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Annual Age-Grouping and Athlete Development

A Meta-Analytical Review of Relative Age Effects in Sport

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Abstract

Annual age-grouping is a common organizational strategy in sport. However, such a strategy appears to promote relative age effects (RAEs). RAEs refer both to the immediate participation and long-term attainment constraints in sport, occurring as a result of chronological age and associated physical (e.g. height) differences as well as selection practices in annual age-grouped cohorts. This article represents the first meta-analytical review of RAEs, aimed to collectively determine (i) the overall prevalence and strength of RAEs across and within sports, and (ii) identify moderator variables. A total of 38 studies, spanning 1984–2007, containing 253 independent samples across 14 sports and 16 countries were re-examined and included in a single analysis using odds ratios and random effects procedures for combining study estimates. Overall results identified consistent prevalence of RAEs, but with small effect sizes. Effect size increased linearly with relative age differences. Follow-up analyses identified age category, skill level and sport context as moderators of RAE magnitude. Sports context involving adolescent (aged 15–18 years) males, at the representative (i.e. regional and national) level in highly popular sports appear most at risk to RAE inequalities. Researchers need to understand the mechanisms by which RAEs magnify and subside, as well as confirm whether RAEs exist in female and more culturally diverse contexts. To reduce and eliminate this social inequality from influencing athletes' experiences, especially within developmental periods, direct policy, organizational and practitioner intervention is required.

1. Background

Within many sport contexts, the youth stages of participation are often organized into annual age-groups using specific cut-off dates (e.g. 1 September in the UK). Whilst with honourable intention and for the purposes of competition organization and values of fair play, such a policy remains insensitive to the subtle chronological age differences (referred to as 'relative age' differences) between members within an annual cohort.[1] These differences are associated with immediate and long-term consequences, commonly known as 'relative age effects' (RAEs).[1-3]

Grondin et al.[2] were the first to assess the consequences of annual age-grouping in sports, following consistent reports of attainment differentials according to relative age in education.[4-6] They examined the birth-date distributions of Canadian ice-hockey and volleyball players, participating at recreational, competitive and senior professional levels for the 1981–2 season. Their results identified significant and repeated over-representations of ice-hockey players born in the first quartile (i.e. the 3 months after age-group cut-off dates) for each age-group category and level of competition, including professionals, while in volleyball over-representations were observed for the elite representative levels. Barnsley et al.[1] also identified birth-date differentials amongst ice-hockey players in the Canadian elite developmental leagues and National Hockey League (NHL) for 1983–4, and later found similar inequalities in the junior representative leagues (at ages ≥11 years).[3] Together, these studies suggested that being relatively older within an annual sporting cohort provided significant attainment advantages when compared with those who were relatively younger. Many studies have identified similar differentials in birth-date patterns across youth age-groups and levels of competition for the sports of baseball,[7-8] ice hockey,[9] soccer[10-12] and tennis.[13,14] Studies have also identified RAEs in other sports, but essentially in high performing samples, including Australian Rules football,[15] cricket,[16,17] netball[17] and both codes of rugby.[15] It is important to note that RAEs are not universal. In fact, in several contexts (e.g. golf[18]) RAEs have not been identified or predicted to occur. These contexts are typically free of annual age-grouping and other requisite precursor conditions (e.g. selection processes in tiers of youth competition).

1.1 Explanations for Relative Age Effects

Although previous studies (until recently[19]) did not include physical or maturational indices, most suggested physical differences (i.e. greater chronological age and likelihood of more advanced physical characteristics) as being primarily responsible for RAEs.[3,20,21] Attributes of greater height, mass (to a degree), aerobic power, muscular strength, endurance and speed do provide performance advantages in most sports.[22-23] Furthermore, during adolescence, a time when annual age-groupings are employed and where sport competition can be intensive, a 1-year age difference, especially during the stages of puberty (i.e. 13–15 years of age in boys; 12–14 years in girls) can heighten physical[24,25] and performance[23,26] differences. Thus, relatively older athletes may have an increased likelihood of exhibiting advanced physical characteristics and entering puberty earlier, compared with their relatively younger peers. In sports where body size, strength and power convey advantages, elite junior athletes have been identified as above average for height and weight when compared with age-matched normative data (e.g. soccer[27,28]). Likewise in gymnastics, where height and mass gain impedes flexibility, rotational speed and the strength to mass ratio, maturational delay in more highly skilled gymnasts has been observed.[14] In fact, a greater frequency of relatively younger gymnasts has been reported in high performance contexts.[29]

A complementary and interacting mechanism, relating to selection and experience, has also been proposed to account for the long-term propagation of RAEs. Being relatively older is more likely to provide a performance and selection advantage when assessed or evaluated (by coaches) against annual age-group peers. This selection advantage increases the likelihood of access to higher levels of competition, training and coaching.[30] It is likely that such access will be accompanied by increases in volumes of practice, training load and competition frequency, thereby generating an experience advantage over nonselected and likely relatively younger peers. In contrast, those not selected are considered less able to access practice and coaching expertise facilities, or higher levels of competition, constraining their sporting involvement and development. Events associated with selection, trials or talent identification are thus postulated to differentiate an individual's ability to invest in practice and accumulate sport-specific skill and experience, factors deemed critical for attainment.[31,32] Selection and exposure to practice and match-play may provide significant technical and game intelligence advantages[33,34] to selected relatively older players, accounting for their overrepresentation in senior professional sports.

Other interacting psychological and broader sociocultural mechanisms have also been presented to account for RAEs. Linked with selection and experience differences according to relative age, psychological disparities have also been suggested.[21] Relatively older players may be more likely to develop higher perceptions of competence[35,36] and self-efficacy.[37] In comparison, relatively younger athletes, faced with consistent sport selection disadvantages, may be more likely to have negative sport experiences, develop low competence perceptions, and thus terminate sport involvement.[38-40] Related to sociocultural influences, two studies have associated population and sport participation growth with heightened competition in youth sport contexts, and thereby an inflated likelihood of RAEs.[41,42] Likewise, sport policies that have attempted to address performance concerns on the international stage by adopting earlier competition, talent identification and streaming have also been associated with the first appearances of RAEs in sport.[41] Such sociocultural forces should be kept in mind with reference to the rationale and purpose for the present study.

1.2 Rationale for a Meta-Analysis

RAEs appear to be complex phenomena, with sociocultural antecedents combining with interindividual age and physical differences to affect sport attainment. To date, a variety of sports contexts differing in age categories, levels of competition and cultures have been assessed for RAEs. Since the narrative review of Musch and Grondin,[21] many more samples within studies have been collected and examined, yet several questions remain unresolved. For example, how prevalent and robust are RAEs across and within sports contexts? What factors modify the risk of RAEs in a sports context? By employing meta-analytical methods, these questions can be addressed as most previous studies provided consistent sample and sport context information, often presenting birth-date frequency data (i.e. the proxy measure to identify relative age in an annual age-grouping) in quarterly or half-yearly distributions. Such information is valuable if support toward direct intervention is to be generated. Furthermore, by identifying potential factors that moderate risk size, sports contexts can consider strategies that will help address and remove the unnecessary RAE inequality.

1.3 Study Purpose

The purpose of this meta-analytical review was to generate a broad picture of RAE prevalence in sport by systematically re-examining the numerous 'snap-shots' taken of sport contexts in previous studies. For the first time, meta-analytical methods were used to ascertain the risk size and moderating factors of RAEs across and within sports. We hypothesized that RAEs were apparent across sexes in highly popular team sport contexts where (i) annual age-grouping policies were employed in youth participation stages, and (ii) youth stages would include intensive competition and a skill level hierarchy, which involved selection mechanisms regulating access to higher levels of competition. In an attempt to directly explain and account for the consistent birth-date discrepancies in senior professional sport, we further hypothesized that RAE risk size increased with skill level and chronological age.

2. Methods

2.1 Sample of Studies

Published research papers, including those published in peer-reviewed conference proceedings, were tracked, collected and analysed over a 3-month period, specifically November 2006 to January 2007. This included searches of PubMed, PsychINFO and PsychARTICLES databases using the keywords 'relative age effect', 'birth-date effect', 'season of birth', 'age position' and their derivations. Additional criteria for inclusion in the meta-analysis were that papers reported both sample characteristics and information regarding the sport context. Sample characteristics pertaining to birth date, sex and chronological age at the time of data collection were extrapolated along with the type of sport, level of competition, country and competition year(s) of data collection. Those studies reporting birth-date distribution in quartiles (i.e. per 3 months), halves (i.e. 6 months) or both were included.

After obtaining all listed studies, reference sections were further examined to locate other relevant studies. All articles written in French and English were identified and interpreted. At the time of writing, we were not aware of any RAE-related publications in other languages. Finally, where sample and sport context information was not presented, authors were contacted for respective information. Five authors were contacted for further information, with three able to return required information, which often related to sample characteristics (e.g. sport context, skill level). These authors were also asked if they were aware of any additional studies not included in our list. No study additions were made through this procedure.[1] The overall process yielded 38 studies, spanning 1984 (i.e. the first published study of RAEs in sport[2]) to January 2007,[2] with 253 independent samples in 14 sports, across 16 countries. Participants involved in identified studies were either current or former sports players who competed at a range of levels, including recreational, junior and national senior representatives.

2.2 Study Review Procedure

All articles were read and examined in full by the first author. Information extracted from each of the studies was categorized and cross-validated by an independent reviewer. No categorization or reporting accuracy errors were evident in the extraction of variable information. Of the 38 studies, only three (reflecting ten samples) failed to report complete sample information for either total sample size or the distribution of birth dates after contacting the authors. These samples therefore had to be excluded from particular or whole aspects of the data analysis.

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[1] The search and data collection procedure missed one study, which came to light following data analysis.[43]

[2] Since the time of data collection and analysis several more studies have been published.

2.3 Data Analysis

Across sport contexts, studies generally standardized relative age differences by categorizing birth date into quartiles (i.e. 3-month periods) following cut-off dates. From these original data, odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for both quartile and half-year distributions.[3] Specifically, for each sample reported, birth-date distributions (e.g. number of people in quartile 1) were compared against an expected frequency, assuming an equal distribution (e.g. $N = 100$, expected quartile count $= 100/4 = 25$). This comparator (or control group) value was utilized similar to previous studies (except for Grondin et al.[2]). To clarify this assumption, however, national population statistics were checked and findings suggest that variations in birth-date distribution occur across a calendar year. For example, for the period of 1970–2000 in Canada and the UK (countries where many relative age studies have been conducted), a consistently higher number of births occurred in the spring–summer (i.e. April–August) months.[45,46] In comparison, the months/quartiles coinciding with dates used for age-grouping in sport for these countries reported a consistently lower number of births. So, while the assumption of equal distribution was not completely accurate, birth distributions were not correlated with age-grouping and participation trends in sport, thus national census data were deemed unlikely to bias or influence sample OR calculations.

