0.60, 5.29)	1.33 (0.43, 4.11)
	14	Tennis		176	2.50 (1.36, 4.58)	1.36 (0.71, 2.58)	1.43 (0.75, 2.71)
	15	Tennis		313	2.33 (1.46, 3.73)	1.87 (1.16, 3.01)	1.76 (1.08, 2.84)
	16	Tennis		397	1.61 (1.07, 2.41)	1.55 (1.03, 2.33)	1.44 (0.95, 2.17)
	17	Tennis		343	1.29 (0.84, 1.98)	1.26 (0.82, 1.94)	1.21 (0.78, 1.86)
	18	Tennis		217	1.12 (0.66, 1.90)	1.25 (0.74, 2.12)	0.88 (0.51, 1.53)
	Senior (19+)	Tennis	Grand Slam tournament(s) ^E	211	1.94 (1.12, 3.38)	1.61 (0.92, 2.83)	1.31 (0.73, 2.33)
O'Donoghue (2009) †††† [114]	13	Tennis	ITF Junior Tour (2008) ^E	62	34.0 (4.12, 280.3)	22.0 (2.63, 184.0)	5.00 (0.52, 47.9)
	14	Tennis		195	2.79 (1.55, 5.01)	1.39 (0.74, 2.61)	1.79 (0.97, 3.29)
	15	Tennis		357	1.91 (1.24, 2.95)	1.65 (1.06, 2.56)	1.70 (1.10, 2.64)
	16	Tennis		506	1.44 (1.01, 2.04)	1.33 (0.93, 1.90)	1.15 (0.80, 1.64)
	17	Tennis		450	0.99 (0.69, 1.43)	1.03 (0.71, 1.48)	0.93 (0.64, 1.35)
	18	Tennis		214	0.89 (0.52, 1.53)	1.00 (0.59, 1.71)	1.07 (0.63, 1.82)
	Senior (19+)	Tennis	Grand Slam tournament(s) ^E	183	1.83 (0.99, 3.37)	1.86 (1.01, 3.43)	1.62 (0.87, 3.01)

Includes participant sample from Edgar & O'Donoghue, 2005[29]

Author(s)	Sample Age (Years)	Sport	Competition Level	(N)	Odds ratio comparisons – Quartile 1-4 (95% Confidence intervals)		
					Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4
Schorer, Cobley, Büsch, Bräutigam, & Baker, 2009† [55]	12-15	Handball	German: D-Squad (regional development system) ^{Rp}	333	1.90 (1.21, 3.00)	2.00 (1.27, 3.15)	1.63 (1.02, 2.58)
	15-17	Handball	D/C-Squad (youth national) ^E	502	3.01 (2.05, 4.41)	2.39 (1.62, 3.53)	1.94 (1.31, 2.89)
	18-20	Handball	C-Squad (junior national) ^E	327	1.89 (1.21, 2.96)	1.75 (1.12, 2.75)	1.20 (0.75, 1.92)
	19+	Handball	B-Squad (national team) ^E	138	2.70 (1.34, 5.41)	1.45 (0.69, 3.03)	1.75 (0.85, 3.61)
	19+	Handball	A-Squad (national team) ^E	434	0.97 (0.68, 1.39)	0.71 (0.49, 1.03)	0.59 (0.40, 0.87)
<i>Sample overlaps with Schorer et al., 2013 [121]</i>							
Schorer, Baker, Busch, Wilhelm, & Pabst, 2009† [119]	13-15	Handball*	German national youth tryouts ^{Rp} <i>Note: Participants passed regional selection</i>	238	2.19 (1.29, 3.70)	1.81 (1.06, 3.09)	1.25 (0.72, 2.18)
<i>Includes participant sample from Schorer et al., 2010 [120], 2015 [53]</i>							
Delorme, Boiché, & Raspaud, 2010†† [56]	U8	Soccer	French Soccer Federation (FSF) ^{RcC}	5434	1.29 (1.16, 1.43)	1.24 (1.12, 1.39)	1.15 (1.03, 1.28)
	U10	Soccer		7520	1.17 (1.06, 1.28)	1.22 (1.11, 1.33)	1.14 (1.04, 1.25)
	U12	Soccer		7774	0.99 (0.90, 1.08)	1.09 (1.00, 1.19)	1.04 (0.95, 1.14)
	U14	Soccer		5616	1.15 (1.04, 1.28)	1.17 (1.06, 1.30)	1.14 (1.02, 1.26)
	U17	Soccer		8784	1.03 (0.95, 1.12)	1.12 (1.03, 1.22)	1.06 (0.97, 1.15)
	Adult (18+)	Soccer		22764	0.95 (0.91, 1.01)	1.04 (0.99, 1.09)	1.01 (0.96, 1.06)
Till, Cobley, Wattie, O'Hara, Cooke, & Chapman, 2010†† [10]	U14	Rugby	Rugby Football League ^{Rc}	190	1.15 (0.66, 2.02)	1.04 (0.59, 1.85)	0.93 (0.52, 1.67)
	U16	Rugby		174	1.49 (0.82, 2.69)	0.89 (0.48, 1.67)	1.32 (0.73, 2.41)
	Senior (17+)	Rugby		261	1.03 (0.64, 1.66)	1.00 (0.62, 1.62)	0.87 (0.53, 1.41)
Weir, Smith, Paterson, & Horton, 2010† [85]	U18	Ice hockey	Provincial team ^{Rp}	369	1.54 (1.01, 2.35)	1.77 (1.16, 2.69)	1.37 (0.89, 2.11)
	U18, U22, Senior	Ice hockey	National team ^E	291	1.72 (1.05, 2.80)	2.22 (1.38, 3.57)	1.39 (0.84, 2.29)
<i>Includes participant sample from Wattie et al., 2007[22]</i>							
Okazaki, Keller, Fontana, & Gallagher, 2011‡ [81]	13	Volleyball	Brazilian national youth tournament ^{Rp}	58	5.00 (1.50, 16.7)	3.80 (1.12, 12.9)	1.80 (0.48, 6.69)
	14	Volleyball		62	3.25 (1.13, 9.38)	2.38 (0.80, 7.03)	1.13 (0.34, 3.68)

