

Auditing the Representation of Female Athletes in Sports Medicine Research: Achilles Repair

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Abstract

Background: Establishing evidence-based recommendations specific to female athletes has been overlooked in sports medicine. Achilles tendon rupture is one of the most common musculoskeletal injuries, occurring in 15 to 55 per 100 000 people annually. Differences in injury rates could be due to hormonal effects, as estrogen receptors have been identified in tendons along with decreased tendon strain based on oral contraceptive use. The primary purpose of this study was to audit the representation of female athletes in the literature regarding Achilles repair.

Methods: An electronic search was performed using PubMed to identify articles related to Achilles repair using the protocol by Smith et al. Studies were assessed by population, size, athletic caliber, study impact, research theme, and menstrual status.

Results: Female representation across all studies was 1783 of 10 673 subjects (16.7%). Composition of included studies was predominantly mixed-sex cohorts with 131 of 169 (77.5%) included studies. Within mixed-sex cohort studies, the total representation of female athletes was 1654 of 8792 participants (18.9%). Thirty-two studies were male only, constituting 1540 participants, whereas 3 studies were female only composed of 86 athletes. Importantly, the disparity between male and female representation worsened as the athletic caliber of the study population increased, with 5.0% female representation in studies with professional athletes. No study collected data related to menstrual status and its potential relationship to Achilles rupture or postoperative outcomes.

Conclusion: Mixed-sex cohort studies underrepresented female athletes, and male-only cohort studies were more common than female-only studies. These findings indicate a need for increased representation of female athletes as well as acknowledgment of menstrual status in research related to Achilles repair. Future studies should focus on representation of female athletes and data collection related to sex-specific hormones, hormonal contraceptive use, and menstrual status to improve treatment of Achilles tendon ruptures for female athletes.

Level of Evidence: Level IV, case series.

Keywords: Achilles tendon, Achilles repair, female athlete

Introduction

Efforts have been made to promote awareness of female athlete differences from their male counterparts in sports.²⁹ However, a critical component has been overlooked: whether or not there is enough female participation in research to apply evidence-based management guidelines of sports injuries to female athletes. Smith et al²² recently raised a call to action to focus on improving female representation in research to mirror the proportion of females

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that participate in sport. In 2014, Costello et al⁷ studied the proportion of male vs female participants in published works of 3 major sports and exercise medicine journals. The authors evaluated more than 1382 articles consisting of 6076580 participants and found that only 39% of those participants were female, whereas 61% were male.⁷ This study revealed a longstanding disparity in the female sport science and sports medicine (SSSM) sector. When considering why females have been excluded from SSSM research in the past, Smith et al²² reveals it could be because female SSSM research is more complex, more time necessitating, and requires additional study costs because of the consideration of female reproductive hormone levels, menstrual cycle phase, and hormonal contraceptive use.^{4,8} This lack of female-specific literature has likely hampered the opportunities of women to maximize their athletic potential and might be limiting our medical care as well. Female athletes are often underrepresented in the sample population of studies despite increased participation of female athletes in organized sport, thus failing to capture potential differences in injury risk and repair outcomes by sex.⁷

Achilles tendon rupture is one of the most common musculoskeletal injuries, occurring in 15 to 55 per 100000 people every year.¹⁰ Although this injury tends to occur in men more than women with a reported ratio of 5:1-6:1, respectively, up to 70% to 80% of acute ruptures occur with athletic activity regardless of sex.^{12,25} It remains unclear whether operative or nonoperative management is superior for acute Achilles tendon rupture. Although a recent randomized controlled trial showed that there was no significant difference in outcomes between nonoperative, open surgical repair, and minimally invasive surgical repair of acute Achilles tendon rupture, the rate of rerupture in the nonoperative group (6.2%) was greater than the open or minimally invasive repair groups (0.6% each).¹⁶ It is also worth noting that of the 526 patients enrolled in this study, only 135 (25.7%) were female sex.¹⁶