When comparing quartiles and half-year distributions in all OR analyses, quartile 4 (i.e. the relatively youngest members) and the second 6 months of annual age-groupings were assigned as referent groups. Overall summary effect sizes were calculated using DerSimonian and Laird[47] methods for combining samples (see Sutton et al.[48]). Since heterogeneity between studies was expected because of variety in sport contexts and samples characteristics, a random effects model was used. The outcomes were weighted by the inverse variance. Heterogeneity was assessed using the Cochran Q value.[49] When heterogeneity was detected, sources of heterogeneity were explored using sub-stratification analysis. All analyses were conducted using either Microsoft Excel or RevMan 4.2.[50]

3. Results

3.1 Overall Results

For quartile analyses, the birth dates of 124 524 sport participants (former or present) in 246 samples were compared. Descriptive analyses identified an uneven distribution of birth dates in the overall sample (i.e. quartile 1 [Q1] = 31.2%; quartile 2 [Q2] = 26.1%; quartile 3 [Q3] = 22.3%; quartile 4 [Q4] = 20.6%). For half-year comparisons, data from seven additional samples were included,[16,51] raising total participants to 130 108 across 253 independent samples. This sample equated to 57.26% (born in the first 6 months of an age-grouping year) and 42.74% (born in the second 6 months of an age-grouping year).

Based on established criteria for interpreting effect sizes,[52] DerSimonian and Laird[47] procedures revealed a significant overall, but small, OR of 1.65 (95% CI 1.54, 1.77; $Z = 14.46$, $p < 0.001$) across all samples for the likelihood of sports participants to be born in Q1 versus Q4 of an age-grouping year. Heterogeneity was also evident between samples (Q value = 1731.1, degrees of freedom [df] = 245, $p < 0.0001$). A decreasing linear trend of RAE risk was identified following comparisons between Q2 and Q4, with an overall OR of 1.37 (95% CI 1.30, 1.44; $Z = 11.59$, $p < 0.001$) and Q3 and Q4, OR 1.13 (95% CI 1.10, 1.16; $Z = 7.88$, $p < 0.001$). Heterogeneity was also apparent for these comparisons (Q2 and Q4: Q value = 957.9, df = 245, $p < 0.0001$; Q3 and Q4: Q value = 306.2, df = 245, $p < 0.005$). Relative age effect sizes were also small when comparing

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[3] An odds ratio is considered as a comparison between the odds of exposure (i.e. to a sport context) compared to the odds of exposure (i.e. general population). Confidence intervals quantify the uncertainty in measurement. It is usually reported as 95% CI, which is the range of values within which we can be 95% sure that the true value for the whole population lies. See Rudas[44] for an introduction.

between the first 6 months and the second 6 months, with an OR of 1.39 (95% CI 1.32, 1.47, Z = 12.73, $p < 0.0001$) found. Heterogeneity between studies was again apparent (Q value = 1416.9, df = 252, $p < 0.001$). For all analyses, funnel plot assessments did not suggest publication bias was evident.[53,54] However, as evidence for heterogeneity was consistent, follow-up subgroup stratification analyses were conducted (as recommended by Gelber and Goldhirsch[55] as well as Yusuf et al.[56]) to identify possible sources of influence. Similar procedures were used; however, only comparisons between Q1 versus Q4 and the first 6 months versus the second 6 months were made.

3.2 Subgroup Results

3.2.1 Sex

Tables I and II, respectively, show the results of ORs for individual male and female samples as well as overall summary analyses. Of these samples, only 24 directly examined relative age effects in female athletes, comprising 3321 (or 2%) of all participants. Considering samples available, sex made little difference to the overall ORs, whether based on quartile or half-yearly distributions (males Q1 vs Q4 = OR: 1.65, 95% CI 1.54, 1.77; first 6 months vs second 6 months = OR: 1.39, 95% CI 1.32, 1.47; females Q1 vs Q4 = OR: 1.21, 95% CI 1.10, 1.33; first half vs second half = OR: 1.39, 95% CI 1.26, 1.54).

3.2.2 Age Category

To consider age as a moderator of risk, ages within samples were categorized into child (<11 years), junior (11–14 years), adolescent (15–18 years) and senior (>18 years) for subcategory analyses. We excluded samples from the analysis where ages spanned across these categories (e.g. Baxter-Jones et al.[25]). Table III summarizes results of age-category analyses.

Overall summary calculations identified small significant effects across age categories, regardless of whether relative age was considered in quarter- or half-yearly distributions. Risk progressively increased with age from the child category to the adolescent (15–18 years) age range. For the comparison between Q1 and Q4, small-moderate effects (OR: 2.36, 95% CI 2.00, 2.79) were evident at the adolescent stage, before declining at the senior (19 years plus) age category (OR: 1.44, 95% CI 1.35, 1.53).

3.2.3 Skill Level

Prior to analysis, all samples were categorized into one of four skill levels: recreational (e.g. leisure and house leagues), competitive (often associated with juniors and amateurs), representative (often associated with regional and national representation) and elite (regarded as professional or senior national representative). Overall, summary results identified small significant ORs regardless of skill category (see table IV); however, risk increased with skill level, with the highest risk evident at the representative (pre-elite) stage (i.e. Q1 vs Q4 = OR: 2.77, 95% CI 2.36, 3.24). Interestingly, summary ORs suggest that the risks of RAEs are lower at the elite stage than in the representative stage (OR: 1.42, 95% CI 1.34, 1.51).

3.2.4 Sport Context

While 14 sports have been assessed for relative age effects, most studies focused upon ice hockey (32.8%), soccer (30%) and baseball (13%). Regardless of whether quartile or half-yearly summary ORs were considered, small effects were apparent in these sports, as well as in basketball and volleyball (i.e. the next two mostly examined contexts; see table V). Only in American Football were ORs non-significant. Other sports contexts were not examined due to low sample numbers.

4. Discussion

4.1 General Findings

This article represents the first meta-analytical study of RAEs, synthesizing data from samples in previous research (spanning 1984 to January 2007) into a single analysis, whilst partially controlling for wider population trends in this period. Its primary purpose was to determine the overall prevalence and strength of RAEs in sport. A secondary purpose was to identify risk change according to moderator variables, with such

Table I. Unadjusted odds ratios (ORs) for independent male subjects examining relative age effect in sport

Study	Subject age (y)	Sport	Level of competition	No. of subjects	OR comparisons [Q1–4/1st and 2nd 6 mo] (95% CI)			
					Q1 vs Q4	Q2 vs Q4	Q3 vs Q4	1st vs 2nd
Grondin et al.[2]	8–9	Ice hockey	Junior AA	94	3.09 (1.27, 7.51)	2.54 (1.03, 6.27)	1.90 (0.75, 4.82)	1.93 (0.48, 3.95)
	8–9	Ice hockey	Junior BB	171	2.59 (1.35, 4.96)	2.27 (1.17, 4.38)	1.90 (0.97, 3.72)	1.67 (0.59, 2.82)
	8–9	Ice hockey	Junior CC	256	2.37 (1.43, 3.94)	1.67 (0.99, 2.82)	1.35 (0.78, 2.3)	1.72 (0.65, 2.64)
	8–9	Ice hockey	Novice recreation	110	1.60 (0.74, 3.45)	2.05 (0.96, 4.34)	0.85 (0.36, 1.95)	1.97 (0.51, 3.81)
	10–11	Ice hockey	Junior AA	124	5.27 (2.33, 11.9)	2.90 (1.24, 6.78)	2.09 (0.87, 5.01)	2.64 (0.52, 4.99)
	10–11	Ice hockey	Junior BB	206	2.31 (1.31, 4.07)	1.93 (1.08, 3.44)	1.18 (0.64, 2.18)	1.94 (0.61, 3.14)
	10–11	Ice hockey	Junior CC	273	1.58 (0.96, 2.61)	2.04 (1.25, 3.32)	1.30 (0.78, 2.17)	1.57 (0.66, 2.38)
	10–11	Ice hockey	Novice recreation	138	1.24 (0.62, 2.44)	1.03 (0.51, 2.07)	1.48 (0.76, 2.88)	0.91 (0.56, 1.63)
	12–13	Ice hockey	Junior AA	120	3.05 (1.45, 6.44)	1.94 (0.89, 4.2)	1.05 (0.45, 2.43)	2.42 (0.52, 4.61)
	12–13	Ice hockey	Junior BB	202	3.09 (1.66, 5.74)	3.04 (1.63, 5.65)	2.04 (1.07, 3.88)	2.01 (0.61, 3.28)
	12–13	Ice hockey	Junior CC	298	1.21 (0.76, 1.93)	1.46 (0.93, 2.3)	0.96 (0.6, 1.55)	1.36 (0.67, 2.02)
	12–13	Ice hockey	Novice recreation	90	1.09 (0.47, 2.48)	1.00 (0.43, 2.29)	1.00 (0.43, 2.29)	1.04 (0.48, 2.13)
	14–15	Ice hockey	Youth AA	131	2.30 (1.15, 4.58)	1.56 (0.76, 3.19)	0.82 (0.37, 1.79)	2.11 (0.54, 3.89)
	14–15	Ice hockey	Youth BB	194	2.00 (1.12, 3.56)	1.39 (0.76, 2.53)	1.48 (0.81, 2.69)	1.36 (0.61, 2.22)
	14–15	Ice hockey	Youth CC	301	1.29 (0.81, 2.05)	1.65 (1.05, 2.59)	0.98 (0.6, 1.58)	1.48 (0.67, 2.2)
	14–15	Ice hockey	Novice recreation	67	0.87 (0.32, 2.34)	1.31 (0.51, 3.35)	1.00 (0.37, 2.63)	1.09 (0.43, 2.5)
	Senior	Ice hockey	NHL professional	386	1.71 (1.14, 2.58)	1.42 (0.93, 2.15)	1.29 (0.85, 1.96)	1.36 (0.7, 1.93)
	Senior	Ice hockey	Varsity	177	1.30 (0.72, 2.33)	1.17 (0.64, 2.12)	0.95 (0.51, 1.74)	1.26 (0.59, 2.11)
	Senior	Ice hockey	College AAA	150	2.20 (1.13, 4.27)	1.91 (0.98, 3.74)	1.12 (0.55, 2.29)	1.94 (0.56, 3.41)
	16–19	Ice hockey	Junior elite developmental	171	3.47 (1.82, 6.62)	2.00 (1.01, 3.92)	1.66 (0.83, 3.31)	2.05 (0.58, 3.49)
	14–15	Ice hockey	Youth AAA elite developmental	167	3.05 (1.57, 5.91)	2.60 (1.32, 5.08)	1.70 (0.84, 3.42)	2.09 (0.58, 3.58)
	12–13	Volleyball	Junior	46	1.66 (0.45, 6.12)	3.00 (0.87, 10.3)	2.00 (0.55, 7.16)	1.55 (0.36, 4.26)
	14–15	Volleyball	Youth cadet	31	0.77 (0.19, 3.16)	0.88 (0.22, 3.52)	0.77 (0.19, 3.16)	0.93 (0.29, 3.17)
	16–17	Volleyball	Youth juvenile	24	0.83 (0.16, 4.29)	1.00 (0.2, 4.95)	1.16 (0.24, 5.61)	0.84 (0.24, 3.38)
	14–15	Volleyball	Provincial youth cadet	211	1.21 (0.7, 2.08)	1.17 (0.67, 2.01)	1.10 (0.63, 1.91)	1.13 (0.62, 1.8)
	16–17	Volleyball	Provincial youth juvenile	210	1.17 (0.67, 2.03)	0.93 (0.53, 1.64)	1.45 (0.85, 2.48)	0.85 (0.62, 1.37)
	17–19	Volleyball	Provincial youth junior	64	1.14 (0.42, 3.09)	0.92 (0.33, 2.58)	1.50 (0.56, 3.95)	0.82 (0.42, 1.93)
	Senior	Volleyball	Provincial senior	50	2.80 (0.77, 10.1)	3.20 (0.89, 11.4)	3.00 (0.83, 10.7)	1.50 (0.38, 3.94)