Author(s)	Sample Age (Years)	Sport	Competition Level	(N)	Odds ratio comparisons – Quartile 1-4 (95% Confidence intervals)		
					Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4
Romann & Fuchslocher, 2011 [115] <i>Jugend & Sport (J&S)</i> †† <i>Talent development & national team</i> †††	10-14	Soccer	<i>J&S</i> ^{Rc}	2987	1.21 (1.05, 1.40)	1.24 (1.07, 1.43)	1.11 (0.96, 1.29)
	15-20	Soccer		3242	1.01 (0.88, 1.16)	1.11 (0.96, 1.27)	1.07 (0.94, 1.23)
	10-14	Soccer	Talent development ^C	450	1.85 (1.26, 2.72)	1.68 (1.14, 2.49)	1.63 (1.10, 2.41)
	15-20	Soccer		617	1.22 (0.89, 1.67)	1.18 (0.85, 1.62)	1.11 (0.80, 1.53)
	U17	Soccer	National team ^E	87	1.33 (0.54, 3.26)	1.93 (0.82, 4.57)	1.53 (0.64, 3.70)
	U19	Soccer		80	1.71 (0.69, 4.24)	1.43 (0.57, 3.59)	1.57 (0.63, 3.91)
	Senior	Soccer		72	2.09 (0.79, 5.52)	1.55 (0.57, 4.21)	1.91 (0.72, 5.08)
Albuquerque, Lage, da Costa, Fereira, Pena, et al., 2012† [100]	Not specified	Taekwondo	Olympic Games ^E	139	1.45 (0.74, 2.82)	1.14 (0.57, 2.26)	1.21 (0.61, 2.38)
Nakata & Sakamoto, 2012†† [33]	Not specified	Softball	Japan Softball Association ^E	530	1.23 (0.87, 1.73)	1.37 (0.97, 1.93)	1.18 (0.83, 1.67)
	Not specified	Soccer	Japan Women's Football League ^E	238	1.30 (0.78, 2.18)	1.22 (0.73, 2.05)	1.24 (0.74, 2.08)
	Not specified	Volleyball	V-League ^E	138	2.09 (1.05, 4.18)	2.18 (1.09, 4.35)	1.00 (0.47, 2.13)
	Not specified	Basketball	Women's Japan Basketball League (WJBL) ^E	172	1.62 (0.87, 3.03)	1.86 (1.00, 3.46)	1.45 (0.77, 2.73)
	Not specified	Track & field	Japan Industrial Track & Field ^E	124	1.03 (0.51, 2.08)	1.16 (0.58, 2.32)	0.81 (0.39, 1.66)
	Not specified	Badminton	Badminton Nippon League ^E	133	0.71 (0.35, 1.44)	1.21 (0.62, 2.34)	1.00 (0.51, 1.97)
van den Honert, 2012 †† [123]	U15, U17	Australian football	Football Federation Australia (FFA) – State team ^{Rp}	268	1.41 (0.86, 2.31)	1.27 (0.77, 2.10)	1.57 (0.96, 2.55)
	U20, Senior	Australian football	FFA – National team ^E	52	2.09 (0.73, 5.99)	0.73 (0.22, 2.39)	0.91 (0.29, 2.87)
Costa, Marques, Louro, Ferreira, & Marinho, 2013† [28]	12	Swimming	Portuguese Swimming Federation (Top 50 in individual events) ^{Rp}	624	4.72 (3.29, 6.78)	3.70 (2.56, 5.34)	1.53 (1.02, 2.28)
	13	Swimming		650	1.90 (1.38, 2.63)	2.02 (1.47, 2.78)	1.33 (0.95, 1.85)
	14	Swimming		644	0.96 (0.69, 1.32)	1.23 (0.90, 1.68)	1.45 (1.06, 1.97)
	15	Swimming		623	1.39 (1.02, 1.91)	1.19 (0.86, 1.64)	1.11 (0.80, 1.53)
	16	Swimming		519	2.00 (1.37, 2.91)	2.41 (1.67, 3.49)	2.00 (1.37, 2.91)
	17	Swimming		392	1.41 (0.93, 2.13)	2.32 (1.56, 3.45)	0.96 (0.62, 1.48)
	18	Swimming		280	0.67 (0.41, 1.10)	1.52 (0.98, 2.37)	0.64 (0.39, 1.06)

Author(s)	Sample Age (Years)	Sport	Competition Level	(N)	Odds ratio comparisons – Quartile 1-4 (95% Confidence intervals)		
					Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4
Dixon, Liburdi, Horton, & Weir, 2013†† [107]	19-24	Softball	National Collegiate Athletic Association (NCAA) – Division I ^{Cp}	380	4.57 (2.81, 7.43)	4.50 (2.77, 7.33)	2.60 (1.57, 4.33)
Hancock, Seal, Young, Weir, & Ste-Marie, 2013† [84]	4	Ice hockey	Ontario Hockey Federation: Minor Pre-Novice ^{Rc/C}	719	1.69 (1.25, 2.28)	1.73 (1.28, 2.34)	1.24 (0.91, 1.70)
	5-6	Ice hockey	Major Pre-Novice ^{Rc/C}	3879	1.27 (1.12, 1.44)	1.35 (1.19, 1.54)	1.24 (1.09, 1.42)
	7	Ice hockey	Minor Novice ^{Rc/C}	3279	1.58 (1.37, 1.82)	1.59 (1.38, 1.83)	1.31 (1.13, 1.44)
	8	Ice hockey	Major Novice ^{Rc/C}	4525	1.46 (1.29, 1.64)	1.45 (1.29, 1.64)	1.28 (1.13, 1.44)
	9	Ice hockey	Minor Atom ^{Rc/C}	5807	1.45 (1.30, 1.61)	1.51 (1.36, 1.67)	1.32 (1.19, 1.47)
	10	Ice hockey	Major Atom ^{Rc/C}	6536	1.28 (1.16, 1.41)	1.47 (1.33, 1.62)	1.24 (1.12, 1.37)
	11	Ice hockey	Minor Peeewe ^{Rc/C}	7279	1.29 (1.17, 1.42)	1.42 (1.30, 1.56)	1.24 (1.13, 1.36)
	12	Ice hockey	Major Peeewe ^{Rc/C}	7180	1.25 (1.13, 1.37)	1.39 (1.27, 1.53)	1.19 (1.08, 1.31)
Romann & Fuchslocher 2013† [116]	U17	Soccer	FIFA World Cup ^E	672	1.34 (0.99, 1.82)	1.25 (0.92, 1.70)	1.15 (0.84, 1.57)
Smith & Weir, 2013† [20]	U8	Ice hockey	Ontario Women's Hockey Association: Novice A/AA/AAA ^C	156	2.18 (1.12, 4.28)	2.50 (1.29, 4.87)	1.41 (0.70, 2.85)
	U8	Ice hockey	Novice B/BB ^C	266	2.15 (1.30, 3.57)	1.75 (1.04, 2.93)	1.75 (1.04, 2.93)
	U8	Ice hockey	Novice C/CC ^C	405	1.36 (0.92, 2.01)	1.11 (0.74, 1.65)	1.14 (0.76, 1.69)
	U8	Ice hockey	Novice house league ^{Rc}	2626	1.19 (1.01, 1.39)	1.36 (1.17, 1.59)	1.25 (1.07, 1.47)
	U10	Ice hockey	Atom A/AA/AAA ^C	494	2.92 (2.01, 4.24)	2.01 (1.36, 2.95)	1.54 (1.03, 2.29)
	U10	Ice hockey	Atom B/BB ^C	894	1.73 (1.31, 2.28)	1.83 (1.39, 2.41)	1.57 (1.19, 2.07)
	U10	Ice hockey	Atom C/CC ^C	669	1.41 (1.03, 1.93)	1.45 (1.06, 1.98)	1.41 (1.03, 1.93)
	U10	Ice hockey	Atom house league ^{Rc}	2854	1.12 (0.97, 1.30)	1.18 (1.02, 1.37)	1.14 (0.98, 1.32)
	U12	Ice hockey	Peeewe A/AA/AAA ^C	942	2.13 (1.63, 2.78)	1.92 (1.46, 2.51)	1.55 (1.17, 2.04)
	U12	Ice hockey	Peeewe B/BB ^C	1269	1.51 (1.20, 1.90)	1.60 (1.27, 2.00)	1.33 (1.05, 1.67)
	U12	Ice hockey	Peeewe C/CC ^C	865	1.39 (1.06, 1.83)	1.55 (1.18, 2.04)	1.36 (1.03, 1.80)
	U12	Ice hockey	Peeewe house league ^{Rc}	3502	1.15 (1.01, 1.32)	1.29 (1.13, 1.48)	1.20 (1.05, 1.38)
	U14	Ice hockey	Bantam A/AA/AAA ^C	1368	1.92 (1.55, 2.40)	1.82 (1.46, 2.27)	1.31 (1.04, 1.65)
	U14	Ice hockey	Bantam B/BB ^C	1353	1.40 (1.12, 1.75)	1.68 (1.35, 2.09)	1.41 (1.13, 1.76)
	U14	Ice hockey	Bantam C/CC ^C	850	1.21 (0.92, 1.59)	1.49 (1.14, 1.96)	1.18 (0.89, 1.55)
U14	Ice hockey	Bantam house league ^{Rc}	3232	1.04 (0.91, 1.20)	1.26 (1.10, 1.45)	1.23 (1.07, 1.41)	
U17	Ice hockey	Midget A/AA/AAA ^C	1659	1.74 (1.43, 2.13)	1.85 (1.52, 2.26)	1.40 (1.14, 1.71)	

