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

By

Kristy L. Smith[1], MHK, Patricia L. Weir[1], PhD, Kevin Till[2], PhD,

Michael Romann[3], PhD & Stephen Cobley[4], PhD.

Affiliations:

[1] Faculty of Human Kinetics, University of Windsor, Ontario, Canada

[2] Institute for Sport, Physical Activity and Leisure, Leeds Beckett University, Leeds, United Kingdom

[3] Swiss Federal Institute of Sport Magglingen, Switzerland

[4] Faculty of Health Sciences, Exercise and Sport Sciences, The University of Sydney, NSW, Australia.

Corresponding Author:

Dr. Stephen Cobley

Exercise & Sports Science, Faculty of Health Sciences

Cumberland Campus; The University of Sydney,

75 East St, Lidcombe, NSW, Australia, 2141,

Email: stephen.cobley@sydney.edu.au

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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.

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1 Introduction

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

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

1.1 Brief background on RAEs

RAEs were initially recognized in the education system [15-17] and only identified in sport some several decades later. Grondin, Deschaies and Nault [18] first reported an unequal distribution of birthdates among Canadian ice hockey players. Across various skill levels, those born in the first quartile[1] of a same-age group were over-represented relative to those born in the last quartile. At a similar time, Barnsley and colleagues 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.

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

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

1.2 Explanations for RAEs

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

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

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

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

1.3 Rationale for a meta-analysis

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

1.4 Study objective

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

2 Methods

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

2.1 Inclusion & exclusion criteria

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

2.2 Systematic search

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

(Insert Figure 1 about here)

2.3 Data extraction

The systematic search yielded 57 studies spanning 1984-2016 and specific information was then extracted, including: Author(s), year of publication, location, sample characteristics (e.g., age, nationality, number of participants), sport setting (e.g., type of sport, level of competition), competition year, method of grouping athletes, relative age distributions (e.g., quartiles) and the distributions used for comparison purposes (e.g., 25% per quartile, population birth rates etc.). Corresponding authors were contacted when any information was not provided or where further clarity was needed (e.g., age or competition level)[3]. In total, 22 authors were contacted. Nine provided requested information; seven were unable to provide required information (e.g., data no longer accessible); four failed to respond, and two could not be located. Data from 44 of the 57 studies were used where possible in overall meta and subgroup analyses. In cases where participant numbers were not reported, but presented in tables or figures, estimates were extracted[4]. Samples that could not be utilized due to missing information were still assessed for methodological quality and reported in review summary tables.

2.4 Study quality assessment

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

2.5 Meta-analyses: Data inclusion & exclusion

Data identified from the systematic search was included in meta-analyses. Inclusion criteria specified that with the exception of elite national levels, samples had to have examined ≥ 50 participants in a given age category or competition level, to help avoid artificially inflating RAE estimates. Where samples of < 50 participants were apparent, but multiple independent samples in the sport context were reported (e.g., age 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.

from two studies were modified this way [25, 61]. Sport contexts where a participant may have been present in several samples, due to multiple event entries (e.g., Breaststroke and Freestyle in swimming) were included as this was reflective of the organisational structures employed in the respective sport. However, studies that examined RAEs in multi-sport samples and a broader overall athlete population (e.g., Youth Olympic Games) were excluded due to inherent variability and small sample size. Further, to keep the analysis relevant to modern participant trends, samples derived from archival data prior to 1981 were excluded. This competition year coincided with the first documented evidence of RAEs in sport [18], and corresponded to birthdates from the early 1960s onward. When applied, criteria yielded 308 independent samples from 44 studies. Retained samples examined 25 different sport contexts in at least 17 countries[5]. A range of junior-adult ages and a variety of competition levels (i.e., local community recreational - adult elite professional) were included.

2.6 Meta-analyses

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

Pooled OR estimates along with accompanying 95% confidence intervals indicated whether overall effects existed in a given analysis. Accompanying Z and p values tested the null hypothesis that OR estimates between relatively older and younger distributions (i.e., Q1-Q3 v Q4 comparisons) were not statistically different. The Cochran Q statistic[6] [63] (with df and p) tested whether all studies shared a common effect size. I^2 identified the proportion of observed variance reflecting differences in true effect sizes as opposed to sampling error. Moderate (> 50%) to high values (> 75%) were used to indicate value in subgroup analyses and to account 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.

