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Review

Hip Internal Rotation in Healthy Baseball Athletes: A Scoping Review

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ABSTRACT

Objective. The aim of this scoping review was to evaluate hip internal rotation (IR) range of motion (ROM) across different age groups of baseball athletes to identify those at greater risk of injury. Additional objectives included comparing hip IR ROM between dominant and non-dominant legs and between pitchers and position players.

Data Sources. PubMed, Embase, OVID, and CINAHL.

Study Selection. Inclusion criteria required studies to be full text, written in English, involve healthy baseball athletes cleared for participation, and include measurements of bilateral passive hip IR ROM prior to any interventions.

Data Extraction. Three independent reviewers systematically extracted data on population age, competition level, passive dominant hip IR ROM, and passive non-dominant hip IR ROM. When available, means, standard deviations, and sample sizes also were extracted.

Data Synthesis. The initial search yielded 155 studies, of which 23 met inclusion criteria. Aggregate data were analyzed using weighted means, pooled standard deviations, and sample sizes. Athlete groups were categorized as youth (<13 years), high school, college, and professional. College and professional groups were further stratified into pitchers and position players.

Conclusions. All groups exhibited deficits in bilateral passive hip IR ROM. Professional athletes demonstrated greater bilateral hip IR compared to college-aged athletes. The difference in mean non-dominant versus dominant hip IR between pitchers and position players was minimal, measuring less than two degrees.

INTRODUCTION

Throwing a baseball is a complex movement involving the entire kinetic chain. The energy required for the throwing motion originates in the lower body and is transferred to the upper body through the core.[1] Axial spine rotation and hip motion, particularly hip internal rotation (IR), are key components in transferring kinetic energy, especially during the arm-cocking phase of pitching.[2-4]

Normative values for hip IR range of motion (ROM) vary with age. Svenningsen et al.[5] studied 761 participants to establish baseline hip ROM values, finding the mean hip IR ROM in males to be 51° in those aged ≤8 years, 46° in 11-year-olds, 41° in 15-year-olds, and 38° in adult males with a mean age of 23.

Deficits in hip IR ROM may result in compensatory movements at other joints during throwing,[4] which can increase the risk of injury, particularly in the upper body.[6,7] Reduced hip IR has been correlated with higher injury rates in the lower body, core, and upper extremities of baseball athletes. To mitigate this risk, some clinicians have incorporated hip mobility exercises into warm-up routines and daily programs to improve hip ROM.[8]

Pitchers and position players have distinct physical demands. Pitchers perform repetitive throwing motions that may influence hip IR ROM, but this relationship remains unclear.

Also unknown is which age group or competitive level of baseball is most affected by hip IR ROM deficits. The primary aim of this scoping review was to examine hip IR ROM across different populations of baseball athletes. Secondary aims included comparing hip IR ROM between the dominant/pivot and non-dominant/stride legs, and between pitchers and position players.

METHODS

Search Strategy and Study Selection. A systematic review of the literature was performed following the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines (Appendix 1; available online at journals.ku.edu/kjm). The review was registered with the Prospective Register of Systematic Reviews (PROSPERO; CRD42023456002), and no similar meta-analyses or systematic reviews were identified. Databases utilized included PubMed, Embase, OVID, and CINAHL. The electronic database search was performed from database inception through September 2023, the date of the literature search. Records sought were restricted to full-text manuscripts available in the English language. Key words in the search included: "hip" AND "baseball" AND ("internal rotation" OR "medial rotation"). Appendix 1 provides further specific details regarding the location of PRISMA checklist items in the manuscript.