Author(s)	Sample Age (Years)	Sport	Competition Level	(N)	Odds ratio comparisons – Quartile 1-4 (95% Confidence intervals)		
					Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4
Smith & Weir, 2013† [20]	U17	Ice hockey	Midget B/BB ^C	1485	1.19 (0.97, 1.46)	1.40 (1.14, 1.71)	1.15 (0.93, 1.42)
	U17	Ice hockey	Midget C/CC ^C	941	1.16 (0.90, 1.52)	1.44 (1.11, 1.86)	1.25 (0.96, 1.62)
	U17	Ice hockey	Midget house league ^{Rc}	2431	1.01 (0.86, 1.19)	1.14 (0.98, 1.34)	1.10 (0.94, 1.29)
	U21	Ice hockey	Intermediate A/AA/AAA ^C	696	1.78 (1.31, 2.42)	1.87 (1.37, 2.54)	1.34 (0.97, 1.85)
	U21	Ice hockey	Intermediate B/BB ^C	132	1.12 (0.57, 2.18)	1.00 (0.51, 1.97)	0.76 (0.38, 1.54)
	U21	Ice hockey	Intermediate C/CC ^C	86	1.23 (0.54, 2.79)	0.82 (0.34, 1.94)	0.86 (0.37, 2.03)
	U21	Ice hockey	Intermediate house league ^{Rc}	1656	0.97 (0.80, 1.18)	1.16 (0.96, 1.41)	1.11 (0.91, 1.34)
	Adult	Ice hockey	Senior A/AA/AAA ^C	880	1.31 (1.00, 1.72)	1.32 (1.01, 1.73)	1.28 (0.98, 1.68)
	Adult	Ice hockey	Senior B/BB ^C	1086	1.18 (0.93, 1.50)	1.16 (0.91, 1.47)	1.01 (0.79, 1.29)
	Adult	Ice hockey	Senior C/CC ^C	580	1.11 (0.80, 1.54)	1.00 (0.72, 1.40)	1.18 (0.85, 1.63)
Adult	Ice hockey	Senior house league ^{Rc}	3178	1.03 (0.89, 1.18)	1.15 (1.00, 1.32)	1.04 (0.90, 1.19)	
Albuquerque, Teoldo da Costa, Oliveria, et al., 2014† [101]	Not specified	Wrestling	Olympic Games ^E	146	2.00 (0.58, 2.16)	1.00 (0.51, 1.95)	1.30 (0.68, 2.48)
Baker, Janning, Wong, Cobley, & Schorer, 2014† [78]	Born in 1970 or later	Ski jump	International competitions ^E	165	1.47 (0.79, 2.74)	1.47 (0.79, 2.74)	1.22 (0.65, 2.30)
		Cross country ski		2571	1.49 (1.27, 1.73)	1.18 (1.00, 1.38)	1.16 (0.99, 1.36)
		Alpine ski		5828	1.23 (1.11, 1.36)	1.21 (1.09, 1.34)	1.08 (0.97, 1.20)
	14-28	Snowboard		915	1.09 (0.84, 1.42)	1.05 (0.81, 1.37)	1.30 (1.00, 1.68)
		Figure skating	National team ^E	91	0.78 (0.34, 1.83)	1.13 (0.50, 2.54)	1.04 (0.46, 2.36)
		Gymnastics*	Junior national team ^E	120	1.56 (0.73, 3.36)	1.94 (0.92, 4.09)	1.75 (0.82, 3.72)
15-24	Gymnastics*	Senior national team ^E	148	1.06 (0.52, 2.12)	2.11 (1.10, 4.04)	1.39 (0.71, 2.73)	
Delorme, 2014†† [106]	14-15	Boxing	French Boxing Federation	124	1.73 (0.84, 3.56)	1.14 (0.53, 2.43)	1.77 (0.86, 3.65)
	16-17	Boxing	(FBF) - Amateur ^C	168	1.13 (0.62, 2.06)	0.95 (0.51, 1.76)	1.13 (0.62, 2.06)
	18-18+	Boxing		416	0.76 (0.52, 1.13)	1.10 (0.76, 1.59)	0.79 (0.54, 1.16)
Lidor, Arnon, Maayan, Gershon, & Côté, 2014† [111]	18-36	Basketball	Division I – Professional ^E	46	0.89 (0.25, 3.12)	1.11 (0.33, 3.75)	2.11 (0.68, 6.59)
	16-38	Handball	Division I – Semi-	107	0.86 (0.40, 1.84)	1.07 (0.51, 2.25)	0.89 (0.42, 1.91)
	16-35	Soccer	Professional ^{Rp}	156	1.16 (0.62, 2.15)	0.89 (0.47, 1.70)	1.05 (0.56, 1.97)
	16-36	Volleyball		80	1.05 (0.44, 2.51)	0.90 (0.37, 2.19)	1.05 (0.44, 2.51)