Female sex has also been shown to be a significant risk factor for development of wound complications after open Achilles tendon repair.³ Differences in injury rates and complications could be due to hormonal effects, as estrogen receptors have been identified in lower limb tendons along with decreased Achilles tendon strain based on oral contraceptive (OCP) use.^{2,3,13} These studies indicate the need to assess the literature surrounding Achilles tendon rupture management to determine if there is satisfactory evidence considering these differences based on sex. When considering treatment, recovery, training, and prevention of new injuries/reinjury, it is in the best interest of the patient for clinicians to recommend the most appropriate evidence-based approach to maximize their functionality and athletic potential. Therefore, the purpose of this study was to evaluate the representation of female athletes in research related to Achilles tendon repair to understand if future research should focus on renewed recommendations specific to female athletes.

Methods

The audit for this project was performed according to the methods thoroughly outlined by Smith et al.²² Because of the review design of this study, institutional review board (IRB) approval was not required. The guidelines outlined by Smith et al²² were used to obtain search results. An electronic search was performed using PubMed, to identify and collect articles related to operative management and results of Achilles tendon rupture.

Search Strategy

To capture the relevant articles, the following search terms were used in PubMed to identify the studies for inclusion in this review:

("athlete" OR "sport" OR "healthy") AND ("Achilles repair" OR "Achilles tear" OR "Achilles rupture") AND ("exercise" OR "performance" OR "endurance" OR "aerobic" OR "strength" OR "power" OR "anaerobic" OR "speed" OR "skill" OR "tactics") NOT "animal" NOT "rodent"

There were no date restrictions on search results.

Eligibility Criteria

Study inclusion criteria focused on studies with direct measurements of outcomes following treatment for Achilles rupture with operative Achilles repair. Studies had to be reported in the English language and report the sex of study participants. Exclusion criteria included studies that failed to investigate treatment as the primary outcome, nonsurgical management of Achilles ruptures, studies including revision of previous Achilles repair, studies that failed to report the sex of study participants, or studies that had populations with significant stated comorbidities (ie, diabetes mellitus, obesity, hypertension). Additionally, cadaveric studies, narrative reviews, and editorials were excluded.

Study Selection Criteria and Procedures

Following the literature search, papers were uploaded into Rayyan for the initial abstract screening process.¹⁸ Duplicates were removed and articles meeting any of the previously listed exclusion criteria were removed. Review articles were screened for additional relevant papers not detected in the primary search. Two independent reviewers assessed the titles and abstracts based on prespecified eligibility criteria. Those deemed eligible based on title and abstract review were assessed in full text. Those that met criteria after full-text review are included in the review. Any discrepancies were resolved by consensus or by a third reviewer.

Data Extraction

From all studies included after full-text review, the following metrics were extracted: population, athletic