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

To determine the presence of publication bias, funnel plot asymmetry[7] was assessed with Log OR estimates plotted against corresponding standard error. The Egger test [64] confirmed asymmetry; as a result, Duval & Tweedie's 'trim and fill' procedure[8] [65] was applied to determine whether estimates required adjustment based on missing studies. Asymmetry assessments and adjustments for all comparisons (i.e., Q1-Q3 v Q4) are reported.

2.7 Sub-stratification (subgroup) analyses

To determine whether age moderated Q1 v Q4 pooled OR estimates, samples were categorised as pre-adolescent (≤ 11 years), adolescent (12-14 years [37, 39-42]), post-adolescent (15-19 years) and adult (> 19 years of age[9]). Samples where ages spanned across categories were excluded from the analysis. To determine whether competition level moderated OR estimates, all samples were categorised based on an adaptation from Cobley et al. [37]: recreational (i.e., typified by an absence of selection or official competition), competitive (i.e., local community level with structured competition), representative (i.e., regional or provincial representative levels based on selection) and elite (i.e., competition at an international level or a career athlete). Elite was further subdivided into adolescent, post-adolescent, adult and combination categories; following age divisions outlined above. If competition level was unclear, data was added to a 'not codable' subgroup for analysis. To determine if the type of sport context moderated OR estimates, samples were categorised into team and individual types. Consistent with prior work [67], team sports were those often played with multiple team members (i.e., more than one participant per team), and individual sports were those involving a single participant in a given event or in direct competition against another. Individual sports were further subdivided into those deemed physically demanding (i.e., predominantly determined by strength or endurance for example [68, 69]); technique or skill-based sports, typically identified by judging of movement criteria [68, 69]; and 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].

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

3 Results

3.1 Studies systematically identified

Figure 1 summarises the systematic search and study selection process. Initial database searches identified 1,806 studies with 12 studies identified through other sources. Following title and abstract screening, 89 full-text articles were selected for further review. Twenty-one of these were removed as they examined male sport contexts (not reported in abstracts); while 11 were removed as they did not report relative age (quartile) comparisons (see Figure 1). Overall, 57 studies met inclusion and reporting criteria[10].

(Insert Figure 1 about here)

3.2 Study quality

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

(Insert Table 1 about here)

3.3 Summary of sample distributions

With consideration of the annual cut-off dates employed in each respective sport context (e.g., August 1st, January 1st etc.), the descriptive relative age distributions for the total sample of 646,383 female sport 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.

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

(Insert Table 2 about here)

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

(Insert Table 3 about here)

3.4 Meta-analyses

Based on 44 studies containing 308 independent samples, overall pooled data comparing participation distributions of the relatively oldest (Q1) v relatively youngest (Q4) identified a significant, but small, OR estimate = 1.25 (95%CI = 1.21-1.30; Z = 13.74, p = 0.0001), suggesting the relatively older were 25% more likely to be represented. The Q statistic of 2135.50 (df = 307, p = 001) highlighted the true effect size was not similar across samples. I^2 = 85.62 indicating approximately 85% of variance in the observed effects were due to true effects, while T^2 and T were 0.04 and 0.21 (in log units) respectively. A similar RAE magnitude was 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 (OR = 1.13; 95%CI = 1.11-1.15, Z = 14.18, p < 0.01) respectively. Akin to the Q1 v Q4 findings, heterogeneity 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 = 40.24). Descriptive Q2 total participation numbers were marginally higher than Q1; thus, a Q1 v Q2 comparison was also conducted. No overall pooled OR differences were identified 0.99 (95%CI = 0.97-1.01; $Z = -1.21$, $p = 0.23$). As evidence for heterogeneity was consistent, follow-up subgroup stratification analyses examined their potential sources using Q1 v Q4 data.