Author(s)	Sample Age (Years)	Sport	Competition Level	(N)	Odds ratio comparisons – Quartile 1-4 (95% Confidence intervals)		
					Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4
Romann & Fuchslocher, 2014a [61] <i>J&S</i> ^{††} <i>Talent development</i> ^{†††}	U11	Fencing	J&S ^{Rc}	327	1.48 (0.95, 2.30)	0.86 (0.53, 1.38)	1.86 (1.20, 2.86)
	U12	Fencing		276	1.85 (1.11, 3.08)	2.23 (1.35, 3.69)	2.00 (1.20, 3.33)
	U13	Fencing		351	1.81 (1.18, 2.77)	1.71 (1.12, 2.63)	1.05 (0.66, 1.65)
	U14	Fencing		438	1.27 (0.86, 1.86)	1.13 (0.77, 1.67)	1.47 (1.01, 2.14)
	U15	Fencing		387	0.94 (0.63, 1.40)	1.12 (0.76, 1.66)	0.85 (0.57, 1.27)
	U16	Fencing		315	0.81 (0.52, 1.28)	0.89 (0.57, 1.39)	1.19 (0.77, 1.82)
	U17	Fencing		351	1.87 (1.23, 2.83)	1.00 (0.64, 1.56)	1.22 (0.79, 1.88)
	U18	Fencing		330	0.94 (0.61, 1.43)	0.74 (0.48, 1.15)	0.87 (0.57, 1.33)
	U19	Fencing		249	2.58 (1.53, 4.35)	1.33 (0.76, 2.33)	2.00 (1.17, 3.41)
	U20	Fencing		348	0.65 (0.42, 1.00)	0.77 (0.50, 1.19)	1.32 (0.89, 1.98)
	U12-U17**	Fencing	Talent development ^C	143	0.78 (0.40, 1.50)	0.98 (0.51, 1.85)	0.83 (0.43, 1.59)
	U18-U19**	Fencing		52	0.53 (0.18, 1.56)	0.58 (0.20, 1.69)	0.63 (0.22, 1.81)
	U11	Alpine ski	J&S ^{Rc}	23763	1.51 (1.44, 1.59)	1.39 (1.32, 1.46)	1.21 (1.15, 1.28)
	U12	Alpine ski		17742	1.20 (1.13, 1.27)	1.14 (1.08, 1.21)	1.09 (1.03, 1.16)
	U13	Alpine ski		20961	1.28 (1.21, 1.35)	1.14 (1.08, 1.21)	1.11 (1.05, 1.17)
	U14	Alpine ski		25140	1.20 (1.14, 1.26)	1.14 (1.09, 1.20)	1.18 (1.13, 1.25)
	U15	Alpine ski		25836	1.01 (0.96, 1.06)	1.07 (1.02, 1.12)	1.13 (1.08, 1.19)
	U16	Alpine ski		24147	0.89 (0.84, 0.93)	0.97 (0.92, 1.02)	1.05 (1.00, 1.10)
	U17	Alpine ski		19491	0.82 (0.77, 0.87)	0.90 (0.85, 0.95)	0.99 (0.94, 1.04)
	U18	Alpine ski		13008	0.68 (0.63, 0.73)	0.80 (0.75, 0.86)	0.93 (0.87, 0.99)
U19	Alpine ski		7320	0.68 (0.62, 0.75)	0.79 (0.72, 0.87)	0.99 (0.90, 1.08)	
U20	Alpine ski		9060	0.85 (0.78, 0.92)	0.87 (0.80, 0.95)	0.97 (0.89, 1.05)	
U11-U14**	Alpine ski	Talent development ^C	573	2.51 (1.77, 3.56)	2.03 (1.42, 2.89)	1.63 (1.13, 2.33)	
U15-U16**	Alpine ski		313	2.12 (1.34, 3.36)	1.86 (1.17, 2.96)	1.28 (0.79, 2.08)	
U17-U18**	Alpine ski		245	1.45 (0.88, 2.39)	1.32 (0.80, 2.18)	0.85 (0.50, 1.45)	
U19-U20**	Alpine ski		95	0.48 (0.21, 1.11)	0.64 (0.29, 1.40)	0.76 (0.35, 1.64)	
U11	Table tennis	J&S ^{Rc}	591	1.29 (0.93, 1.78)	1.55 (1.12, 2.13)	0.86 (0.61, 1.21)	
U12	Table tennis		483	1.15 (0.80, 1.65)	1.38 (0.97, 1.98)	1.21 (0.84, 1.74)	
U13	Table tennis		504	0.78 (0.54, 1.12)	1.07 (0.76, 1.52)	1.24 (0.88, 1.75)	
U14	Table tennis		531	1.10 (0.78, 1.55)	1.18 (0.83, 1.65)	1.15 (0.82, 1.62)	
U15	Table tennis		438	0.86 (0.59, 1.26)	1.06 (0.73, 1.53)	1.14 (0.79, 1.65)	
U16	Table tennis		378	0.69 (0.46, 1.05)	0.83 (0.56, 1.24)	0.97 (0.66, 1.44)	
U17	Table tennis		285	0.57 (0.35, 0.93)	0.71 (0.45, 1.14)	1.11 (0.71, 1.72)	
U18	Table tennis		186	0.69 (0.38, 1.25)	1.00 (0.57, 1.77)	1.19 (0.68, 2.08)	
U19	Table tennis		96	0.29 (0.12, 0.67)	0.50 (0.23, 1.08)	0.50 (0.23, 1.08)	
U20	Table tennis		183	0.50 (0.27, 0.93)	0.61 (0.34, 1.11)	1.28 (0.74, 2.20)	