Eligibility Criteria. Inclusion criteria consisted of peer-reviewed studies that contained full-length text, were written in the English language, utilized healthy baseball athletes of any age that were cleared for participation in organized activity, and measured and recorded bilateral passive hip IR ROM prior to any interventions. Appendix 1 provides further details regarding the inclusion and exclusion of studies in the literature search. Baseball athletes were defined as participants that were actively participating or had participated in a season of organized baseball activity. Corresponding authors of articles that did not include athlete age or specify dominant versus non-dominant data were contacted to gather that information; however, no additional information was obtained. Evaluation of articles for inclusion and exclusion criteria was conducted by a sole author.

Data Extraction. Data were extracted from each selected study by the primary author and cross-checked by each additional author to limit bias and ensure accuracy. Information sought included mean population age and standard deviation, if available, population competition level, baseball position of population, and mean passive dominant and non-dominant hip IR ROM and standard deviations. All ROM measurements were recorded in degrees, and mean ROM measurements were utilized over individual ROM measurements when available.

Risk of Bias Assessment. An assessment of potential bias was performed by two authors on each included manuscript using the Methodological Index for Nonrandomized Studies (MINORS) criteria. The MINORS criteria is a validated instrument to assess the quality of non-randomized studies using a score between 0 and 16 for noncomparative studies, and 0 and 24 for comparative studies.[9] In the case of discrepancies in scoring, a third independent reviewer was utilized to break the tie.

Statistical Analysis. Aggregate data from each study were summarized using weighted means for athlete's age, dominant hip IR ROM, and non-dominant hip IR ROM. Weighted means were calculated using the following formula:

$$\bar{x} = \frac{\sum w_n \times x_n}{\sum w_n}$$

where w_n is the weight of each value, x_n is the individual mean value, and $\bar{x}$ is the calculated weighted mean. Weighting was based on population size per study.

To account for variation in sample size across multiple studies, pooled standard deviations were calculated using the formula:

$$SD_{pooled} = \sqrt{\frac{\sum(n_i - 1) * SD_i^2}{\sum(n_i - 1)}}$$

where n_i is the sample size and SD_i is the standard deviation of each individual study. Confidence intervals (CIs) for the weighted means were calculated using the confidence.norm function in excel, which uses the following formula with an alpha set at 0.05 for a 95% confidence interval:

$$CI = \bar{x} \pm CONFIDENCE.NORM(\alpha, SD_{pooled}, n_{total})$$

Studies were grouped into four categories based on the mean age of the participants within the study. The categories included youth (<13 years old), high school-aged (≥13 and <18 years old), college-aged (≥18 and <22 years old), and professional (≥22 years old) athletes. Data that did not have a corresponding reporting age were placed in the most accurate category per the subjective population description within each individual study. College-aged and professional populations were stratified to pitchers and position players.

When studies reported both control and comparison groups with bilateral hip IR data, each group was treated as an independent entry in the meta-analysis, resulting in 33 total groups from 23 studies.

A random-effects meta-analysis was conducted using the DerSimonian and Laird method to account for between-study variability. Heterogeneity was assessed using Cochran's Q statistic and the I^2 index. An I^2 value above 50% was considered indicative of substantial heterogeneity. Confidence intervals for tau² and I^2 were calculated using the Jackson method. All analyses were performed using the meta and meta for packages in R.

In addition to the meta-analysis, we calculated weighted means, pooled standard deviations, and 95% confidence intervals for dominant and non-dominant hip IR ROM stratified by age category (youth, high school, college, professional) and player position (pitcher, position player). These descriptive summaries were used to explore population-level trends. Due to limited numbers of studies per subgroup, formal meta-analyses were not conducted for these comparisons.

RESULTS

Literature Search. The initial search yielded 155 studies. After removing 66 duplicates using Microsoft Excel, 89 abstracts were screened, and 50 studies were excluded based on relevance. The full texts of the remaining 39 studies were assessed using the predetermined inclusion criteria. Of these, 23 studies met all inclusion criteria.[4,7,8,10-30] The full selection process is illustrated in Appendix 1.