Continued next page

Table I. Contd

Study	Subject age (y)	Sport	Level of competition	No. of subjects	OR comparisons [Q1–4/1st and 2nd 6 mo] (95% CI)			
					Q1 vs Q4	Q2 vs Q4	Q3 vs Q4	1st vs 2nd
Barnsley et al.[1]	16–20	Ice hockey	WHL amateur developmental	698	4.56 (3.23, 6.42)	3.23 (2.27, 4.59)	2.10 (1.46, 3.03)	2.50 (0.76, 3.27)
	16–20	Ice hockey	OHL amateur developmental	350	3.76 (2.36, 5.98)	2.84 (1.76, 4.56)	1.60 (0.97, 2.65)	2.53 (0.68, 3.69)
	Senior	Ice hockey	NHL professional	715	1.97 (1.45, 2.67)	1.83 (1.35, 2.49)	1.35 (0.98, 1.85)	1.61 (0.77, 2.09)
Daniel and Janssen[41]	Senior	Basketball	NBA professional	297	1.11 (0.7, 1.75)	0.94 (0.59, 1.5)	1.18 (0.75, 1.86)	0.94 (0.67, 1.39)
	Senior	Baseball	MLB professional	682	1.24 (0.92, 1.67)	1.11 (0.82, 1.5)	0.90 (0.66, 1.23)	1.23 (0.77, 1.60)
	Senior	Football	CFL professional	342	1.00 (0.64, 1.54)	1.17 (0.76, 1.79)	1.32 (0.87, 2.02)	0.93 (0.69, 1.34)
	Senior	Football	CFL professional	436	0.89 (0.61, 1.3)	0.96 (0.66, 1.4)	0.93 (0.64, 1.35)	0.96 (0.72, 1.33)
	Senior	Football	AFC professional	777	1.25 (0.94, 1.66)	1.21 (0.91, 1.61)	1.18 (0.89, 1.57)	1.12 (0.78, 1.44)
	Senior	Football	NFC professional	749	1.15 (0.86, 1.53)	0.98 (0.73, 1.31)	1.09 (0.82, 1.46)	1.01 (0.78, 1.3)
	Senior	Ice hockey	NHL professional	103	1.10 (0.52, 2.33)	0.60 (0.26, 1.36)	0.96 (0.45, 2.06)	0.87 (0.51, 1.7)
	Senior	Ice hockey	NHL professional	318	0.92 (0.59, 1.41)	0.87 (0.56, 1.35)	0.81 (0.52, 1.27)	0.98 (0.68, 1.44)
	Senior	Ice hockey	NHL professional	320	1.05 (0.67, 1.63)	0.97 (0.62, 1.51)	1.12 (0.73, 1.74)	0.95 (0.68, 1.39)
	Senior	Ice hockey	NHL professional	355	0.94 (0.62, 1.43)	1.03 (0.68, 1.56)	0.96 (0.63, 1.46)	1.00 (0.69, 1.44)
	Senior	Ice hockey	NHL professional	775	2.14 (1.59, 2.88)	2.05 (1.52, 2.75)	1.37 (1.00, 1.87)	1.76 (0.78, 2.26)
	Senior	Ice hockey	NHL professional	217	2.21 (1.29, 3.78)	1.31 (0.74, 2.31)	1.18 (0.66, 2.09)	1.61 (0.62, 2.57)
Barnsley and Thompson[3]	7–8	Ice hockey	Junior-minor-mite	1 676	1.12 (0.93, 1.36)	1.08 (0.89, 1.31)	0.98 (0.81, 1.19)	1.11 (0.84, 1.31)
	9–10	Ice hockey	Junior-minor-mite	1 839	1.10 (0.91, 1.32)	1.17 (0.97, 1.4)	1.07 (0.89, 1.29)	1.09 (0.85, 1.28)
	11–12	Ice hockey	Junior-minor-pee wee	1 536	1.13 (0.92, 1.38)	1.23 (1.01, 1.51)	1.05 (0.86, 1.29)	1.15 (0.84, 1.37)
	13–14	Ice hockey	Junior-minor-bantam	1 112	1.37 (1.08, 1.75)	1.24 (0.97, 1.59)	0.89 (0.68, 1.15)	1.39 (0.8, 1.71)
	15–16	Ice hockey	Youth-minor midget	815	1.18 (0.89, 1.56)	1.39 (1.05, 1.83)	1.19 (0.9, 1.58)	1.17 (0.78, 1.48)
	17–18	Ice hockey	Youth-minor-juvenile	220	1.45 (0.85, 2.48)	1.52 (0.89, 2.59)	1.02 (0.58, 1.78)	1.47 (0.63, 2.33)
	19–20	Ice hockey	Youth representative	115	0.90 (0.44, 1.85)	0.66 (0.31, 1.4)	0.90 (0.44, 1.85)	0.82 (0.53, 1.55)
	7–8	Ice hockey	Mite-lowest tier	1 676	1.12 (0.93, 1.36)	1.08 (0.89, 1.31)	0.98 (0.81, 1.19)	1.11 (0.84, 1.31)
	9–10	Ice hockey	Mite-low tier	764	0.80 (0.6, 1.06)	0.88 (0.67, 1.17)	0.96 (0.72, 1.27)	0.86 (0.78, 1.1)
	9–10	Ice hockey	Mite-mid tier	789	1.08 (0.81, 1.43)	1.18 (0.89, 1.56)	1.06 (0.8, 1.41)	1.09 (0.78, 1.39)
	9–10	Ice hockey	Mite-upper tier	286	3.15 (1.88, 5.28)	2.90 (1.73, 4.88)	1.87 (1.09, 3.21)	2.10 (0.66, 3.18)
	11–12	Ice hockey	Pee wee low tier	461	0.73 (0.5, 1.07)	1.06 (0.74, 1.52)	1.00 (0.7, 1.44)	0.89 (0.72, 1.23)
	11–12	Ice hockey	Pee wee mid tier	746	1.02 (0.76–1.36)	1.21 (0.91, 1.61)	1.02 (0.76, 1.37)	1.10 (0.77, 1.41)
	11–12	Ice hockey	Pee wee upper tier	329	2.40 (1.54, 3.75)	1.69 (1.06, 2.67)	1.23 (0.76, 1.98)	1.83 (0.68, 2.68)

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Table I. Contd

Study	Subject age (y)	Sport	Level of competition	No. of subjects	OR comparisons [Q1–4/1st and 2nd 6 mo] (95% CI)			
					Q1 vs Q4	Q2 vs Q4	Q3 vs Q4	1st vs 2nd
Barnsley and Thompson[3]	13–14	Ice hockey	Bantam low tier	586	0.81 (0.58, 1.13)	0.86 (0.62, 1.2)	1.14 (0.83, 1.56)	0.78 (0.75, 1.04)
	13–14	Ice hockey	Bantam mid tier	206	1.47 (0.85, 2.55)	1.28 (0.73, 2.24)	1.14 (0.64, 2.01)	1.28 (0.62, 2.07)
	13	Ice hockey	Junior AA minor	183	4.23 (2.16, 8.26)	3.23 (1.63, 6.39)	2.29 (1.13, 4.62)	2.26 (0.59, 3.8)
	14	Ice hockey	Junior AA major	137	3.35 (1.63, 6.88)	2.58 (1.24, 5.38)	1.11 (0.49, 2.5)	2.80 (0.54, 5.15)
	15–16	Ice hockey	Youth midget low	463	0.91 (0.63, 1.33)	1.18 (0.82, 1.69)	1.10 (0.77, 1.59)	0.99 (0.72, 1.36)
	15–16	Ice hockey	Youth midget mid	227	1.24 (0.72, 2.13)	1.60 (0.94, 2.7)	1.20 (0.69, 2.05)	1.29 (0.63, 2.03)
	15	Ice hockey	Youth AA major	125	2.81 (1.32, 5.98)	2.25 (1.04, 4.85)	1.75 (0.79, 3.85)	1.84 (0.53, 3.41)
	17–18	Ice hockey	Youth mid tier	220	1.88 (1.06, 3.31)	1.08 (0.59, 1.98)	2.20 (1.26, 3.85)	0.92 (0.62, 1.48)
	19–20	Ice hockey	Youth mid tier	115	1.21 (0.61, 2.38)	0.66 (0.32, 1.38)	0.90 (0.45, 1.83)	0.98 (0.54, 1.8)
Boucher and Halliwell[57]	Senior	Ice hockey	NHL professional	1 116	2.15 (1.68, 2.74)	1.86 (1.45, 2.38)	1.28 (0.99, 1.66)	1.75 (0.81, 2.15)
	8–17	Ice hockey	Junior regional representative	1 085	2.53 (1.96, 3.26)	2.18 (1.68, 2.83)	1.76 (1.35, 2.29)	1.70 (0.81, 2.1)
Grondin and Trudeau[58]	Senior	Ice hockey	NHL professional	388	1.55 (1.02, 2.34)	1.82 (1.21, 2.74)	1.24 (0.81, 1.9)	1.50 (0.7, 2.12)
	Senior	Ice hockey	NHL professional	79	1.62 (0.67, 3.92)	1.00 (0.39, 2.54)	1.31 (0.53, 3.23)	1.13 (0.46, 2.43)
	Senior	Ice hockey	NHL professional	54	1.45 (0.49, 4.26)	1.54 (0.53, 4.5)	0.90 (0.29, 2.84)	1.57 (0.39, 3.99)
Thompson et al.[7]	Senior	Baseball	MLB professional	682	1.36 (1.00, 1.84)	1.30 (0.95, 1.76)	1.10 (0.81, 1.5)	1.26 (0.77, 1.64)
	Senior	Baseball	MLB professional	837	1.29 (0.99, 1.7)	1.12 (0.85, 1.47)	1.03 (0.78, 1.36)	1.19 (0.79, 1.5)
Barnsley et al.[11]	Senior	Soccer	Professional national	528	1.50 (1.05, 2.12)	1.38 (0.96, 1.96)	1.40 (0.98, 1.99)	1.20 (0.74, 1.61)
	16–17	Soccer	Junior elite national	287	5.86 (3.35, 10.2)	4.40 (2.5, 7.77)	1.77 (0.95, 3.28)	3.70 (0.64, 5.7)
	19–20	Soccer	Developmental elite national	288	6.13 (3.51, 10.7)	4.27 (2.42, 7.53)	1.68 (0.90, 3.12)	3.88 (0.64, 5.99)
Brewer et al.[27]	16–17	Soccer	National junior	59	34.0 (4.09, 281)	12.0 (1.37, 104)	12.0 (1.37, 104)	3.53 (0.38, 9.13)
Glamser and Marciani[59]	18–24	Football	College	59	4.75 (1.29, 17.3)	5.00 (1.37, 18.2)	4.00 (1.07, 14.8)	1.95 (0.4, 4.8)
	18–24	Baseball	College	26	1.75 (0.33, 9.02)	2.75 (0.56, 13.3)	1.00 (0.17, 5.82)	2.25 (0.25, 8.85)
	18–24	Football	College	49	12.0 (2.31, 62.2)	5.00 (0.9, 27.7)	6.50 (1.20, 35.0)	2.26 (0.36, 6.15)
	18–24	Baseball	College	20	1.50 (0.25, 8.81)	1.25 (0.20, 7.61)	1.25 (0.20, 7.61)	1.22 (0.21, 5.59)
Thompson et al.[8]	4–6	Baseball	T-ball beginners	335	1.47 (0.96, 2.27)	1.14 (0.73, 1.78)	1.23 (0.79, 1.91)	1.17 (0.68, 1.70)
	7–9	Baseball	Junior	894	0.99 (0.76, 1.29)	0.93 (0.72, 1.22)	0.90 (0.69, 1.17)	1.01 (0.79, 1.27)
	10–12	Baseball	Junior	1 235	1.13 (0.90, 1.41)	0.97 (0.78, 1.22)	0.95 (0.76, 1.19)	1.07 (0.82, 1.30)
	13–15	Baseball	Junior league	823	0.97 (0.74, 1.27)	0.81 (0.62, 1.07)	0.96 (0.73, 1.26)	0.91 (0.78, 1.15)
	16–18	Baseball	Youth league	127	1.40 (0.70, 2.82)	1.37 (0.68, 2.75)	0.92 (0.44, 1.92)	1.44 (0.54, 2.64)
	10	Baseball	Minor	321	1.00 (0.64, 1.53)	0.78 (0.50, 1.23)	0.98 (0.64, 1.52)	0.89 (0.68, 1.31)
	10	Baseball	Major	35	1.50 (0.41, 5.47)	1.00 (0.25, 3.88)	0.87 (0.21, 3.48)	1.33 (0.31, 4.21)