Author(s)	Sample Age (Years)	Sport	Competition Level	(N)	Odds ratio comparisons – Quartile 1-4 (95% Confidence intervals)		
					Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4
Romann & Fuchslocher, 2014a [61] <i>J&S††</i> <i>Talent development †††</i>	U11	Table tennis	Talent development ^C	102	2.29 (1.04, 5.06)	1.65 (0.73, 3.72)	1.06 (0.45, 2.50)
	U12-U13**	Table tennis		129	0.77 (0.38, 1.59)	1.06 (0.53, 2.13)	1.32 (0.67, 2.60)
	U14-U15**	Table tennis		105	0.92 (0.42, 2.02)	1.21 (0.56, 2.60)	1.25 (0.58, 2.68)
	U16-U18**	Table tennis		80	0.68 (0.27, 1.75)	1.21 (0.51, 2.88)	1.32 (0.56, 3.11)
	U11	Tennis	J&S ^{Rc}	9207	1.50 (1.38, 1.63)	1.36 (1.25, 1.48)	1.18 (1.08, 1.29)
	U12	Tennis		5700	1.19 (1.07, 1.32)	1.16 (1.04, 1.28)	1.07 (0.96, 1.19)
	U13	Tennis		6552	1.17 (1.06, 1.29)	1.15 (1.05, 1.27)	1.05 (0.95, 1.16)
	U14	Tennis		6972	1.14 (1.03, 1.25)	1.00 (0.91, 1.10)	1.05 (0.96, 1.16)
	U15	Tennis		6699	1.09 (0.99, 1.21)	1.08 (0.98, 1.19)	1.13 (1.02, 1.24)
	U16	Tennis		6204	0.86 (0.78, 0.96)	1.05 (0.95, 1.16)	1.08 (0.98, 1.19)
	U17	Tennis		5508	1.01 (0.91, 1.13)	0.94 (0.85, 1.05)	1.04 (0.94, 1.16)
	U18	Tennis		4122	0.91 (0.81, 1.03)	0.94 (0.83, 1.06)	0.98 (0.87, 1.11)
	U19	Tennis		3222	0.85 (0.74, 0.98)	0.97 (0.84, 1.11)	1.01 (0.88, 1.16)
	U20	Tennis		3969	0.94 (0.83, 1.06)	0.93 (0.82, 1.05)	0.92 (0.81, 1.04)
	U11-U12**	Tennis	Talent development ^C	215	3.63 (2.05, 6.42)	1.81 (0.99, 3.32)	1.52 (0.82, 2.81)
	U13-U14**	Tennis		102	3.08 (1.34, 7.07)	2.15 (0.91, 5.07)	1.62 (0.67, 3.91)
	U15-U18**	Tennis		89	2.69 (1.13, 6.40)	1.77 (0.72, 4.35)	1.38 (0.55, 3.49)
	U11	Snowboard	J&S ^{Rc}	81	2.20 (0.92, 5.24)	1.60 (0.66, 3.90)	0.60 (0.21, 1.68)
	U12	Snowboard		93	2.75 (1.15, 6.60)	2.00 (0.81, 4.92)	2.00 (0.81, 4.92)
	U13	Snowboard		141	1.33 (0.67, 2.64)	1.22 (0.61, 2.44)	1.67 (0.85, 3.25)
	U14	Snowboard		198	1.77 (1.01, 3.09)	1.23 (0.69, 2.19)	1.08 (0.60, 1.94)
	U15	Snowboard		300	0.72 (0.46, 1.14)	1.10 (0.72, 1.70)	0.62 (0.39, 0.99)
	U16	Snowboard		345	0.91 (0.60, 1.37)	0.94 (0.62, 1.42)	0.75 (0.49, 1.15)
	U17	Snowboard		324	0.72 (0.46, 1.13)	1.14 (0.75, 1.73)	0.86 (0.56, 1.33)
	U18	Snowboard		306	1.22 (0.78, 1.91)	1.09 (0.69, 1.71)	1.13 (0.72, 1.78)
	U19	Snowboard		192	2.43 (1.27, 4.64)	3.00 (1.59, 5.66)	2.71 (1.43, 5.15)
	U20	Snowboard		198	1.50 (0.82, 2.75)	1.90 (1.05, 3.44)	2.20 (1.23, 3.95)
	U11-U14**	Snowboard	Talent development ^C	99	1.04 (0.47, 2.30)	0.88 (0.39, 1.96)	1.21 (0.56, 2.63)
	U15-U16**	Snowboard		98	0.71 (0.32, 1.59)	0.79 (0.36, 1.73)	1.00 (0.46, 2.15)
	U17-U18**	Snowboard		80	1.06 (0.43, 2.58)	1.11 (0.46, 2.70)	1.28 (0.53, 3.06)
	U11	Track & field	J&S ^{Rc}	8094	1.55 (1.42, 1.69)	1.30 (1.18, 1.42)	1.21 (1.11, 1.32)
	U12	Track & field		5400	1.16 (1.05, 1.30)	1.17 (1.05, 1.30)	1.09 (0.98, 1.21)
	U13	Track & field		6321	1.24 (1.12, 1.37)	1.21 (1.09, 1.33)	1.10 (1.00, 1.22)
U14	Track & field		5832	1.15 (1.04, 1.27)	1.22 (1.10, 1.35)	1.09 (0.98, 1.21)	
U15	Track & field		5832	1.23 (1.11, 1.37)	1.10 (0.99, 1.22)	1.21 (1.09, 1.34)	
U16	Track & field		4632	0.91 (0.81, 1.02)	0.99 (0.89, 1.12)	0.96 (0.86, 1.08)	

Author(s)	Sample Age (Years)	Sport	Competition Level	(N)	Odds ratio comparisons – Quartile 1-4 (95% Confidence intervals)			
					Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4	
Romann & Fuchslocher, 2014a [61] <i>J&S††</i> <i>Talent development †††</i>	U17	Track & field	J&S ^{Rc}	3744	1.32 (1.16, 1.50)	1.10 (0.97, 1.25)	1.04 (0.91, 1.18)	
	U18	Track & field		2877	0.92 (0.79, 1.06)	1.05 (0.90, 1.21)	1.02 (0.88, 1.18)	
	U19	Track & field		2199	1.35 (1.14, 1.60)	1.21 (1.02, 1.44)	1.13 (0.96, 1.35)	
	U20	Track & field		2649	1.12 (0.96, 1.30)	1.25 (1.08, 1.46)	1.09 (0.93, 1.27)	
	U15-U16**	Track & field	Talent development ^C	257	2.33 (1.39, 3.93)	2.28 (1.35, 3.84)	1.53 (0.89, 2.63)	
	U17-U18**	Track & field		218	2.61 (1.47, 4.63)	2.21 (1.24, 3.97)	1.96 (1.09, 3.54)	
	U19	Track & field		87	1.16 (0.49, 2.72)	1.47 (0.64, 3.39)	0.95 (0.39, 2.28)	
Romann & Fuchslocher, 2014b†† [31]	U8	Alpine ski	Migros Ski Grand Prix – Qualification Finisher ^C	747	1.17 (0.87, 1.56)	1.30 (0.97, 1.73)	1.15 (0.86, 1.54)	
	U9	Alpine ski		897	1.06 (0.81, 1.37)	1.07 (0.82, 1.39)	0.99 (0.76, 1.29)	
	U10	Alpine ski		1097	0.95 (0.75, 1.20)	0.96 (0.76, 1.21)	0.95 (0.75, 1.21)	
	U11	Alpine ski		1065	1.11 (0.88, 1.42)	1.06 (0.83, 1.35)	1.04 (0.81, 1.32)	
	U12	Alpine ski		1021	0.98 (0.76, 1.25)	0.98 (0.77, 1.25)	0.95 (0.75, 1.22)	
	U13	Alpine ski		917	0.89 (0.69, 1.15)	0.88 (0.68, 1.14)	0.91 (0.71, 1.18)	
	U14	Alpine ski		688	0.81 (0.60, 1.09)	0.77 (0.57, 1.04)	0.88 (0.66, 1.18)	
	U15	Alpine ski		574	0.91 (0.66, 1.25)	0.81 (0.59, 1.13)	0.87 (0.63, 1.20)	
Saavedra-García, Gutiérrez Aguilar, Fernández Romero, Fernández Lastra, & Eiras Oliveira, 2014† [79]	U17	Basketball	World Championships ^E	144	2.17 (1.11, 4.27)	1.74 (0.87, 3.47)	1.35 (0.66, 2.74)	
	U19	Basketball		194	2.54 (1.40, 4.58)	2.04 (1.11, 3.72)	1.36 (0.72, 2.55)	
	U21	Basketball		144	1.46 (0.74, 2.88)	1.81 (0.93, 3.52)	1.27 (0.64, 2.53)	
Stenling & Holmström, 2014† [21]	5-6	Ice hockey	Licensed youth players ^{Rc/C}	458	1.92 (1.32, 2.80)	1.42 (0.96, 2.09)	1.46 (0.99, 2.14)	
	7-9	Ice hockey		693	1.17 (0.86, 1.58)	1.36 (1.01, 1.84)	1.28 (0.95, 1.74)	
	10-12	Ice hockey		495	1.52 (1.06, 2.17)	1.41 (0.99, 2.02)	1.18 (0.81, 1.70)	
	13-15	Ice hockey		460	1.29 (0.88, 1.88)	1.60 (1.11, 2.31)	1.22 (0.84, 1.79)	
	16-20	Ice hockey		705	1.65 (1.21, 2.24)	1.52 (1.12, 2.07)	1.47 (1.08, 2.00)	
	U18	Ice hockey		U-18 regional tournament ^{Rp}	399	1.98 (1.32, 2.99)	1.75 (1.16, 2.65)	1.50 (0.98, 2.28)
				National championship;	688	2.07 (1.51, 2.83)	1.96 (1.43, 2.69)	1.59 (1.15, 2.19)
	Adult	Ice hockey		Riksserien league ^E				
Albuquerque, Franchini, Lage, et al., 2015† [70]	16+	Judo	Olympic Games ^E	665	1.21 (0.89, 1.65)	1.14 (0.84, 1.56)	1.23 (0.90, 1.67)	