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

3.5 Sub-stratification (subgroup) analyses

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

(Insert Table 4 about here)

3.5.1 Age

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

3.5.2 Competition level

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

3.5.3 Sport type

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

3.5.4 Sport context

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

(Insert Table 5 about here)

3.5.5 Study quality

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

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

4 Discussion

4.1 Overview of main findings

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

4.2 Summary of subgroup analyses

Related to the age subgroup analyses, the highest level of RAE risk was associated with the youngest age category (≤ 11 years; OR = 1.33); a finding partially contradicting the prior meta-analysis [37] where the highest risk was associated with adolescence. This may be explained by the large proportion of male samples in previous work (i.e., females comprised only 2% of participants in Cobley et al. [37]), and genuinely different RAE patterns could be evident in females. If accurate, the earlier emergence of RAEs pre-maturation implicates the influences of both normative biological growth disparities (pre-maturation) within age-grouped peers and other psycho-social processes. For instance, growth charts tracking stature and body mass across chronological age highlight the potential for important relative (within age-group) differences in a given year [71, 72]. These may also relate to motor coordination, control and physical (e.g., muscular force) characteristic development advantages that assist sport-related performance (e.g., soccer). Interacting with age-related biological differences, parental and young participants' choices may also account for increased RAE magnitude. As part of initial recreation and participation experiences, the identification of an appropriate 'sporting fit' relative to physical characteristics of similarly aged girls (and possibly boys - in early age mixed sport contexts; e.g., soccer) may occur.

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

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

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

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

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

Individual sport types were initially examined holistically, identifying an RAE below the pooled estimate (i.e., Q1 v Q4 OR = 1.18 v 1.25) with a high level of within-group heterogeneity. To follow-up, individual sports were re-categorised with consideration of predominant sport demands (i.e., physical/endurance, technique/skill) as well as those implementing weight-categorisation instead of age-based cohort grouping. Findings identified variable RAE risk. Individual sports associated with strength and/or endurance requirements illustrated some of the highest RAEs at particular age and competition levels. For instance, Alpine skiing OR's ranged between 2.00-2.51 between 11-14 years at competitive/representative levels [61, 82]. In track and field, Romann and Fuchslocher [61] reported OR's of 2.30-2.6 in competitive 15-16-year-olds; while Costa et al. [28] identified OR's exceeding 4.00 in a sample of junior representative swimmers. Overall, these findings are novel for individual sport contexts, and efficacy for these estimates can be derived from the multiple large samples spanning age groups and competition settings.

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

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

4.3 Unexpected findings

One unexpected finding, even though OR comparisons showed no differences, was that Q2 representation was either similar or descriptively higher than Q1. Marginal Q2 over-representation has previously been reported, primarily in Canadian ice-hockey [20, 84, 85] but also in adult female soccer [52, 56]. Canadian ice-hockey samples provided 12.63% of relative weight to present analyses, and so their influence may be apparent. Further examination in this context also identifies subtle but pervasive shifts in Q1+Q2 over-representation according to age and competition categories. Specifically, Q1 over-representations are apparent at pre-adolescent (≤ 11 years) competitive levels, while Q2 over-representation is evident at age equivalent recreational levels. By adolescence (12-14 years) however, Q2's were over-represented at both recreational and competitive levels in the same sport system. These transitions potentially suggest adverse effects from intensified involvement at a younger age (where RAE OR's are highest), and possible interactions with growth and maturational processes. Rather than an accumulated advantage as suggested by the 'maturation-selection' hypothesis, intensified involvement in pre-adolescence and during adolescence (maturation) in Canadian ice-hockey may be associated with greater risks of injury, burnout and sport withdrawal [11, 86, 87]. By contrast, a lower intensity-level involvement until adolescence (or post-peak growth) may be more protective and conducive to long-term participation. Nonetheless, caution is necessary for recognising the specificity of Q2 trends and in attempting to account for them accurately.