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Table I. Contd

Study	Subject age (y)	Sport	Level of competition	No. of subjects	OR comparisons [Q1–4/1st and 2nd 6 mo] (95% CI)			
					Q1 vs Q4	Q2 vs Q4	Q3 vs Q4	1st vs 2nd
Thompson et al.[8]	11	Baseball	Minor	105	0.93 (0.44, 1.96)	0.61 (0.27, 1.34)	0.83 (0.39, 1.77)	0.84 (0.51, 1.63)
	11	Baseball	Major	342	1.62 (1.05, 2.48)	1.40 (0.91, 2.17)	1.15 (0.73, 1.79)	1.40 (0.69, 2.03)
	12	Baseball	Minor	49	0.40 (0.12, 1.25)	0.30 (0.08, 1.00)	0.75 (0.26, 2.11)	0.40 (0.36, 1.09)
	12	Baseball	Major	383	1.09 (0.73, 1.63)	1.11 (0.75, 1.66)	0.86 (0.57, 1.29)	1.18 (0.70, 1.68)
	13	Baseball	Senior	145	0.88 (0.45, 1.72)	0.88 (0.45, 1.72)	1.37 (0.72, 2.58)	0.74 (0.56, 1.31)
	13	Baseball	Junior	239	1.26 (0.77, 2.06)	0.75 (0.44, 1.27)	0.90 (0.54, 1.50)	1.06 (0.64, 1.64)
	14	Baseball	Senior	207	0.92 (0.54, 1.59)	0.89 (0.52, 1.53)	0.80 (0.46, 1.39)	1.00 (0.62, 1.61)
	14	Baseball	Junior	23	0.44 (0.08, 2.31)	0.33 (0.05, 1.90)	0.77 (0.17, 3.55)	0.43 (0.23, 1.87)
	10–14	Baseball	Lower level junior	827	0.90 (0.69, 1.18)	0.76 (0.57, 1.00)	0.96 (0.73, 1.25)	0.85 (0.78, 1.07)
	10–14	Baseball	High level junior	1 022	1.27 (0.99, 1.62)	1.07 (0.83, 1.37)	0.94 (0.73, 1.22)	1.20 (0.80, 1.48)
	10–14	Baseball	Tournament juniors	410	1.83 (1.22, 2.74)	1.82 (1.21, 2.72)	1.36 (0.90, 2.07)	1.54 (0.71, 2.16)
	10–14	Baseball	Recreation juniors	951	0.99 (0.77, 1.27)	0.81 (0.63, 1.05)	0.81 (0.63, 1.05)	0.99 (0.80, 1.24)
Verhulst[10]	Senior	Soccer	Professional div 1	369	1.11 (0.74, 1.68)	1.28 (0.85, 1.92)	0.98 (0.65, 1.50)	1.20 (0.70, 1.72)
	Senior	Soccer	Professional div 2	342	1.47 (0.96, 2.25)	1.22 (0.79, 1.89)	1.18 (0.76, 1.83)	1.23 (0.69, 1.78)
	Senior	Soccer	Professional div 1	411	2.19 (1.47, 3.26)	1.52 (1.00, 2.29)	1.43 (0.94, 2.16)	1.52 (0.71, 2.13)
	Senior	Soccer	Professional div 2	768	1.90 (1.43, 2.53)	1.22 (0.90, 1.65)	1.39 (1.03, 1.87)	1.30 (0.78, 1.67)
	Senior	Soccer	Professional div 2	399	1.77 (1.19, 2.65)	1.55 (1.03, 2.33)	1.22 (0.8, 1.85)	1.50 (0.71, 2.11)
	Senior	Soccer	Professional div 2	401	1.76 (1.18, 2.61)	1.45 (0.97, 2.17)	1.12 (0.73, 1.69)	1.51 (0.71, 2.13)
Boucher and Mutimer[9]	8–9	Ice hockey	Junior novice	68	1.83 (0.69, 4.85)	1.50 (0.55, 4.04)	1.33 (0.48, 3.64)	1.42 (0.43, 3.26)
	10–11	Ice hockey	Atom	213	2.75 (1.56, 4.87)	1.96 (1.09, 3.53)	1.62 (0.89, 2.94)	1.80 (0.62, 2.89)
	12–13	Ice hockey	Pee wee	224	3.34 (1.84, 6.07)	3.13 (1.72, 5.69)	2.26 (1.22, 4.18)	1.98 (0.62, 3.15)
	14–15	Ice hockey	Bantam	302	3.10 (1.9, 5.06)	2.18 (1.32, 3.62)	1.86 (1.11, 3.10)	1.84 (0.67, 2.75)
	16–17	Ice hockey	Midget	144	3.60 (1.72, 7.51)	2.66 (1.25, 5.65)	2.33 (1.09, 4.99)	1.88 (0.56, 3.34)
	Senior	Ice hockey	NHL professional	884	2.28 (1.72, 3.01)	2.09 (1.58, 2.77)	1.36 (1.01, 1.83)	1.85 (0.79, 2.33)
Dudink[60]	Senior	Soccer	Professional premier	761	2.11 (1.59, 2.81)	1.39 (1.03, 1.88)	1.08 (0.79, 1.47)	1.68 (0.77, 2.16)
	Senior	Soccer	Professional div 1	734	1.79 (1.34, 2.39)	1.14 (0.85, 1.55)	1.04 (0.77, 1.42)	1.43 (0.77, 1.85)
	Senior	Soccer	Professional div 2	673	1.91 (1.41, 2.58)	1.28 (0.93, 1.75)	0.93 (0.67, 1.30)	1.64 (0.76, 2.14)
	Senior	Soccer	Professional div 3	609	2.12 (1.53, 2.94)	1.65 (1.18, 2.31)	1.18 (0.83, 1.67)	1.73 (0.75, 2.28)
Edwards[16]	Senior	Cricket	Professional county	292	NR	NR	NR	1.16 (0.67, 1.73)