Author(s)	Sample Age (Years)	Sport	Competition Level	(N)	Odds ratio comparisons – Quartile 1-4 (95% Confidence intervals)		
					Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4
Fukuda, 2015† [108]	U17-U20/21	Judo	International Judo Federation; Junior World Championships ^E	710	1.39 (1.03, 1.87)	1.16 (0.85, 1.57)	1.32 (0.97, 1.77)
Hancock, Starkes, & Ste-Marie, 2015 [110] <i>U15 Regional</i> † <i>All other samples</i> †††	U15	Gymnastics	Regional ^{Rp}	387	1.14 (0.76, 1.71)	1.28 (0.86, 1.91)	1.08 (0.72, 1.62)
	15+	Gymnastics		74	0.46 (0.18, 1.18)	0.62 (0.25, 1.51)	0.77 (0.32, 1.83)
	U15	Gymnastics	Provincial ^{Rp}	208	1.10 (0.64, 1.89)	1.12 (0.65, 1.92)	0.94 (0.54, 1.63)
	15+	Gymnastics		62	0.63 (0.24, 1.62)	0.42 (0.15, 1.16)	0.54 (0.20, 1.44)
	U15	Gymnastics	Elite provincial ^{Rp}	85	2.42 (0.98, 5.96)	1.92 (0.76, 4.82)	1.75 (0.69, 4.43)
	15+	Gymnastics		28	0.50 (0.10, 2.46)	0.75 (0.17, 3.33)	1.25 (0.31, 5.07)
	U15	Gymnastics	National ^E	56	1.50 (0.47, 4.79)	2.75 (0.92, 8.24)	1.75 (0.56, 5.48)
15+	Gymnastics	21		0.40 (0.05, 3.07)	2.20 (0.44, 10.97)	0.60 (0.09, 3.91)	
Müller, Hildebrandt, & Raschner, 2015 [82] <i>Age 7-11</i> † <i>Age 12-15</i> †††	7	Alpine ski	Kids Cup (Provincial races) ^C	71	1.78 (0.62, 5.07)	2.33 (0.84, 6.48)	2.78 (1.02, 7.60)
	8	Alpine ski		96	1.55 (0.70, 3.44)	1.15 (0.50, 2.62)	1.10 (0.48, 2.52)
	9	Alpine ski		108	1.22 (0.57, 2.62)	1.22 (0.57, 2.62)	1.26 (0.59, 2.71)
	10	Alpine ski	Teenager Cup (Provincial races) ^C	144	1.39 (0.71, 2.72)	1.39 (0.71, 2.72)	1.36 (0.69, 2.66)
	11	Alpine ski		161	2.00 (1.08, 3.69)	1.13 (0.59, 2.17)	1.06 (0.55, 2.05)
	12	Alpine ski		102	1.20 (0.56, 2.58)	1.20 (0.56, 2.58)	0.68 (0.30, 1.55)
	13	Alpine ski		110	1.37 (0.62, 3.03)	1.63 (0.75, 3.55)	1.79 (0.83, 3.87)
	14	Alpine ski		97	1.74 (0.78, 3.85)	1.11 (0.48, 2.55)	1.26 (0.55, 2.88)
	15	Alpine ski		78	1.00 (0.43, 2.35)	0.78 (0.32, 1.89)	0.61 (0.24, 1.52)
Müller, Müller, Kornexl, & Raschner, 2015†/†† [32]	9-10	Alpine ski	Ski boarding school entrance exam ^C	194	1.61 (0.89, 2.90)	1.64 (0.91, 2.95)	1.64 (0.91, 2.95)
	14-15	Alpine ski		185	1.82 (1.01, 3.28)	1.45 (0.80, 2.66)	1.33 (0.73, 2.45)
Nagy, Okros, & Sos, 2015† [113]	11-26	Swimming	Champions of Future; National team ^{Cp/E}	183	2.92 (1.57, 5.42)	2.33 (1.24, 4.38)	1.38 (0.71, 2.68)
Sedano, Vaeyens, & Redondo, 2015†† [122]	U10, U12, U14	Soccer	Spanish Royal Federation of Soccer (SRFS): First division ^C	936	1.42 (1.09, 1.85)	1.74 (1.34, 2.25)	1.12 (0.86, 1.48)
	U10, U12, U14	Soccer	Second division ^C	1711	1.26 (1.04, 1.52)	1.33 (1.10, 1.61)	0.92 (0.75, 1.12)