4.4 Limitations

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

4.5 Implications: RAE intervention and removal

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

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

4.6 Future research

Based on current evidence and findings, future research should seek to further examine female sport contexts where minimal samples and data are available (as highlighted). Sampling across and within these contexts will help establish a better understanding for how growth and biological development interacts with sport development systems and their psycho-social climate to affect sporting experience and behaviour. Further, moving beyond reporting RAEs in female sport to better isolate and confirm underlying causes will prove beneficial. Such work will likely inform the necessary interventions that attempt to remove RAEs and/or organisation/practitioner strategies mitigating their effects. To this end, a shift in research methodologies may also prove valuable, including qualitative investigations with sport stakeholders (e.g., athletes, coaches, parents, administrators) [20, 21, 96] to consider the influence of sport organisation processes and practitioner behaviours. Qualitative idiographic investigations examining child/athlete experiences within sporting structures at early and onward stages of participation would also strengthen understanding of how RAEs manifest and operate in the pre-maturational years.

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

5 Conclusions

Overall, RAEs have a consistent but likely small-moderate influence on female sport participation. Findings highlight the impact of interactions between athlete developmental stages, competition level, sport context demands and sociocultural factors on RAE prevalence and effect magnitudes across and within female contexts. To reduce and eliminate RAE-related inequalities in female athletic development, direct policy, organisational and practitioner intervention are required.