Demographic Data. A total of 2,196 bilateral hip IR ROM measurements were extracted. Results are reported as weighted mean ± standard deviation (SD), with 95% confidence intervals (CI):

- Youth population: 966 bilateral measurements; mean age = 10.61 ± 1.41 years (95% CI: 10.52, 10.70),
- High school-aged population: 113 bilateral measurements; mean age = 15.93 ± 1.67 years (95% CI: 15.62, 16.24),
- College-aged population: 295 bilateral measurements; mean age = 19.54 ± 1.69 years (95% CI: 19.35, 19.73),
- Professional population: 822 bilateral measurements; mean age = 24.29 ± 3.61 years (95% CI: 23.93, 24.65).

Details of individual studies are provided in Table 1.

Within the college-aged population, there were:

- 101 bilateral measurements in the pitcher subgroup, with a mean age of 19.95 ± 1.56 years (95% CI: 19.65, 20.25),
- 85 bilateral measurements in the position player subgroup, with a mean age of 19.80 ± 1.80 years (95% CI: 19.42, 20.18),
- 109 additional bilateral measurements from athletes whose position was mixed or unspecified; these were not assigned to either subgroup.

In the professional population, there were:

- 255 bilateral measurements in the pitcher subgroup, with a mean age of 24.31 ± 4.00 years (95% CI: 23.82, 24.80),
- 130 bilateral measurements in the position player subgroup, with a mean age of 24.26 ± 2.86 years (95% CI: 23.77, 24.75).

MINORS Risk of Bias Analysis. Bias was assessed using the Methodological Index for Non-Randomized Studies (MINORS) criteria. The analysis identified:

- 15 comparative studies[4,7,8,10-15,18,19,22,24-26] with a mean score of 16.33 ± 1.86 (out of 24 points),
- 8 non-comparative studies[16,17,20,21,23,27-29] with a mean score of 8.75 ± 1.03 (out of 16 points).

Full details of the bias assessment are available in Appendix 2 (accessible online at journals.ku.edu/kjm).

Table 1a. Demographic and statistical data of included studies.

Authors	Control Group Competition Level	Comparison Group Competition Level	Control Group Condition	Comparison Group Condition	Control Group N	Comparison Group N	Group(s) Utilized within this Systematic Review
Camp[11]	Professional	Professional	PP	Pitchers	42	54	Both
Camp[12]	Professional	Professional	PP	Pitchers	129	129	Both
Chan[13]	Professional	Professional	PP	Pitchers	136	186	Both
Cheng[14]	HS	HS	Healthy	GIRD	13	12	Both
Garrison[15]	HS + Collegiate (Collegiate)	HS + Collegiate (Collegiate)	Healthy	Previous UCL Tear	87	87	Control Group
Hamano[16]	Youth	Youth	Healthy	Injured	211	52	Both
Harding[17]	Youth	NA	Healthy	NA	28	NA	Control Group
Ishigaki[18]	College	NA	Healthy (Pitchers and PP)	NA	22	NA	Control Group
Kim[19]	Youth + HS (Youth)	Youth	Healthy	Shoulder Pain	35	60	Control Group
Laudner[8]	Professional	Professional	PP	Pitchers	40	40	Both
McCulloch[20]	Professional	NA	Pitchers	NA	111	NA	Control Group
Oliver[21]	Youth	NA	Healthy	NA	26	NA	Control Group
Oliver[22]	Youth	Youth	Pregame	Postgame	19	19	Control Group
Picha[23]	Youth + HS (Youth)	NA	Healthy	NA	72	NA	Control Group
Plummer[24]	HS	NA	Healthy	NA	25	NA	Control Group
Robb[4]	Professional	NA	Pitchers	NA	19	NA	Control Group
Saito[25]	Youth	Youth	Healthy	Elbow Pain	89	33	Control Group
Sakata[9]	Youth	Youth	Healthy	Injured Medial Elbow	242	78	Control Group
Sauers[26]	Professional	Professional	PP	Pitchers	49	50	Both
Sekiguchi[27]	Youth	Youth	Healthy	Pain	161	16	Control Group
Takeuchi[28]	College	College	PP	Pitchers	85	64	Both
Yanagisawa[29]	College	NA	Pitchers	NA	23	NA	Control Group
Zeppieri[30]	College	College	Pitchers (preseason)	Pitchers (postseason)	14	14	Control Group