Author(s)	Sample Age (Years)	Sport	Competition Level	(N)	Odds ratio comparisons – Quartile 1-4 (95% Confidence intervals)		
					Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4
Sedano, Vaeyens, & Redondo, 2015†† [122]	U10, U12, U14	Soccer	Third division ^C	870	1.21 (0.93, 1.57)	0.88 (0.67, 1.15)	1.04 (0.80, 1.36)
	U17, U19, U21, Senior	Soccer	National team ^E	232	2.42 (1.41, 4.18)	2.21 (1.28, 3.83)	1.39 (0.78, 2.48)
	U17, U19	Soccer	Regional team ^{Rp}	286	1.95 (1.23, 3.09)	1.62 (1.01, 2.59)	0.64 (0.37, 1.09)
Arrieta, Torres-Unda, Gil, & Irazusta, 2016 †† [80]	U16	Basketball	European Basketball	396	2.03 (1.36, 3.02)	1.58 (1.05, 2.37)	0.97 (0.63, 1.50)
	U18	Basketball	Championships ^E	407	2.01 (1.36, 2.98)	1.24 (0.82, 1.88)	1.24 (0.82, 1.88)
	U20	Basketball		299	1.50 (0.95, 2.38)	1.34 (0.84, 2.15)	1.31 (0.82, 2.09)
Brazo-Sayavera, Martínez-Valencia, Müller, Andronikos, & Martindale† [103] <i>Note: Also used weighted mean scores to compare selected & unselected</i>	U15	Track & field	Spanish National Athletics	407	1.96 (1.32, 2.90)	1.55 (1.04, 2.32)	0.99 (0.65, 1.51)
	U17	Track & field	Federation (RFEA) – Selected ^{Rp}	227	1.12 (0.66, 1.89)	1.42 (0.85, 2.37)	0.83 (0.48, 1.43)
	U15	Track & field	RFEA - Unselected ^C	9575	1.36 (1.25, 1.47)	1.23 (1.13, 1.33)	1.07 (0.99, 1.16)
	U17	Track & field		3299	1.16 (1.01, 1.33)	1.20 (1.04, 1.37)	1.05 (0.92, 1.21)
Chittle, Horton, & Dixon, 2016†† [104]	18-25	Basketball	NCAA Division I ^C	265	5.40 (2.98, 9.80)	4.29 (2.35, 7.85)	3.19 (1.72, 5.92)
Lemez, Macmahon, & Weir, 2016†††† [25]	8-10	Rugby	Developmental leagues	68	1.36 (0.49, 3.81)	1.91 (0.71, 5.15)	1.91 (0.71, 5.15)
	11-14	Rugby	(Can.) ^{Rc/C}	118	2.26 (1.08, 4.76)	1.58 (0.73, 3.41)	1.37 (0.63, 2.99)
	15	Rugby		213	1.51 (0.87, 2.61)	1.49 (0.86, 2.58)	1.20 (0.68, 2.10)
	16	Rugby		298	1.15 (0.72, 1.83)	1.11 (0.70, 1.78)	1.55 (0.98, 2.44)
	17	Rugby		386	1.38 (0.92, 2.07)	1.28 (0.85, 1.92)	1.23 (0.82, 1.85)
	18-20	Rugby		385	1.20 (0.80, 1.79)	1.05 (0.70, 1.58)	1.23 (0.83, 1.84)
	4	Rugby	Developmental leagues	278	2.49 (1.53, 4.04)	1.70 (1.03, 2.81)	1.28 (0.76, 2.15)
	5	Rugby	(NZ) ^{Rc/C}	519	1.31 (0.93, 1.85)	1.09 (0.77, 1.54)	1.08 (0.76, 1.53)
	6	Rugby		789	1.23 (0.93, 1.62)	1.06 (0.80, 1.40)	0.89 (0.67, 1.18)
	7	Rugby		1080	1.27 (1.00, 1.61)	1.17 (0.92, 1.49)	1.04 (0.82, 1.33)
	8	Rugby		1322	1.09 (0.88, 1.35)	1.12 (0.91, 1.39)	0.91 (0.73, 1.13)
	9	Rugby		1864	1.50 (1.25, 1.81)	1.26 (1.05, 1.52)	1.25 (1.03, 1.50)
	10	Rugby		2023	0.63 (0.53, 0.76)	0.92 (0.77, 1.09)	1.08 (0.91, 1.27)
	11	Rugby		1294	1.51 (1.22, 1.87)	1.03 (0.82, 1.29)	1.05 (0.84, 1.32)
12	Rugby		1124	0.54 (0.42, 0.69)	0.91 (0.72, 1.14)	1.12 (0.90, 1.40)	
13	Rugby		627	0.84 (0.61, 1.15)	0.99 (0.72, 1.35)	1.07 (0.78, 1.45)	
14	Rugby		622	1.17 (0.85, 1.60)	1.06 (0.77, 1.46)	1.09 (0.79, 1.50)	

Author(s)	Sample Age (Years)	Sport	Competition Level	(N)	Odds ratio comparisons – Quartile 1-4 (95% Confidence intervals)		
					Q1 vs. Q4	Q2 vs. Q4	Q3 vs. Q4
Lemez, Macmahon, & Weir, 2016†††† [25]	15	Rugby	Developmental leagues (NZ) ^{Rc/C}	710	1.01 (0.75, 1.36)	1.04 (0.77, 1.39)	1.13 (0.84, 1.51)
	16	Rugby		704	0.79 (0.59, 1.07)	1.01 (0.76, 1.35)	0.96 (0.72, 1.29)
	17	Rugby		504	0.43 (0.30, 0.63)	0.72 (0.51, 1.02)	1.16 (0.84, 1.62)
	18	Rugby		187	0.73 (0.41, 1.30)	0.71 (0.40, 1.27)	0.89 (0.51, 1.56)
	19	Rugby		137	1.03 (0.53, 2.01)	0.85 (0.43, 1.69)	1.15 (0.59, 2.22)
	20	Rugby		115	1.10 (0.54, 2.25)	0.70 (0.33, 1.50)	1.03 (0.50, 2.12)
	19-43	Rugby	World Cup ^E	498	0.86 (0.61, 1.23)	0.93 (0.66, 1.32)	0.95 (0.67, 1.34)
Werneck et al., 2016 [125]	27.1 +/- 3.9	Basketball	Olympic Games ^E	147	0.78 (0.40, 1.53)	1.22 (0.65, 2.29)	0.97 (0.51, 1.86)

Table Notes: Odds ratio (CI) calculations were based on the assumption of an equal distribution of birth dates per quartile. The expected distribution used in each study is denoted by the use of the following symbols: † Observed distribution compared to an equal distribution of birth dates (i.e., 25% per quartile); †† Observed distribution compared to the birth rate in the general population (i.e., national birth statistics); †/†† Assumed 25% based on birth rate in the population; ††† Observed distribution compared to the birth distribution present in the selection population; †††† Observed distribution compared to a birth distribution based on the number of days per quartile; ‡ Expected birth distribution not stated; * Raw numbers were not available and ORs have been estimated based on graphical representation of the data; **Age groups were combined in accordance with age bands used in each respective sport; 0.5 added to raw data when Quartile 4 = 0, preventing odds ratio calculation. Procedure recommended by Sutton et al. [126].

Table 3: Summary sample and participant numbers (and percentages) according to subgroup category as applied in the meta-analyses.