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Table I. Contd

Study	Subject age (y)	Sport	Level of competition	No. of subjects	OR comparisons [Q1–4/1st and 2nd 6 mo] (95% CI)			
					Q1 vs Q4	Q2 vs Q4	Q3 vs Q4	1st vs 2nd
Baxter-Jones[14]	11–17	Soccer	Elite junior	65	7.40 (2.32, 23.5)	3.20 (0.94, 10.8)	1.40 (0.36, 5.33)	4.41 (0.39, 11.1)
	11–17	Swimming	Elite junior	54	2.85 (0.90, 8.97)	2.71 (0.86, 8.56)	1.14 (0.32, 4.04)	2.60 (0.38, 6.79)
	9–17	Tennis	Elite junior	74	3.54 (1.40, 8.97)	1.27 (0.45, 3.52)	0.90 (0.31, 2.65)	2.52 (0.44, 5.72)
Baxter-Jones et al.[25]	9–18	Gymnastics	Elite junior	38	1.25 (0.34, 4.55)	1.12 (0.30, 4.16)	1.37 (0.38, 4.94)	1.00 (0.33, 3.00)
Brewer et al.[61]	16–17	Soccer	Youth elite development	59	34 (4.09, 281)	12 (1.37, 104)	12 (1.37, 104)	3.53 (0.38, 9.13)
	Senior	Soccer	Professional national	16	17 (0.71, 405)[a]	11 (0.44, 272)[a]	7 (0.27, 184)[a]	4.33 (0.15, 28.1)
Stanaway and Hines[62]	Senior	Baseball	MLB professional	600	1.22 (0.88, 1.68)	1.25 (0.90, 1.72)	0.97 (0.69, 1.34)	1.25 (0.75, 1.65)
	Senior	Football	Hall of fame	167	1.20 (0.64, 2.25)	1.58 (0.86, 2.91)	1.11 (0.59, 2.1)	1.31 (0.59, 2.23)
Helsen et al.[30]	Senior	Soccer	Professional	408	1.78 (1.2, 2.64)	1.44 (0.96, 2.16)	1.13 (0.74, 1.71)	1.51 (0.71, 2.13)
	10–16	Soccer	Junior elite national	369	4.62 (2.92, 7.30)	2.37 (1.47, 3.84)	1.97 (1.20, 3.21)	2.35 (0.69, 3.39)
	6–16	Soccer	Youth elite club	485	2.62 (1.79, 3.82)	1.95 (1.32, 2.88)	1.77 (1.19, 2.62)	1.65 (0.73, 2.25)
	6–10	Soccer	Youth leagues	270	1.84 (1.13, 2.97)	1.46 (0.89, 2.39)	1.10 (0.66, 1.83)	1.57 (0.65, 2.38)
	12–16	Soccer	Junior leagues	226	1.16 (0.68, 1.96)	1.08 (0.63, 1.84)	1.28 (0.75, 2.15)	0.98 (0.63, 1.54)
Montelpare et al.[51]	Senior	Ice hockey	NHL professional	1 090	NA	NA	NA	1.78 (0.81, 2.19)
	16–18	Ice hockey	Junior national	231	NA	NA	NA	1.85 (0.64, 2.92)
	19–26	Ice hockey	College representative	2 047	NA	NA	NA	1.44 (0.86, 1.67)
	Senior	Ice hockey	Amateur representative	476	NA	NA	NA	1.78 (0.73, 2.45)
	8–16	Ice hockey	Junior and youth representative	474	NA	NA	NA	1.49 (0.73, 2.05)
	8–16	Ice hockey	Junior minor	974	NA	NA	NA	1.17 (0.80, 1.46)
Musch and Hay[63]	Senior	Soccer	Professional	207	1.58 (0.91, 2.77)	1.38 (0.78, 2.43)	1.33 (0.75, 2.34)	1.27 (0.62, 2.04)
	Senior	Soccer	Professional	61	1.76 (0.66, 4.72)	1.00 (0.35, 2.84)	0.92 (0.32, 2.65)	1.44 (0.41, 3.45)
	Senior	Soccer	Professional	486	1.70 (1.18, 2.45)	1.49 (1.03, 2.16)	1.39 (0.95, 2.01)	1.33 (0.73, 1.82)
	Senior	Soccer	Professional	355	1.31 (0.87, 1.98)	1.06 (0.69, 1.61)	0.95 (0.62, 1.45)	1.21 (0.69, 1.74)
	Senior	Soccer	Professional	360	2.20 (1.44, 3.35)	1.78 (1.15, 2.74)	1.01 (0.64, 1.61)	1.97 (0.69, 2.84)
Helsen et al.[64]	10–12	Soccer	Junior representative	410	2.15 (1.45, 3.19)	1.57 (1.04, 2.35)	1.12 (0.73, 1.72)	1.75 (0.71, 2.46)
	10–12	Soccer	Junior representative	507	1.78 (1.25, 2.54)	1.13 (0.78, 1.65)	1.52 (1.06, 2.18)	1.15 (0.73, 1.56)
	12–14	Soccer	Junior representative	452	2.15 (1.45, 3.19)	1.95 (1.31, 2.90)	1.84 (1.23, 2.75)	1.44 (0.72, 1.98)
	12–14	Soccer	Junior representative	520	1.87 (1.33, 2.63)	1.02 (0.71, 1.48)	1.14 (0.79, 1.64)	1.35 (0.74, 1.82)
	14–16	Soccer	Youth representative	449	3.58 (2.41, 5.32)	1.98 (1.3, 2.99)	1.44 (0.94, 2.22)	2.27 (0.71, 3.16)

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Table I. Contd

Study	Subject age (y)	Sport	Level of competition	No. of subjects	OR comparisons [Q1–4/1st and 2nd 6 mo] (95% CI)			
					Q1 vs Q4	Q2 vs Q4	Q3 vs Q4	1st vs 2nd
Helsen et al.[64]	14–16	Soccer	Youth representative	385	1.35 (0.95, 1.92)	1.03 (0.72, 1.49)	1.17 (0.82, 1.68)	1.09 (0.73, 1.49)
	16–18	Soccer	Youth representative	458	2.24 (1.55, 3.23)	1.26 (0.86, 1.87)	1.07 (0.72, 1.59)	1.69 (0.72, 2.33)
	16–18	Soccer	Youth representative	501	0.68 (0.47, 0.97)	0.66 (0.46, 0.94)	0.97 (0.69, 1.36)	0.68 (0.73, 0.92)
Hoare[65]	15–16	Basketball	Junior regional representative	130	9.14 (3.64, 22.9)	4.85 (1.88, 12.5)	3.57 (1.35, 9.41)	3.06 (0.53, 5.74)
	15–16	Basketball	Junior regional representative	113	5.22 (2.15, 12.6)	3.44 (1.39, 8.53)	2.88 (1.15, 7.24)	2.22 (0.51, 4.29)
	17–18	Basketball	Junior regional representative	118	3.25 (1.52, 6.93)	1.75 (0.78, 3.88)	1.37 (0.60, 3.12)	2.10 (0.52, 3.99)
	Senior	Basketball	Professional	89	2.42 (1.03, 5.71)	1.78 (0.74, 4.30)	1.14 (0.45, 2.88)	1.96 (0.48, 4.09)
Grondin and Koren[66]	Senior	Baseball	MLB professional	5 033	1.12 (1.00, 1.25)	1.02 (0.91, 1.14)	0.97 (0.86, 1.08)	1.09 (0.90, 1.20)
	Senior	Baseball	MLB professional	1 123	1.25 (0.99, 1.58)	1.16 (0.92, 1.47)	0.99 (0.78, 1.26)	1.21 (0.81, 1.48)
	Senior	Baseball	MLB professional	1 260	1.17 (0.94, 1.46)	1.08 (0.87, 1.35)	0.95 (0.76, 1.19)	1.15 (0.82, 1.40)
	Senior	Baseball	MLB professional	1 032	1.04 (0.82, 1.33)	1.01 (0.79, 1.28)	0.89 (0.70, 1.14)	1.08 (0.80, 1.34)
	Senior	Baseball	MLB professional	1 000	0.98 (0.76, 1.25)	0.98 (0.77, 1.26)	0.88 (0.69, 1.13)	1.04 (0.80, 1.29)
	Senior	Baseball	MLB professional	1 303	1.21 (0.97, 1.5)	1.08 (0.87, 1.35)	1.01 (0.81, 1.26)	1.13 (0.82, 1.37)
	Senior	Baseball	MLB professional	1 514	1.31 (1.07, 1.61)	1.19 (0.97, 1.46)	1.02 (0.83, 1.26)	1.23 (0.83, 1.47)
	Senior	Baseball	MLB professional	1 405	1.48 (1.19, 1.83)	1.37 (1.10, 1.69)	1.25 (1.01, 1.56)	1.26 (0.83, 1.51)
	Senior	Baseball	Professional	744	2.39 (1.77, 3.23)	1.82 (1.34, 2.48)	1.47 (1.07, 2.02)	1.70 (0.77, 2.19)
Simmons and Paull[67]	15–16	Soccer	Youth national developmental	79	12.2 (3.70, 40.4)	4.50 (1.28, 15.7)	2.00 (0.51, 7.73)	5.58 (0.41, 13.4)
	9–16	Soccer	Junior/youth representative	8 857	5.04 (4.59, 5.54)	2.84 (2.58, 3.13)	1.09 (0.98, 1.22)	3.76 (0.92, 4.06)
	14–15	Soccer	Junior national	78	16.6 (4.43, 62.6)	5.33 (1.33, 21.2)	3.00 (0.70, 12.7)	5.50 (0.41, 13.2)
	15–16	Soccer	Junior national	63	2.23 (0.85, 5.80)	0.61 (0.19, 1.89)	1.00 (0.35, 2.82)	1.42 (0.42, 3.36)
Musch[68]	7–8	Soccer	Junior leagues	4 795	0.97 (0.87, 1.09)	0.90 (0.81, 1.01)	0.86 (0.77, 0.97)	1.00 (0.90, 1.11)
	9–10	Soccer	Junior leagues	5 332	1.12 (1.01, 1.25)	0.96 (0.86, 1.07)	1.04 (0.93, 1.16)	1.02 (0.91, 1.12)
	11–12	Soccer	Junior leagues	5 417	1.14 (1.03, 1.27)	1.01 (0.91, 1.13)	1.00 (0.89, 1.11)	1.08 (0.91, 1.18)
	13–14	Soccer	Junior leagues	4 478	1.23 (1.09, 1.38)	1.13 (1.00, 1.27)	0.96 (0.85, 1.08)	1.20 (0.90, 1.33)
	15–16	Soccer	Junior leagues	3 266	1.24 (1.08, 1.42)	1.17 (1.02, 1.34)	1.02 (0.88, 1.17)	1.19 (0.88, 1.34)
	17–18	Soccer	Junior leagues	2 033	1.24 (1.04, 1.48)	1.12 (0.94, 1.34)	1.05 (0.88, 1.25)	1.15 (0.86, 1.34)
Glamser and Vincent[69]	17–18	Soccer	Youth regional representative	147	3.00 (1.48, 6.05)	2.66 (1.31, 5.41)	1.50 (0.70, 3.18)	2.26 (0.56, 4.03)
O'Donoghue et al.[17]	Senior	Cricket	Professional	120	1.37 (0.67, 2.78)	1.33 (0.65, 2.71)	0.74 (0.34, 1.59)	1.55 (0.53, 2.90)
	Senior	Cricket	Professional	75	1.00 (0.41, 2.43)	0.90 (0.36, 2.22)	0.85 (0.34, 2.11)	1.02 (0.45, 2.24)
	Senior	Netball	Professional	128	1.58 (0.80, 3.11)	0.86 (0.41, 1.78)	0.96 (0.47, 1.97)	1.24 (0.54, 2.27)
	Senior	Netball	Professional	119	0.90 (0.43, 1.85)	0.80 (0.38, 1.67)	1.12 (0.55, 2.27)	0.80 (0.53, 1.49)