* HS = high school; PP = position players; GIRD = glenohumeral internal rotation deficit; UCL = ulnar collateral ligament. NA denotes the study did not include a comparison group. Groups with more than one population have the most common denoted in parentheses.

Table 1b. Demographic and statistical data of included studies, continued.

Authors	Mean Control Group Age (SD)	Mean Comparison Group Age (SD)	Mean Control Dominant Hip IR ROM (SD)	Mean Comparison Dominant Hip IR ROM (SD)	Mean Control Nondominant Hip IR ROM (SD)	Mean Comparison Nondominant Hip IR ROM (SD)
Camp[11]	27.3 (3.6)	27.9 (4.7)	34 (10.8)	37.1 (9.7)	34.1 (11.3)	39.1 (9.0)
Camp[12]	NA	NA	40.6 (8.6)	40.8 (8.4)	40.1 (8.7)	40.9 (7.4)
Chan[13]	NA	NA	35.2 (10.2)	36.5 (9.3)	35.3 (11.0)	37.1 (9.0)
Cheng[14]	17.08 (1.23)	16.64 (0.95)	35.62 (7.86)	29.79 (6.770	32.31 (7.20)	29.75 (7.28)
Garrison[15]	18.6 (1.9)	17.7 (2.0)	29.6 (9.5)	30.6 (10.5)	29.5 (9.0)	33.5 (17.5)
Hamano[16]	10.5 (1.5)	11.4 (1.3)	56.8 (10.8)	52.5 (11.3)	55.7 (10.6)	52.3 (13.0)
Harding[17]	13.9 (2.9)	NA	30.2 (6.6)	NA	33.1 (8.9)	NA
Ishigaki[18]	20.4 (1.0)	NA	35.1 (8.4)	NA	34 (9.2)	NA
Kim[19]	16.9 (1.5)	16.7 (0.9)	24.5 (7.8)	24.4 (6.4)	26 (7.4)	27.4 (7.4)
Laudner[8]	23.9 (2.1)	23.5 (2.9)	37.7 (5.8)	34.6 (4.4)	37 (4.8)	34.4 (6.1)
McCulloch[20]	23.9 (4.6)	NA	32.6 (8.7)	NA	31.9 (7.0)	NA
Oliver[21]	11.3 (1.0)	NA	31.3 (8.3)	NA	28.5 (6.1)	NA
Oliver[22]	11.3 (0.6)	11.3 (0.6)	34.9 (8.7)	33.4 (8.6)	28.9 (6.4)	29.7 (7.5)
Picha[23]	12.8 (3.3)	NA	32.8 (7.7)	NA	34.8 (8.8)	NA
Plummer[24]	15.9 (1.1)	NA	25.1 (8.2)	NA	24.2 (6.8)	NA
Robb[4]	NA	NA	50.8 (9.2)	NA	31.3 (6.2)	NA
Saito[25]	11.9 (2.0)	12.5 (1.4)	46.9 (13.3)	36.1 (15.7)	46.9 (12.2)	36.4 (18.1)
Sakata[9]	9.2 (1.3)	10 (1.0)	40.1 (23.8)	36.4 (13.7)	38.2 (12.2)	34.8 (13.3)
Sauers[26]	22 (2.8)	22 (2.8)	36.9 (4.9)	37.2 (5.7)	38.4 (4.7)	37 (5.6)
Sekiguchi[27]	11 (0.8)	11.1 (0.5)	48 (13)	46 (11)	44 (13)	36 (8)
Takeuchi[28]	19.8 (1.8)	20.3 (1.8)	25.4 (6.7)	28.3 (8.2)	28.9 (8.0)	29 (6.9)
Yanagisawa[29]	19.3 (1.0)	NA	45.7 (5.8)	NA	41.8 (7.2)	NA
Zeppieri[30]	19.4 (1.4)	19.4 (1.4)	15.1 (4.6)	14.7 (5.1)	17.1 (7.2)	15.1 (4.2)

* IR = internal rotation; ROM = range of motion; SD = standard deviation. NA denotes that the data was not included within the original manuscript.