Category	N of samples (% of samples)	N of participants (% of participants)
Age		
Pre-adolescent (≤ 11 years)	51 (16.55%)	163,292 (25.26%)
Adolescent (12-14 years)	55 (17.85%)	165,107 (25.54%)
Post-Adolescent (15-19 years)	91 (29.54%)	197,368 (30.53%)
Adult (> 19 years)	32 (10.38%)	36,051 (5.58%)
Not codable into above*	79 (25.64%)	84,565 (13.08%)
Competition Level		
Recreational	76 (24.68%)	369,216 (57.12%)
Competitive	71 (23.05%)	47,321 (7.32%)
Representative	44 (14.29%)	12,095 (1.87%)
Overall – Elite	61 (19.81%)	23,822 (3.63%)
Elite Adolescent	5 (1.62%)	548 (0.08%)
Elite Post-Adolescent	18 (5.84%)	5,390 (0.83%)
Elite Adult	12 (3.90%)	2,186 (0.34%)
Elite - Combination of age	26 (8.44%)	15,698 (2.43%)
Not codable into above	56 (18.18%)	193,929 (30.0%)
Sport Type		
Team	154 (50.0%)	286,208 (44.28%)
<u>Individual:</u>		
Physically Demanding	88 (28.57%)	332,378 (51.42%)
Technique/Skill-Based	59 (19.16%)	25,429 (3.93%)
Weight-Categorised	7 (2.27%)	2,368 (0.37%)

Table Notes: * Not codable = Sample age range in studies traversed age categories.

Table 4: Summary of Quartile (Q1) v Quartile (Q4) subgroup analyses according to identified moderating factors.

Random Effects Model		Subgroup Estimates				Mixed effects Between subgroup analysis		Subgroup Heterogeneity	
<i>Moderator variable</i> Subgroup (No. samples)	Point Estimate	95%CI	Z value	p value	Q Between value	p value	Q in subgroup / Q Within	p in subgroup / p Within	I ² subgroup
<i>Age</i>									
Pre-Adolescent (≤ 11 yrs.)	(51)	1.33	1.25-1.42	8.68	0.0001		238.13	0.0001	79.00
Adolescent (12-14 yrs.)	(55)	1.28	1.19-1.37	7.05	0.0001		241.83	0.0001	77.67
Post-Adolescent (15-19 yrs.)	(91)	1.14	1.08-1.20	4.79	0.0001		707.57	0.0001	87.28
Adult (>19 yrs.)	(32)	1.08	0.97-1.19	1.44	0.14		55.10	0.005	43.74
Not codable into above	(79)	1.37	1.29-1.46	9.74	0.0001	31.24	0.0001	369.12	0.0001
							1611.78	0.0001	
<i>Competition Level</i>									
Recreational	(76)	1.08	1.02-1.14	2.83	0.005		1028.85	0.0001	92.71
Competitive	(71)	1.39	1.30-1.50	9.38	0.0001		243.92	0.0001	71.30
Representative	(44)	1.45	1.31-1.61	7.24	0.0001		126.83	0.0001	66.09
Elite Adolescent	(5)	2.70	1.76-4.12	4.58	0.0001		6.64	0.15	39.81
Elite Post-Adolescent	(18)	1.65	1.41-1.92	6.48	0.0001		35.92	0.005	52.67
Elite Adult	(12)	1.27	1.02-1.50	2.19	0.02		9.20	0.60	0.00
Elite - Combination of age	(26)	1.42	1.26-1.61	5.65	0.0001		56.16	0.0001	55.48
Not codable into above	(56)	1.19	1.12-1.27	5.40	0.0001	77.09	0.0001	357.62	0.0001
							1865.17	0.0001	
<i>Sport Type</i>									
Team	(154)	1.33	1.27-1.39	12.51	0.0001		689.01	0.0001	77.79
Individual	(154)	1.18	1.12-1.24	5.26	0.0001				
Physically demanding	(88)	1.23	1.16-1.30	7.19	0.0001		1125.83	0.0001	92.82
Technique (Skill)-based	(59)	1.06	0.97-1.16	1.36	0.17		118.20	0.0001	51.77
Weight-Categorised	(7)	1.18	0.93-1.51	1.38	0.16	20.58	0.001	7.48	0.27
							2040.54	0.0001	
<i>Study Quality</i>									
Lower (scores 5-9)	(38)	1.63	1.46-1.82	8.55	0.0001		72.48	0.0001	48.95
Medium (scores 10-11)	(92)	1.29	1.22-1.37	8.72	0.0001		348.55	0.0001	73.89
Higher (scores 12-14)	(178)	1.19	1.14-1.25	8.46	0.0001	27.44	0.001	1596.47	0.0001
							2017.51	0.0001	

Table Notes: Point Estimate = Pooled overall odds ratio (Q1 v Q4) estimate; 95%CI = Lower & upper confidence interval estimates; Z value = Reflects the test for an overall effect; p = Indicating probability of significance (p criteria set at ≤ 0.05); Q Value = Dispersion of studies about the point estimate overall or within subgroup; I² = Reflects heterogeneity within subgroup.

Table 5: Summary of Quartile (Q1) v Quartile (Q4) subgroup analyses according to sport context.

Random Effects Model		Subgroup Estimates			
<i>Sport Context Subgroup</i>	(No. samples)	Point Estimate	95%CI	Z value	<i>p</i> value
<i>Sport Context (≥ 6 samples)</i>					
Alpine Skiing	(34)	1.09	1.01-1.19	1.96	0.05
Basketball	(22)	1.36	1.22-1.51	5.67	0.0001
Fencing	(12)	1.21	1.01-1.45	2.12	0.03
Gymnastics	(10)	1.06	0.80-1.41	0.44	0.65
Handball	(16)	1.41	1.19-1.68	3.95	0.0001
Ice-Hockey	(45)	1.39	1.30-1.50	9.11	0.0001
Rugby	(27)	1.06	0.95-1.18	1.10	0.26
Shooting Sports	(6)	1.07	0.87-1.32	0.72	0.46
Snowboarding	(14)	1.16	0.97-1.40	1.63	0.10
Soccer	(33)	1.31	1.19-1.45	5.65	0.0001
Swimming	(8)	1.67	1.37-2.04	5.10	0.0001
Table Tennis	(14)	0.85	0.71-1.01	-1.81	0.07
Tennis	(27)	1.28	1.15-1.42	4.73	0.0001
Track & Field	(18)	1.26	1.12-1.40	4.07	0.0001
Volleyball	(7)	1.81	1.30-2.53	3.51	0.0001
<i>Sport Context (< 6 samples)</i>					
Australian Rules Football	(2)	1.55	0.89-2.70	1.55	0.11
Badminton	(1)	0.70	0.31-1.59	-0.83	0.40
Boxing	(3)	1.02	0.69-1.51	0.12	0.90
Cross-Country Skiing	(1)	1.48	0.96-2.28	1.80	0.07
Figure Skating	(1)	0.78	0.30-1.99	0.51	0.60
Judo	(2)	1.30	0.91-1.85	1.44	0.14
Ski-Jumping	(1)	1.46	0.70-3.08	1.01	0.31
Softball	(2)	2.11	1.40-3.17	3.61	0.0001
Taekwondo	(1)	1.44	0.66-3.15	0.93	0.35
Wrestling	(1)	1.12	0.58-2.15	0.34	0.73

Table Notes: Point Estimate = Pooled overall odds ratio (Q1 v Q4) estimate; 95%CI = Lower & upper confidence interval estimates; Z value = Reflects the test for an overall effect; *p* = Probability of significance (*p* criteria set at ≤ 0.05).