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7 Declaration of Interest

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

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List of Figures and Tables

List of Figures

List of Tables

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

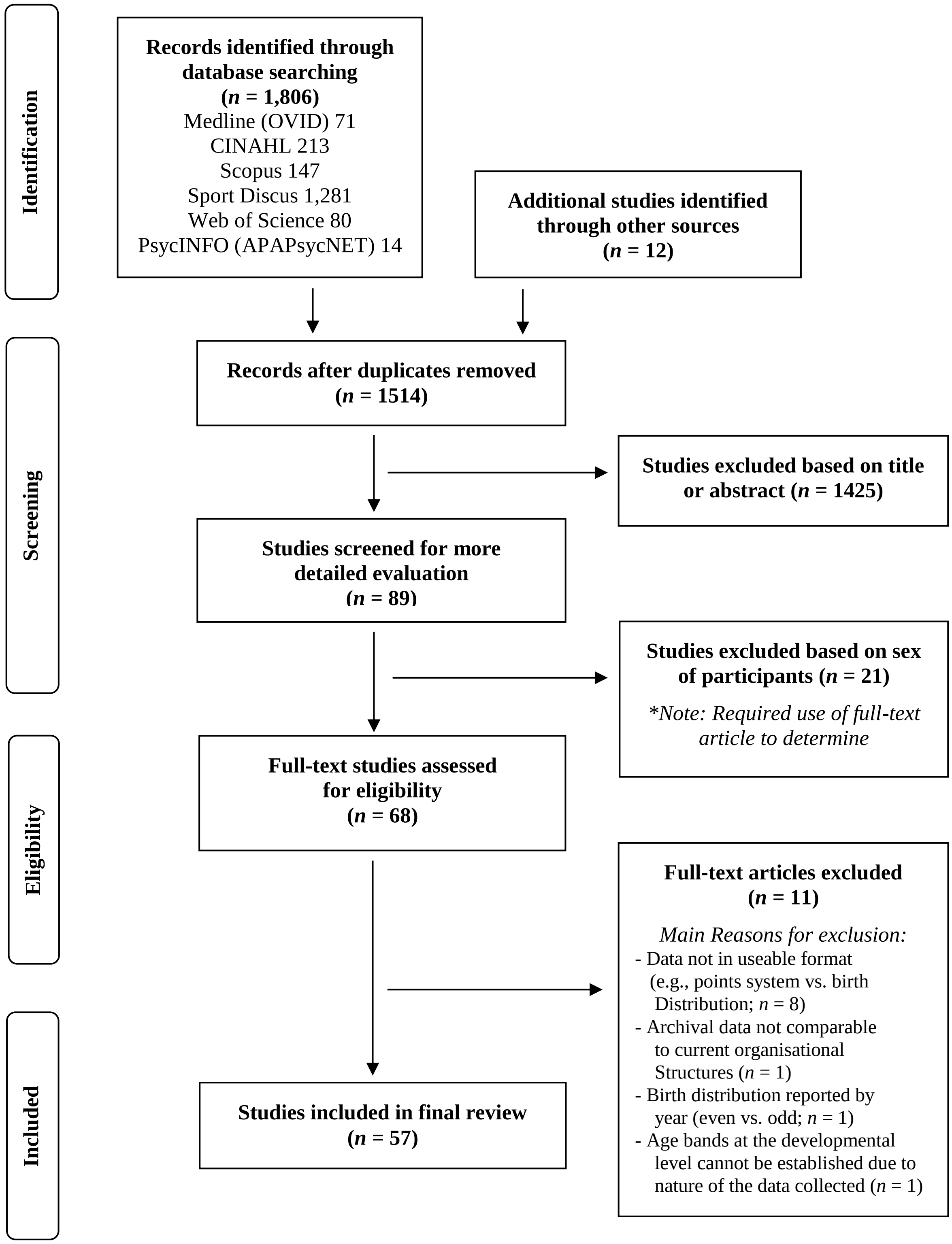

Figure 2: Funnel plot of standard error by log odds ratio (Q1 v Q4 OR analysis).