Table 2. Weighted means analysis of internal rotation for four populations.

Population	n (Age Available)	Weighted Mean Age in Years (SD) [CI]	Normative Hip IR ROM per Svenningsen et al.[5] in Degrees	Weighted Mean Nondominant Hip IR in Degrees (SD) [CI]	Weighted Mean Dominant Hip IR in Degrees (SD) [CI]
Youth	966 (966)	10.61 (1.41) [10.52-10.70]	46[a]	43.54 (11.51) [42.81-44.27]	45.27 (14.58) [44.35-46.19]
HS-Aged	113 (113)	15.93 (1.67) [15.62-16.24]	41[b]	28.49 (7.60) [27.09-29.89]	27.89 (7.49) [26.51-29.27]
College-Aged	295 (295)	19.54 (1.69) [19.35-19.73]	38[c]	29.92 (8.05) [29.00-30.84]	29.09 (7.81) [28.20-29.98]
Professional	822 (385)	24.29 (3.61) [23.93-24.65]	38[c]	37.06 (7.88) [36.52-37.60]	37.44 (8.27) [36.87-38.01]

* SD = standard deviation; CI = confidence interval.
[a] Normative value calculated in 11-year-old males[5]
[b] Normative value calculated in 15-year-old males[5]
[c] Normative value calculated in 23-year-old males[5]

Table 3. Weighted means analysis of internal rotation stratified to pitchers and position players.

Population	Position	n (Age Available)	Weighted Mean Age in Years (SD) [CI]	Weighted Mean Nondominant Hip IR ROM in Degrees (SD) [CI]	Weighted Mean Dominant Hip IR ROM in Degrees (SD) [CI]
College-Aged	Pitcher	101 (101)	19.95 (1.56) [19.65-20.25]	30.27 (7.01) [28.90-31.64]	30.43 (7.15) [29.04-31.82]
College-Aged	Position Player	85 (85)	19.80 (1.80) [19.42-20.18]	28.90 (8.00) [27.20-30.60]	25.40 (6.70) [23.98-26.82]
Professional	Pitcher	479 (255)	24.31 (4.00) [23.82-24.80]	36.68 (7.40) [36.02-37.34]	37.30 (8.17) [36.57-38.03]
Professional	Position Player	343 (130)	24.26 (2.84) [23.77-24.75]	37.60 (8.55) [36.70-38.50]	37.53 (8.40) [36.64-38.42]

* SD = standard deviation; CI = confidence interval.

Statistical Analysis of Included Studies. Weighted mean analyses for dominant and non-dominant hip IR ROM across subgroups are summarized in Tables 2 and 3.

Key findings:

- Across all populations except for college-aged position players, the difference between dominant and non-dominant hip IR was less than two degrees.
- Similarly, the difference in mean hip IR between pitchers and position players also was less than two degrees.
- A notable decrease in bilateral hip IR ROM was observed between the youth and high school-aged groups.

Meta Analysis. A total of 23 studies were included in the systematic review, comprising 33 independent groups (including control and comparison arms) that reported bilateral hip IR data. The pooled mean difference in hip IR between the dominant and non-dominant legs was 0.84° (95% CI: -0.17° to 1.86°; p = 0.103), indicating no statistically significant difference.