Continued next page

Table I. Contd

Study	Subject age (y)	Sport	Level of competition	No. of subjects	OR comparisons [Q1–4/1st and 2nd 6 mo] (95% CI)			
					Q1 vs Q4	Q2 vs Q4	Q3 vs Q4	1st vs 2nd
Edgar and O'Donoghue[70]	Senior	Soccer	Professional	345	1.40 (0.92, 2.14)	1.01 (0.65, 1.57)	1.24 (0.81, 1.90)	1.07 (0.69, 1.55)
	Senior	Soccer	Professional	92	1.13 (0.50, 2.56)	0.90 (0.39, 2.09)	1.13 (0.50, 2.56)	0.95 (0.49, 1.94)
	Senior	Soccer	Professional	69	1.21 (0.49, 2.98)	0.73 (0.28, 1.92)	0.68 (0.25, 1.80)	1.15 (0.44, 2.62)
	Senior	Soccer	Professional	92	0.85 (0.36, 2.01)	1.23 (0.54, 2.79)	1.28 (0.57, 2.89)	0.91 (0.49, 1.86)
	Senior	Soccer	Professional	598	1.25 (0.90, 1.72)	0.99 (0.71, 1.37)	1.15 (0.83, 1.59)	1.04 (0.75, 1.37)
	Senior	Soccer	Professional	115	1.03 (0.50, 2.11)	0.45 (0.19, 1.02)	1.22 (0.60, 2.47)	0.66 (0.52, 1.26)
	Senior	Soccer	Professional	23	0.12 (0.01, 1.34)	0.87 (0.18, 4.07)	0.87 (0.18, 4.07)	0.53 (0.23, 2.25)
	Senior	Soccer	Professional	138	0.84 (0.43, 1.63)	0.53 (0.26, 1.09)	1.15 (0.60, 2.18)	0.64 (0.55, 1.15)
	Senior	Soccer	Professional	736	1.16 (0.87, 1.54)	0.89 (0.66, 1.19)	1.15 (0.86, 1.53)	0.95 (0.77, 1.22)
Abernethy and Farrow[15]b	Senior	Australian Football	Professional	627	1.44 (1.05, 1.96)	1.26 (0.92, 1.74)	0.97 (0.69, 1.34)	1.37 (0.76, 1.80)
	Senior	Rugby union	Professional	74	2.16 (0.84, 5.54)	1.66 (0.63, 4.36)	1.33 (0.49, 3.58)	1.64 (0.45, 3.64)
	Senior	Rugby union	National professional	37	1.42 (0.37, 5.39)	1.71 (0.46, 6.31)	1.14 (0.29, 4.46)	1.46 (0.32, 4.50)
	Senior	Rugby league	Professional	418	2.39 (1.60, 3.56)	1.90 (1.26, 2.86)	1.23 (0.80, 1.89)	1.92 (0.71, 2.69)
	Senior	Rugby league	National professional	92	2.46 (1.07, 5.67)	1.53 (0.64, 3.66)	1.13 (0.45, 2.79)	1.87 (0.48, 3.85)
	Senior	Cricket	Professional	151	1.13 (0.60, 2.11)	1.00 (0.52, 1.89)	0.84 (0.43, 1.61)	1.15 (0.57, 2.01)
	Senior	Cricket	National professional	385	2.33 (0.63, 8.60)	1.83 (0.48, 6.95)	1.33 (0.33, 5.30)	1.78 (0.33, 5.37)
	Senior	Basketball	Professional	94	1.94 (0.86, 4.35)	0.94 (0.39, 2.26)	1.33 (0.57, 3.07)	1.23 (0.49, 2.49)
	Senior	Basketball	National professional	18	2.66 (0.41, 17.1)	1.33 (0.18, 9.72)	1.00 (0.12, 7.89)	2.00 (0.19, 10.2)
Edgar and O'Donoghue[13]	Senior	Tennis	ATP professional	237	1.65 (0.97, 2.81)	1.68 (0.99, 2.85)	1.46 (0.85, 2.50)	1.35 (0.64, 2.10)
	14–18	Tennis	ITF national juniors	237	2.19 (1.28, 3.74)	1.97 (1.15, 3.38)	1.41 (0.81, 2.47)	1.72 (0.63, 2.69)
Helsen et al.[12]	14–18	Soccer	Youth national	99	1.68 (0.79, 3.54)	1.45 (0.68, 3.09)	0.90 (0.40, 2.02)	1.64 (0.52, 3.15)
	14–18	Soccer	Youth national	90	4.12 (1.56, 10.8)	3.62 (1.36, 9.62)	2.50 (0.91, 6.84)	2.21 (0.47, 4.61)
	14–18	Soccer	Youth national	94	2.93 (1.31, 6.57)	0.81 (0.32, 2.05)	1.12 (0.46, 2.72)	1.76 (0.49, 3.58)
	14–18	Soccer	Youth national	41	3.00 (0.84, 10.6)	2.16 (0.59, 7.93)	0.66 (0.14, 3.08)	3.10 (0.32, 9.51)
	14–18	Soccer	Youth national	77	12.0 (3.15, 45.6)	6.0 (1.51, 23.7)	6.66 (1.69, 26.1)	2.34 (0.45, 5.21)
	14–18	Soccer	Youth national	50	3.60 (1.01, 12.7)	4.4 (1.26, 15.3)	1.00 (0.23, 4.33)	4.00 (0.35, 11.3)
	14–18	Soccer	Youth national	36	17.0 (1.84, 156)	11.0 (1.16, 103)	7.00 (0.70, 69.1)	3.50 (0.29, 11.7)
	14–18	Soccer	Youth national	101	3.07 (1.33, 7.08)	1.61 (0.66, 3.91)	2.07 (0.87, 4.91)	1.52 (0.50, 3.01)
	14–18	Soccer	Youth national	72	6.6 (2.09, 20.7)	5.00 (1.56, 15.9)	1.80 (0.50, 6.43)	4.14 (0.41, 9.94)
	15–16	Soccer	Youth national	288	6.4 (3.67, 11.1)	3.22 (1.80, 5.75)	2.45 (1.35, 4.44)	2.78 (0.65, 4.24)

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Table I. Contd

Study	Subject age (y)	Sport	Level of competition	No. of subjects	OR comparisons [Q1–4/1st and 2nd 6 mo] (95% CI)			
					Q1 vs Q4	Q2 vs Q4	Q3 vs Q4	1st vs 2nd
Helsen et al.[12]	17–18	Soccer	Youth national	144	1.65 (0.84, 3.23)	1.69 (0.86, 3.30)	1.19 (0.59, 2.39)	1.52 (0.56, 2.69)
	19–21	Soccer	Youth national	159	1.07 (0.58, 1.97)	0.85 (0.45, 1.60)	0.95 (0.51, 1.76)	0.98 (0.58, 1.69)
	11–14	Soccer	Junior club tournament	677	2.01 (1.47, 2.76)	1.71 (1.24, 2.35)	1.47 (1.06, 2.04)	1.50 (0.76, 1.96)
Vaeyens et al.[71]	Senior	Soccer	Professional	1 930	1.44 (1.20, 1.73)	1.40 (1.17, 1.68)	1.20 (0.99, 1.44)	1.29 (0.85, 1.51)
	Senior	Soccer	Professional	827	1.45 (1.10, 1.91)	1.16 (0.87, 1.54)	1.21 (0.91, 1.60)	1.18 (0.78, 1.49)
Vincent and Glamser[72]	16–17	Soccer	Developmental national	24	3.25 (0.66, 15.9)	0.50 (0.06, 3.84)	1.25 (0.22, 7.08)	1.66 (0.24, 6.76)
Esteva and Drobnic[73]	Youth	Basketball	Youth representative	157	9.75 (4.16, 22.8)	6.62 (2.78, 15.7)	2.25 (0.87, 5.77)	5.03 (0.54, 9.27)
	Senior	Basketball	Professional	404	1.42 (0.95, 2.12)	1.62 (1.09, 2.41)	1.12 (0.74, 1.70)	1.43 (0.71, 2.01)
	Senior	Basketball	NBA Professional	382	0.98 (0.66, 1.47)	0.93 (0.62, 1.4)	0.92 (0.62, 1.38)	1.00 (0.70, 1.41)
Côté et al.[18]	Senior	Ice hockey	NHL professional	151	1.79 (0.94, 3.40)	1.13 (0.58, 2.22)	1.27 (0.65, 2.47)	1.28 (0.57, 2.24)
	Senior	Basketball	NBA professional	436	1.21 (0.83, 1.77)	1.05 (0.71, 1.54)	1.22 (0.84, 1.78)	1.01 (0.72, 1.40)
	Senior	Baseball	MLB professional	907	1.38 (1.06, 1.78)	1.15 (0.88, 1.50)	1.00 (0.76, 1.30)	1.26 (0.79, 1.58)
	Senior	Golf	PGA professional	197	1.12 (0.64, 1.94)	0.91 (0.52, 1.61)	0.97 (0.55, 1.71)	1.03 (0.61, 1.67)
	Senior	Ice hockey	NHL professional	549	1.54 (1.09, 2.16)	1.56 (1.11, 2.19)	1.12 (0.78, 1.60)	1.46 (0.74, 1.95)
Wattie et al.[42]c	Senior	Ice hockey	NHL professional	146	1.07 (0.57, 2.03)	0.97 (0.51, 1.85)	0.78 (0.4, 1.53)	1.14 (0.56, 2.01)
	Senior	Ice hockey	NHL professional	206	1.32 (0.76, 2.28)	1.13 (0.64, 1.96)	1.02 (0.58, 1.79)	1.21 (0.62, 1.95)
	Senior	Ice hockey	NHL professional	252	1.14 (0.69, 1.90)	1.20 (0.72, 1.98)	1.31 (0.79, 2.16)	1.01 (0.65, 1.55)
	Senior	Ice hockey	NHL professional	282	1.23 (0.77, 1.97)	1.17 (0.73, 1.88)	1.06 (0.66, 1.71)	1.16 (0.66, 1.75)
	Senior	Ice hockey	NHL professional	284	0.81 (0.51, 1.28)	0.77 (0.49, 1.23)	0.70 (0.44, 1.12)	0.93 (0.66, 1.39)
	Senior	Ice hockey	NHL professional	423	0.76 (0.51, 1.11)	0.87 (0.59, 1.27)	0.98 (0.67, 1.42)	0.82 (0.71, 1.14)
	Senior	Ice hockey	NHL professional	698	1.50 (1.11, 2.03)	1.34 (0.99, 1.82)	1.20 (0.88, 1.63)	1.29 (0.77, 1.67)
	Senior	Ice hockey	NHL professional	798	1.90 (1.43, 2.54)	1.79 (1.34, 2.40)	1.20 (0.88, 1.62)	1.68 (0.78, 2.14)
	Senior	Ice hockey	NHL professional	600	1.55 (1.12, 2.15)	1.47 (1.06, 2.04)	1.05 (0.74, 1.47)	1.47 (0.75, 1.95)
	Senior	Ice hockey	NHL professional	76	0.76 (0.30, 1.89)	1.33 (0.56, 3.12)	0.52 (0.19, 1.37)	1.37 (0.45, 3.00)
Summary effect size				121 159d	1.65 (1.54, 1.77)	NA	NA	1.39 (1.32, 1.47)

a 0.5 added to raw data as Q4 = 0, preventing OR calculation. Procedure recommended by Sutton et al.[48]

b Authors also reported data for soccer at junior national (16–17 years old), developmental national (21–23 years old) and national professional (senior) levels. However, sample totals were not available for OR calculation.

c Figure excludes total sample numbers from Edwards[16] and Montelpare et al.[51]

d At the time of data collection this paper was in press and accepted for publication, but not published until June 2007.