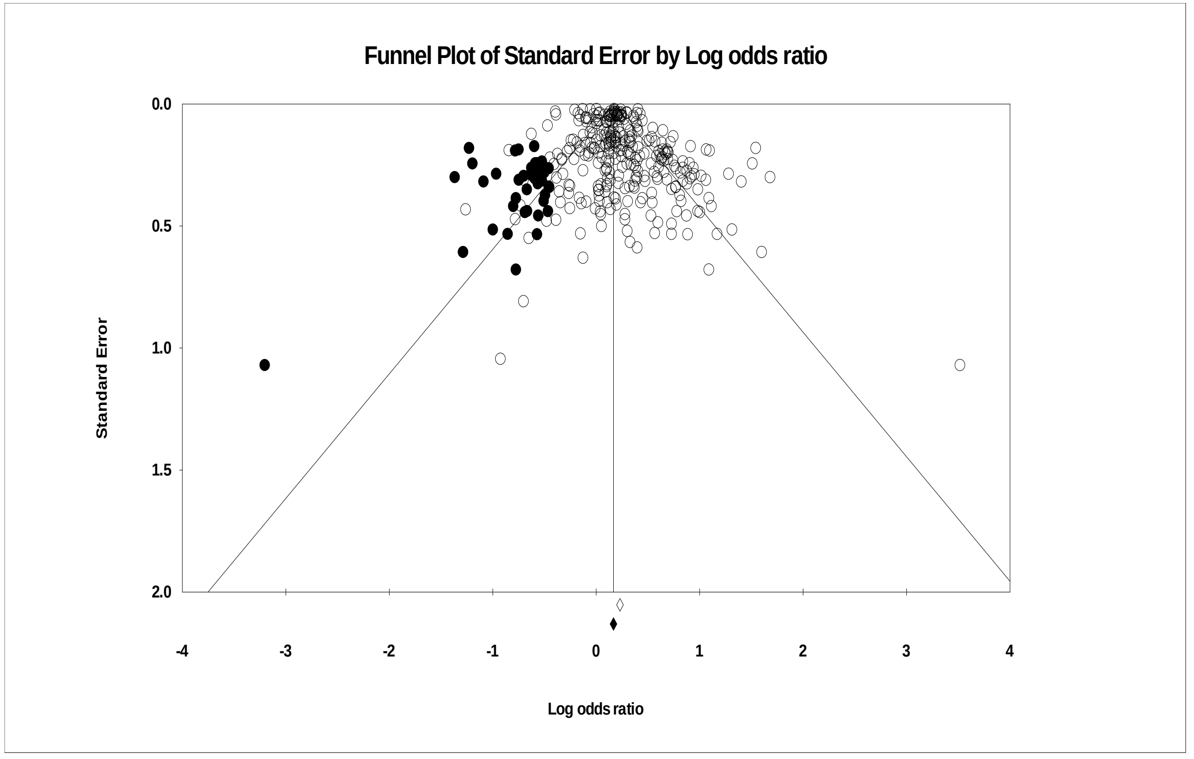

***Figure Notes*:** In the absence of heterogeneity, 95% of the studies should fall within the funnel defined by the two diagonal lines. The plot assumes that those studies with higher precision (higher sample, lower estimates of error) will plot near the overall estimate (vertical line) and will cluster 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	**#1.** In the abstract an informative and balanced summary of what was done and what was found is provided.	**#2.** Explain the scientific background and rationale for the investigation being reported.	**#3.** State clear, specific objectives and/or any prespecified hypotheses.-	**#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'.	**#5a.** Give characteristics of study participants (must include: age, gender, skill level, overall number, and nationality). **#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). **#5c.** Describe the source and procedure for obtaining the sample (e.g., obtained from an online roster, provided by a sport governing body, etc.).	**#6.** Explain and report the reference baseline distribution (e.g., equal distribution vs. population birth rate).	**#7a.** Clearly describe all statistical methods, including specific analytical methods used to examine subgroups. **#7b.** Explain how duplicates (if applicable) and missing data were addressed or incomplete data were handled.	**#8.** Report the number or percentage of participants found in each quartile/semester (and subcategory if applicable).	**#9.** Provide statistical estimate(s) and precision (e.g., 95% confidence interval) for each sample or subgroup group examined.	**#10a.** Post-hoc comparisons between quartiles (e.g., Q1 vs. Q4) are provided when appropriate (i.e., overall test is significant). **#10b.** A measure of effect size is provided (e.g., Cramer's V, phi coefficient, Cohen's w, etc.).	**#11.** A summary of key results with reference to study objectives is provided.	**#12.** Discusses limitations of the study, taking into account sources of potential bias, confounding factors or imprecision.	**#13.** A cautious overall interpretation of results considering objectives and relevant evidence.	**#14.** Discusses the generalizability of the study results to similar or other contexts.	**Quality Score Total / 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
Bidaurrazaga-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, 2008ǂ [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 1st League[Rp]	372	1.03 (0.69, 1.54)	0.94 (0.63, 1.41)	0.87 (0.57, 1.30)
	Adult	Handball	German 1st League[Rp]	145	1.06 (0.55, 2.03)	0.97 (0.50, 1.88)	1.12 (0.58, 2.13)
	Adult	Handball	German 2nd League[Rp]	345	1.07 (0.69, 1.65)	1.22 (0.79, 1.87)	1.38 (0.91, 2.11)
	Adult	Handball	German 1st League[Rp]	100	0.88 (0.39, 1.98)	1.04 (0.47, 2.28)	1.27 (0.59, 2.74)
	Adult	Handball	German 2nd 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 1st League[Rp]	110	1.04 (0.49, 2.20)	0.93 (0.43, 1.98)	1.11 (0.53, 2.34)
	Adult	Handball	German 1st League[Rp]	50	1.40 (0.45, 4.33)	2.00 (0.67, 5.96)	0.60 (0.17, 2.16)
	Adult	Handball	German 2nd 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		12734	1.16 (1.08, 1.24)	1.20 (1.12, 1.29)	1.11 (1.04, 1.19)
	11	Basketball	Youth categories of the FFBB[Rc/C]	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)
Sample overlaps with Schorer et al., 2013 [121]							
Schorer, Baker, Busch, Wilhelm, & Pabst, 2009† [119]	13-15	Handball*	German national youth tryouts[Rp] *Note: Participants passed regional selection*	238	2.19 (1.29, 3.70)	1.81 (1.06, 3.09)	1.25 (0.72, 2.18)
Includes participant sample from Schorer et al., 2010 [120], 2015 [53]							
Delorme, Boiché, & Raspaud, 2010†† [56]	U8	Soccer	French Soccer Federation (FSF)[Rc/C]	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)
Includes participant sample from Wattie et al., 2007[22]							
Okazaki, Keller, Fontana, & Gallagher, 2011ǂ [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]	10-14	Soccer	*J&S*[Rc]	2987	1.21 (1.05, 1.40)	1.24 (1.07, 1.43)	1.11 (0.96, 1.29)
Jugend & Sport (J&S) ††	15-20	Soccer		3242	1.01 (0.88, 1.16)	1.11 (0.96, 1.27)	1.07 (0.94, 1.23)