Heterogeneity among studies was substantial:

- Cochran's Q = 109.88, df = 32, $p < 0.0001$
- I^2 = 70.9% (95% CI: 58.6% to 79.5%)
- Tau^2 = 5.68 (95% CI: 4.91 to 18.66)

These values support the use of a random-effects model and indicate considerable variability in effect sizes across studies. Figure 1 presents a forest plot to visualize individual study effect sizes and their corresponding confidence intervals.

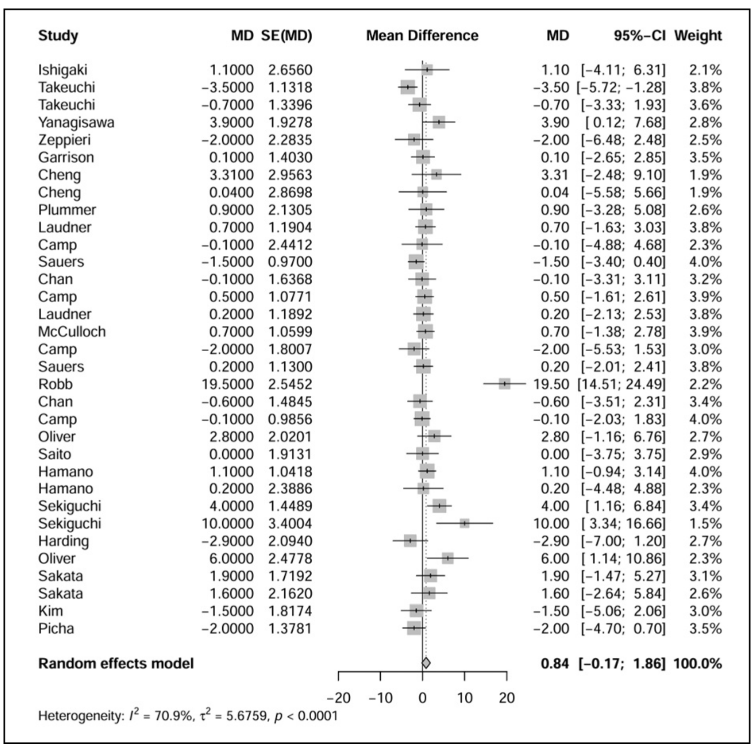

Figure 1. Forest Plot of effect sizes and confidence intervals for included study groups.

DISCUSSION

The scoping review revealed no statistically significant difference in hip IR between dominant and non-dominant legs across studies. However, the high heterogeneity (I^2 = 70.9%) suggests substantial variability among the included studies in terms of population characteristics, measurement techniques, or methodological quality. This variability may obscure small but clinically meaningful differences. The wide confidence intervals for Tau^2 and I^2 further emphasize the uncertainty in estimating between-study variance. Thus, the use of a random-effects model is justified, and the findings underscore the need for more standardized protocols in future research on hip IR in baseball athletes.

Based on the normative hip ROM values reported by Svenningsen et al.,[5] all athlete subgroups exhibited a deficit in bilateral hip IR ROM. This deficit was less than 3 degrees in youth athletes and less than 1 degree in professionals. However, the reductions were more pronounced in high school-aged and college-aged athletes. High school-aged athletes showed a difference in bilateral hip IR of over 12 degrees, while college-aged athletes had a difference of over 8 degrees. Existing literature suggests that reduced hip ROM increases the risk of injury across the kinetic chain,[6,7,30,31] and these findings may indicate that a substantial proportion of baseball athletes, though asymptomatic, are at elevated risk.