AA, AAA, BB, CC = levels of ice hockey competition, where 'As' are more competitive or a higher level than subsequent letters of the alphabet; **AFC** = American Football Conference; **ATP** = Association of Tennis Professionals; **CFL** = Canadian Football League; **div** = division; **MLB** = Major League Baseball; **NBA** = National Basketball Association; **NFC** = National Football Conference; **NR** = sample information not reported; **NA** = quartile data not available following contact with lead author; original data presented in bi-monthly distributions; **NHL** = National Hockey League; **OHL** = Ontario Hockey League; **PGA** = Professional Golfers' Association; **Q** = quartile; **WHL** = Western Hockey League.

information hopefully beneficial to strategies motivated toward eradicating RAEs. Findings suggest RAEs are robust and generally prevalent across the sports contexts examined to date. Across all samples, summary ORs indicate that for every two participants born in the last quartile of an annual age-group, over three are participating from the first quartile of the same age-group. Risk likelihoods increased when the number of months away from the referent group (i.e. quartile 4) was amplified, suggesting a linear profile to RAEs. Findings identified that the relatively youngest sport participants within annual age-groups were (i) less likely to participate in recreational and competitive sport from under 14 years of age; (ii) certainly less likely to participate on representative teams during the 15- to 18-year-old bracket; and (iii) less likely to become an elite athlete in the sport contexts examined. In combining previous literature (e.g. Helsen et al.[30]) with findings from the present study, it seems that sport is less likely to be an activity or career pathway for relatively younger individuals, whose birth dates coincide with the last 3 months of an annual age-grouping strategy.

Several factors influenced the magnitude of RAEs, notably age category, skill level and sport context. Analyses identified sport contexts with distinctive RAE risks; higher risks were associated with basketball, soccer and ice hockey. In these sports, mid to late adolescence (15–18 years) and the representative level of competition (i.e. regional and national representation) were most vulnerable to RAEs. In contrast, while small significant effects remained, childhood (under 11 years) and recreational sports contexts reported the lowest risk of RAEs. In the seven available American Football samples, no evidence of RAEs was found. Related to these contexts, low numbers of samples were available, so findings should be evaluated with caution.

Taken together, findings partially reinforced our hypothesis that RAEs are probably most likely to occur in highly popular sports, prevailing due to a combination of mechanisms primarily associated with maturation and selection of athletes within the developmental tiers and structures of a sport.[3,19,30] Contrary to our hypotheses, RAE risk did not increase linearly with skill level or age category. Rather, at the elite level (professional or senior national representative) risks decreased to below that of the youth representative. At senior ages (i.e. >18 years) RAE risk also decreased to below that of the adolescent ages. Nevertheless, RAEs persisted into older cohorts.

The reduction of RAEs at the senior and elite stages is difficult to explain, with several mechanisms possible. For example, whilst acknowledging that annual age-groupings within sport generally terminate in senior sport (i.e. often 19–21 years old), it could be that differences according to physical maturity become redundant at the senior years,[26] allowing the relatively younger athlete to perform on a more equal footing. Nevertheless, such an explanation is reliant upon relatively younger athletes remaining actively engaged in sport through years of unfavourable selection and attainment. It is worth reminding that Helsen et al.[30] and Barnsley et al.[11] reported higher drop-out rates in relatively younger players across junior and adolescent ages. Another possibility is that senior athletes transfer from one sport to another (even from lower levels of involvement and in contexts where RAEs are more or less likely), thereby avoiding the disadvantaged developmental environment. In elite team sports, Baker et al.[74] noted that elite athlete development profiles were highly variable, suggesting that this type of late-stage transfer is possible, depending on the compatibility of performance requirements.

An alternative explanation is that relatively older athletes, originally selected for additional training and higher levels of skill representation during their junior and adolescent years, withdraw from competitive levels of participation preceding or during their senior years due to injury, overtraining, burnout or boredom. In popular highly competitive sports (e.g. soccer and ice hockey), many talented athletes in the adolescent years (15–18) do not fulfil their early potential by attaining a professional contract. Some limited evidence suggests that highly specialized training environments, such as those conducive to RAE

Table II. Unadjusted odds ratios (ORs) for female independent samples examining relative age effect in sport

Study	Subject age (y)	Sport	Level of competition	No. of subjects	OR comparisons [Q1–4/1st and 2nd 6 mo)] (95% CI)			
					Q1 vs Q4	Q2 vs Q4	Q3 vs Q4	1st vs 2nd
Grondin et al.[2]	12–13	Volleyball	Junior	96	1.56 (0.67, 3.63)	2.37 (1.05, 5.35)	1.06 (0.43, 2.57)	1.9 (0.49, 3.86)
	14–15	Volleyball	Youth cadet	97	1.00 (0.46, 2.15)	1.1 (0.51, 2.36)	0.35 (0.14, 0.89)	1.55 (0.49, 3.11)
	16–17	Volleyball	Youth juvenile	56	1.14 (0.4, 3.2)	1.00 (0.35, 2.85)	0.85 (0.29, 2.49)	1.15 (0.4, 2.86)
	14–15	Volleyball	Provincial youth cadet	219	2.28 (1.3, 3.99)	2.12 (1.21, 3.73)	1.43 (0.79, 2.58)	1.8 (0.62, 2.87)
	16–17	Volleyball	Provincial youth juvenile	188	1.25 (0.7, 2.25)	1.43 (0.8, 2.55)	1.12 (0.62, 2.03)	1.26 (0.6, 2.07)
	17–19	Volleyball	Provincial youth	59	1.06 (0.39, 2.86)	0.81 (0.29, 2.27)	0.81 (0.29, 2.27)	1.03 (0.41, 2.5)
	Senior	Volleyball	Provincial senior	40	0.87 (0.22, 3.34)	1.62 (0.46, 5.62)	1.5 (0.42, 5.24)	1.00 (0.34, 2.92)
Baxter-Jones[14]	11–18	Swimming	Elite junior	60	2.11 (0.72, 6.14)	2.11(0.72, 6.14)	1.44 (0.47, 4.38)	1.72 (0.41, 4.19)
	9–18	Tennis	Elite junior	81	2.23 CI (0.9, 5.47)	1.84 CI (0.74, 4.6)	1.15 CI (0.43, 3.02)	1.89 CI (0.46, 4.07)
Baxter-Jones et al.[25]	9–18	Gymnastics	Elite junior	81	1.64 (0.69, 3.89)	1.23 (0.5, 3)	0.88 (0.34, 2.23)	1.53 (0.46, 3.27)
Hoare[65]	15–16	Basketball	Junior regional representative	130	5.72 (2.56, 12.7)	3.81 (1.67, 8.69)	1.27 (0.5, 3.21)	4.2 (0.52, 8.07)
	15–16	Basketball	Junior regional representative	100	6.71 (2.54, 17.6)	3.42 (1.25, 9.39)	3.14 (1.13, 8.67)	2.44 (0.49, 4.94)
	17–18	Basketball	Junior regional representative	98	1.77 (0.79, 3.97)	1.27 (0.55, 2.93)	1.38 (0.6, 3.16)	1.27 (0.5, 2.54)
	Senior	Basketball	Professional	78	3.00 (1.15, 7.77)	1.8 (0.66, 4.87)	2.00 (0.74, 5.35)	1.6 (0.46, 3.47)
O’Donoghue et al.[17]	Senior	Netball	National professional	128	1.58 (0.8, 3.11)	0.86 (0.41, 1.78)	0.96 (0.47, 1.97)	1.24 (0.54, 2.27)
	Senior	Netball	National professional	119	0.9 (0.43, 1.85)	0.8 (0.38, 1.67)	1.12 (0.55, 2.27)	0.8 CI (0.53, 1.49)
Edgar and O’Donoghue [13]	Senior	Tennis	ATP professional	211	1.94 (1.11, 3.38)	1.61 (0.91, 2.83)	1.3 (0.73, 2.32)	1.54 (0.62, 2.47)
	14–18	Tennis	ITF national juniors	239	1.85 (1.09, 3.13)	1.47 (0.86, 2.52)	1.65 (0.96, 2.8)	1.25 (0.64, 1.94)
Helsen et al.[12]	17–18	Soccer	Youth national	72	1.61 (0.62, 4.18)	2.00 (0.78, 5.08)	0.92 (0.33, 2.56)	1.88 (0.44, 4.24)
Vincent and Glamser[72]	17–18	Soccer	State representative	804	1.11 (0.84, 1.47)	1.14 (0.86, 1.51)	1.10 (0.83, 1.45)	1.07 (0.78, 1.36)
	17–18	Soccer	Regional representative	71	1.33 (0.52, 3.4)	1.53 (0.6, 3.86)	0.86 (0.32, 2.33)	1.53 (0.44, 3.45)
	17–19	Soccer	Developmental national	39	3.00 (0.78, 11.5)	1.40 (0.32, 5.97)	2.40 (0.6, 9.44)	1.29 (0.33, 3.84)
Wattie et al. [42]	Senior	Ice hockey	Senior women	299	1.04 (0.65, 1.65)	1.29 (0.82, 2.03)	1.05 (0.66, 1.67)	1.13 (0.67, 1.68)
Summary effect size				3321	1.21 (1.10, 1.33)			1.39 (1.26, 1.54)

ATP = Association of Tennis Professionals; **ITF** = International Tennis Federation; **Q** = quartile.

Table III. Summary odds ratios (ORs) for relative age effects in sport according to age category[a]

Age category	Q1 vs Q4		1st vs 2nd 6 mo	
	no. of samples (% of total)	summary OR (95% CI)	no. of samples (% of total)	summary OR (95% CI)
≤10 y	17 (6.91)	1.22 (1.08, 1.39)	17 (6.71)	1.12 (1.03, 1.22)
Junior (11–14 y)	42 (17.07)	1.29 (1.29, 1.96)	44 (17.39)	1.36 (1.15, 1.60)
Adolescent (15–18 y)	69 (28.04)	2.36 (2.00, 2.79)	70 (27.66)	1.72 (1.54, 1.92)
Senior (≥19 y)	107 (43.49)	1.44 (1.35, 1.53)	110 (43.47)	1.29 (1.24, 1.35)

a 11 samples from the Q1 vs Q4 comparison and 12 samples from the 1st vs 2nd 6-mo comparisons were excluded from the analysis due to participant samples crossing age-category boundaries applied.

Q = quartile.

occurrence (i.e. through selection and identification processes), are related to shorter playing careers and increased rates of dropout at the senior level.[75] On the whole, we can only speculate as to why RAEs decline at the elite stage. Nonetheless, these results demonstrate that a slightly ‘more even playing-field’ exists for those relatively younger individuals within senior and elite echelons of sport.