Talent development & national team†††	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 Peewee[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 Peewee[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	Peewee 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	Peewee 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	Peewee 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	Peewee 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)
		Snowboard		915	1.09 (0.84, 1.42)	1.05 (0.81, 1.37)	1.30 (1.00, 1.68)
	14-28	Figure skating	National team[E]	91	0.78 (0.34, 1.83)	1.13 (0.50, 2.54)	1.04 (0.46, 2.36)
	12-15	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 (FBF) - Amateur[C]	124	1.73 (0.84, 3.56)	1.14 (0.53, 2.43)	1.77 (0.86, 3.65)
	16-17	Boxing		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-Professional[Rp]	107	0.86 (0.40, 1.84)	1.07 (0.51, 2.25)	0.89 (0.42, 1.91)
	16-35	Soccer		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] *J&S†† Talent development †††*	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]	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)
J&S††	U12-U13**	Table tennis		129	0.77 (0.38, 1.59)	1.06 (0.53, 2.13)	1.32 (0.67, 2.60)
Talent development †††	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]	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)
J&S††	U18	Track & field		2877	0.92 (0.79, 1.06)	1.05 (0.90, 1.21)	1.02 (0.88, 1.18)
Talent development †††	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)
	Adult	Ice hockey	National championship; Riksserien league[E]	688	2.07 (1.51, 2.83)	1.96 (1.43, 2.69)	1.59 (1.15, 2.19)
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]	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 Regional†	U15	Gymnastics	Provincial[Rp]	208	1.10 (0.64, 1.89)	1.12 (0.65, 1.92)	0.94 (0.54, 1.63)
All other samples†††	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]	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)
Age 7-11†	9	Alpine ski		108	1.22 (0.57, 2.62)	1.22 (0.57, 2.62)	1.26 (0.59, 2.71)
Age 12-15†††	10	Alpine ski		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	Teenager Cup (Provincial races)[C]	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, 2015ǂ [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 Championships[E]	396	2.03 (1.36, 3.02)	1.58 (1.05, 2.37)	0.97 (0.63, 1.50)
	U18	Basketball		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]	U15	Track & field	Spanish National Athletics Federation (RFEA) – Selected[Rp]	407	1.96 (1.32, 2.90)	1.55 (1.04, 2.32)	0.99 (0.65, 1.51)
	U17	Track & field		227	1.12 (0.66, 1.89)	1.42 (0.85, 2.37)	0.83 (0.48, 1.43)
Note: Also used weighted mean scores to compare selected & unselected	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 (Can.)[Rc/C]	68	1.36 (0.49, 3.81)	1.91 (0.71, 5.15)	1.91 (0.71, 5.15)
	11-14	Rugby		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 (NZ)[Rc/C]	278	2.49 (1.53, 4.04)	1.70 (1.03, 2.81)	1.28 (0.76, 2.15)
	5	Rugby		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*;* ǂ 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%)
Individual:		
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		
Moderator variable **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
Age										
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	78.86
								1611.78	0.0001	
Competition Level										
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	84.62
								1865.17	0.0001	
Sport Type										
Team	(154)	1.33	1.27-1.39	12.51	0.0001			689.01	0.0001	77.79
Individual	(154)	1.18	1.12-124	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	19.81
								2040.54	0.0001	
Study Quality										
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	88.91
								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; I^2 = Reflects heterogeneity within subgroup.

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

Random Effects Model		**Subgroup Estimates**			
Sport Context Subgroup	**(No. samples)**	Point Estimate	95%CI	*Z* value	*p* value
Sport Context (≥ 6 samples)					
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
Sport Context *(< 6 samples)*					
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).