A measurable decline in bilateral hip IR ROM occurred between youth and high school-aged groups. This is likely due to physiologic changes during puberty, although the extent of such changes has not been clearly defined.[5] Other contributing factors may include increased sport specialization and longer seasons.[12,32] Interestingly, little difference was seen between high school- and college-aged athletes, yet a notable increase in hip IR ROM was observed from college-aged to professional athletes, counter to expectations, as ROM typically decreases with age.[5]

One potential explanation is that greater hip IR ROM provides a competitive advantage. Limited IR ROM can lead to compensatory kinematic movements, altered biomechanics, and reduced energy transfer from lower to upper body, potentially lowering pitch velocity.[4] A study involving 29 high school and college-aged athletes (mean age 18.1 ± 2.5 years) found increased bilateral hip IR ROM in both pitchers and position players, suggesting performance benefits for batting and fielding as well.[33]

Another explanation is that professional athletes benefit from structured interventions to increase hip ROM. These programs often include advanced training equipment and access to certified athletic trainers who can implement targeted stretching and strengthening routines. A key muscle targeted is the gluteus medius, which functions as both a pelvic stabilizer and internal rotator. Weakness in this muscle can reduce hip IR ROM, disrupt the kinetic chain, and increase injury risk.[34]

Within college-aged athletes, pitchers showed slightly higher dominant leg hip IR ROM than position players. This difference is likely multifactorial, potentially reflecting variations in warm-up routines, positional demands, or arm care strategies.

Athletic trainers play a critical role in developing effective injury prevention programs. They are uniquely trained to implement structured routines, coach proper form, and tailor interventions for physically active populations. Studies show that trainer-led programs are more effective and cost-efficient than those led by coaches or self-directed by athletes.[35,36] Unfortunately, many high schools and small colleges, especially in rural areas, lack sufficient athletic training staff, citing inadequate funding as a major barrier.[37] As a result, injury prevention programs may be challenging to implement effectively in these settings.

There is limited research on youth-specific programs to increase hip IR ROM. One exception is a non-randomized controlled trial by Sakata et al.,[8] which evaluated a program consisting of nine strengthening and nine stretching exercises performed daily. After one year, the intervention group demonstrated significantly higher dominant-side hip IR ROM than the control group.

Regarding the MINORS analysis, comparative studies scored higher on average than non-comparative ones. However, the comparisons within original studies did not always match those in this review. As a result, the MINORS tool may have underrepresented the true risk of bias in comparative studies, due to a mismatch between the tool's design and the actual data use in this review.

Limitations. This study has several limitations. First, the lack of individual-level data restricted our ability to analyze how career duration, multisport participation, or age-specific trends influence hip IR ROM. Efforts to obtain individualized datasets from study authors were unsuccessful. Some studies included athletes from multiple subgroups (e.g., both high school and college), but due to limited reporting, we were forced to categorize them based on the best available information.[15,19,23]

Another limitation was the lack of standardization in hip IR ROM measurement techniques. Studies used different patient positions (e.g., prone or seated) and a variety of tools (universal goniometers, bubble goniometers, digital inclinometers), introducing measurement error. To our knowledge, no published studies have validated the accuracy or reliability of these devices specifically for hip ROM.

Despite grouping athletes into four age-based categories, numerous unexplored subcategories remain, such as variations by school size, resource availability, and professional level (e.g., minor vs. major league). Additionally, all studies were conducted in the United States or Japan, limiting generalizability to athletes from other countries or cultural contexts.

CONCLUSIONS

While the pooled estimate showed no significant difference in hip IR between dominant and non-dominant legs, substantial heterogeneity limits the generalizability of this finding. Future studies should aim to reduce methodological variability and explore moderators of hip IR asymmetry.

Across all age groups, deficits in bilateral hip IR ROM were evident, with high school and college-aged athletes showing the largest deficits. These populations may benefit most from targeted IR interventions. The notable decline between youth and high school athletes may be due to puberty, longer competitive seasons, increased physical demands, and sport specialization.

Conversely, the increase in hip IR among professional athletes, despite their longer seasons and greater physical demands, may reflect successful intervention programs at the professional level. Future

research should identify what degree of IR ROM deficit constitutes a significant injury risk and evaluate how professional-level interventions can be adapted for resource-limited settings like high schools and small colleges.

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