4.2 Context-Specific Findings

Meta- and substratification analyses were less able to accurately account for the potential role of context specificity, whereby unique socio-cultural variables could amplify or reduce RAEs. For example, soccer and ice hockey show consistent RAEs, regardless of age and skill level. However, identifying basketball as a context for heightened risk of RAEs contradicts the equivocal findings of some individual studies (e.g. Daniel and Janssen[41]). Upon further examination of basketball samples, over half of the samples (i.e. eight) included in our OR calculations were derived from the data of Hoare[65] examining Australian Basketball. In this context, RAEs were exceptionally high, lending credence to the suggestion that factors distinctive to the developmental structure of Australian Basketball may escalate RAEs. Likewise, factors distinct to the developmental structure of American football (e.g. drafting and selection at later ages) may also reduce the likelihood of RAEs (as argued by Daniel and Janssen[41]). These context-specific findings suggest RAE risk is variable and that those responsible for sport structures can modify and potentially eradicate RAE inequalities.

4.3 Eliminating Relative Age Effects

Several recommendations have been proposed to resolve RAEs. Initially these addressed annual age-groupings, by advocating a change in the age-group cut-off date (e.g. from January to June), rotating cut-off dates from year to year (Barnsley et al.[1]), or altering age-grouping bandwidths. However, changing cut-off dates only leads to a transfer of RAEs,[71] as exemplified in Australian,[63] Belgian[64] and English[67] youth soccer. To prevent a ‘fixed-bias’ across sport development, Grondin et al.[2] proposed an expansion of age-group bandwidths to 15 and 21 months, as opposed to the typical 12-month groupings, to rotate cut-off dates across particular ages and constantly change group composition. Similarly, Boucher and Halliwell[57] proposed a 9-month bandwidth (referred to as the Novem system) to reduce potential age inequalities in a given group, whilst also ensuring that the same participants (i.e. relatively older or younger) were not disadvantaged year after year during youth stages of competition (i.e. present Under 10s to Under 16s). To address the RAE inequality in Canadian ice hockey specifically, Hurley et al.[76] presented the relative age fair (RAF) cycle, whereby cut-off dates altered for each and every consecutive year of participation. In their plan, cut-off dates changed by 3 months between seasons of competition, to ensure players experienced being in each quartile position

Table IV. Summary odd ratios (ORs) for relative age effects according to skill level[a]

Skill level	Q1 vs Q4		1st vs 2nd 6 mo	
	no. of samples (% of total)	summary OR (95% CI)	no. of samples (% of total)	summary OR (95% CI)
Recreational	28 (11.38)	1.12 (1.05, 1.20)	28 (11.06)	1.09 (1.03, 1.15)
Competitive	53 (21.54)	1.63 (1.35, 1.97)	55 (21.73)	1.40 (1.21, 1.62)
Representative	70 (28.45)	2.77 (2.36, 3.24)	73 (28.85)	1.87 (1.68, 2.07)
Elite	95 (38.61)	1.42 (1.34, 1.51)	97 (38.33)	1.28 (1.22, 1.33)

a Samples that could not be clearly categorized into one of the above were excluded from comparison analyses.

Q = quartile.

(i.e. Q1, Q2, Q3 and Q4) across the competitive junior structure of ice hockey. Both the Novem and RAF strategy may help address the RAE problem; however, there is foreseeable complexity in re-structuring and implementing these options within youth sports.

On a separate but related point, Musch and Grondin[21] noted that across sports contexts (and education) many cut-off dates used for age-grouping are actually similar (e.g. 1 September to 31 August in the UK). So, to prevent repeated and consistent (dis)advantages from occurring, they recommended that deliberate variation of cut-off dates be used for across sports contexts. This step would prevent generic RAEs across sports contexts and may reduce the likelihood of persistent negative experiences of sporting involvement relative to age-matched peers, and may help maintain sporting involvement in contexts with favourable conditions (i.e. in which you are relatively older). Nevertheless, it may not prevent RAEs within a given sport, thereby not preventing their occurrence.

Other possible solutions have targeted maturational differences and the process by which athletes are selected. Barnsley and Thompson[3] advocated implementing player quotas, where selection must meet specified birth-date distributions to prevent favouring of relatively older players. More substantially, the average age of a whole team,[30,64] the number of selections and the distribution of playing time could be regulated. Another popular solution has been to suggest grouping participants according to physical (i.e. height and weight) classification,[14,21] similar to that routinely adopted in boxing and wrestling. More sensitive to individual variability in physical characteristics, this may be sensible particularly during developmental stages. Again, these strategies may prove difficult to integrate into sport systems and are as yet unproven in their value for resolving RAEs.

A less challenging solution is to delay the processes of selection, identification and representation beyond stages of puberty and maturation (i.e. 15–16 years of age). Governing bodies and coaches should reconsider the necessity for early selection, intensive training and levels of representation at junior and child ages. Admittedly, the path to success in sport does require intensive long-term training and commitment, often referred to as the ‘10-year rule of attainment’.[77] Yet, peak performance in many sports (e.g. soccer, ice hockey) is often not attained until the late twenties and thirties, providing a sufficient window for training and development subsequent to adolescence. This position is further substantiated by an expanding literature illustrating concerns for the physiological and psychosocial welfare of athletes involved in intensive training from early ages.[78-80] Delaying selection might reduce RAEs and indirectly help reduce the risk of compromising health during an athlete’s development.

Another possibly beneficial approach would be to raise awareness of RAEs among those responsible for the infrastructure and coordination of youth sport. Sports contexts with higher risks of RAEs (e.g. Canadian ice hockey and European soccer) should be targeted. During adolescence, coaches need to be attentive to the possibility that physical attributes, such as height and weight (which underpin speed, power and strength) are being overlooked during early stages of athlete development (i.e. 13–16 years old), conveying selection advantages to the relatively older at a time coinciding with intense identification and selection to competition at representative levels. Whilst monitoring for RAEs in selection and participation, coaches should integrate more movement and skill-based (e.g. movement accuracy, consistency and adaptability) criteria in selection, reducing the association and dependence upon physical attributes. Up to the mid-teenage years (i.e. 15–16), governing bodies and coaches should re-assess whether tiers of competition and levels of representation could be removed to support selection and representation in later years.

To assist, it should be considered that coaches within sport development systems are pressured to obtain immediate performance success. As a result, coaches may face a constant battle of selecting individuals/teams that help guarantee immediate success in youth ages (i.e. likely to be relatively older with advanced physical characteristics at the moment), as opposed to individuals/teams that may be more successful in the longer term. Strategies focusing on raising awareness with recommendations pertaining to the importance of delayed selection may help reduce the emphasis on striving for immediate performance success in youth. Considerate of the findings from the present study, it is certainly feasible that if a relatively younger athlete maintains sport involvement, despite the constant and disadvantaging annual age-grouping policy in youth, this may prove beneficial in the senior years.

4.4 Future Directions

This meta-analytical review has identified several areas where further research is needed. Data consistently and recurrently support the presence of RAEs in specific sports, yet in other contexts the data are less conclusive. For example, data from basketball are somewhat equivocal, while data from women's sports are particularly sparse. Initial data in women's sports (e.g. Wattie et al.[42]) suggests these contexts may not be as susceptible to RAEs. One explanation for the discrepancy associates differences in participation rates and lower competition for selection into representative skill levels as reasons for a reduced likelihood of RAE risk. Researchers should also more broadly consider a range of sociocultural contexts. Largely limited by studies in North America, Europe and Australia to date, examinations of RAEs in African, South American and Asian countries might provide valuable information about the role of sport infrastructure in perpetuating RAEs.

Similarly, a comparison of RAEs between sport development systems utilizing early talent identification systems (e.g. Australia) and those without explicit programmes may be useful. This would determine whether RAEs are the result of greater exposure to high-quality resources or due to the effects of early success on the development of self-efficacy and other feelings of competence. Moreover, this research might prove useful for

Table V. Summary odds ratios (ORs) for relative age effects according to sport context[a]

Sport context	Q1 vs Q4		1st vs 2nd 6 mo	
	no. of samples (% of total)	summary OR (95% CI)	no. of samples (% of total)	summary OR (95% CI)
Ice hockey	77 (31.30)	1.62 (1.45, 1.79)	83 (32.80)	1.40 (1.31, 149)
Soccer	76 (30.89)	2.01 (1.73, 2.32)	76 (30.03)	1.55 (1.37, 1.74)
Baseball	33 (13.41)	1.20 (1.12, 1.30)	33 (13.04)	1.14 (1.08, 1.20)
Basketball	15 (6.09)	2.66 (1.80, 3.93)	15 (5.92)	1.77 (1.34, 2.33)
Volleyball	14 (5.69)	1.33 (1.07, 1.65)	14 (5.53)	1.24 (1.03, 1.49)
American Football	7 (2.84)	1.24 (0.93, 1.65)	7 (2.76)	1.08 (0.94, 1.23)

a Samples examining other sport contexts (e.g. tennis) were not included in any Q1 vs Q4 or 1st vs 2nd 6 mo comparison analyses.

Q = quartile.

determining the effectiveness of talent identification systems, since one measure of utility is certainly the degree to which 'talented' or 'gifted' performers are missed by the system (a type II error). For example, countries and/or sport-governing bodies employing intensive early talent identification and development systems in sport may, ironically, be achieving the opposite effect by constraining and reducing their talent pool through early selection processes and generating RAEs. In this scenario, young athletes may depart sport prior to full maturity, without opportunity to nurture their skills and inherent interest. Qualitative idiographic investigations examining developmental sport structures, coaching practice and the child/athlete experience within them, will certainly strengthen our understanding of how RAEs manifest and operate.

Atheoretical work has dominated the study of RAEs to date and future studies should be grounded in more theoretically sound foundations. In addition to providing pieces to the puzzle that are currently missing, such studies would be valuable for creating a sound theoretical understanding of (i) the origins of RAEs, (ii) their implications in human development, and (iii) ways in which development systems can be modified to reduce or remove RAEs in the future.

5. Conclusions

This meta-analysis suggests consistent small risks of RAEs are apparent across sport, with the relatively younger members of annual age-group cohorts persistently disadvantaged. Risk size is moderated by several factors, including chronological age differences (i.e. number of months) between cohort members, age category, skill level and sport context. Practices that produce RAEs need to be revised, whilst interventions that reduce or eradicate this sporting inequality need to be implemented and evaluated. These steps are necessary as annual age-grouping and associated processes appear to constrain the likelihood of immediate and long-term participation as well as attainment in sport. Whether you are motivated toward realizing the positive effects of sport on youth development (e.g. promoting fun, enjoyment and inclusive participation), or are interested in elite athlete development, the presence of RAEs (we argue) appears contradictive to both these outcomes. Certainly, notions of competition, selection and talent identification, which seem to create RAEs across developmental stages, should be addressed by sport organizations. This is the main challenge facing researchers, sport governing bodies, coaches, parents and athletes alike.

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