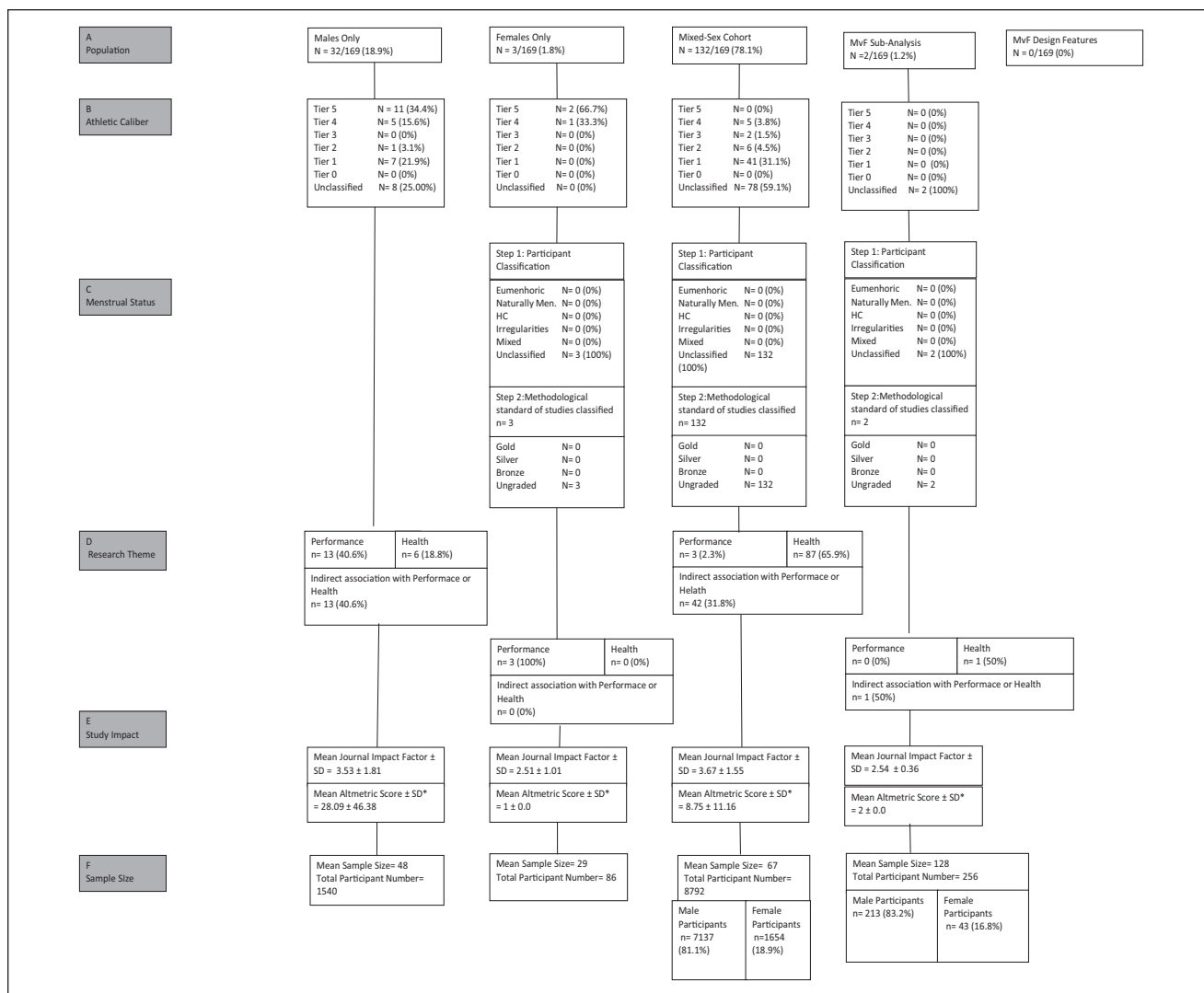


Figure 1. Representative search flowchart.¹³

*Studies after 2011 for which Altmetric scores could be found as outlined by Smith et al²² were included in mean Altmetric score calculation.¹⁴

caliber, menstrual status, research theme, study impact, and sample size, all of which are outlined in the protocol by Smith et al.²² The Microsoft Excel template and flowchart provided by Smith et al were used to organize this information.

Menstrual status assessment involved both classification based on a study’s patient description (eg, menstrual cycles occurring, hormonal contraception use, menstrual irregularities, and menopausal women) and its methodologic control for differences in menstrual status between groups. This control was then tiered (Gold, Silver, Bronze, or Ungraded) based on its equivalence of menstrual status between the 2 comparison groups.²²

Each article’s research theme was used for classification based on the study’s measured outcomes. Studies were assigned a theme of health, performance, or indirect association with health or performance. As outlined by Smith

et al, health studies focused on a condition and usually had a clinical outcome (eg, recovery time, patient-reported outcome scoring systems [Tegner Activity Scale, visual analog scale]) whereas performance studies assessed variables directly related to a sport or activity of the participants (eg, points scored and minutes played).²² Indirect associations of health or performance examined factors that can impact the outcomes listed above, but do not directly do so (eg, force production, calf diameter, and gait assessment).²²

Results

The search of PubMed yielded 951 results, as seen in Figure 1. After initial abstract review of Rayyan, 202 articles were selected to be reviewed in full text. Of the 202 articles reviewed, 33 were excluded for not relating to operative repair, not providing information about patient

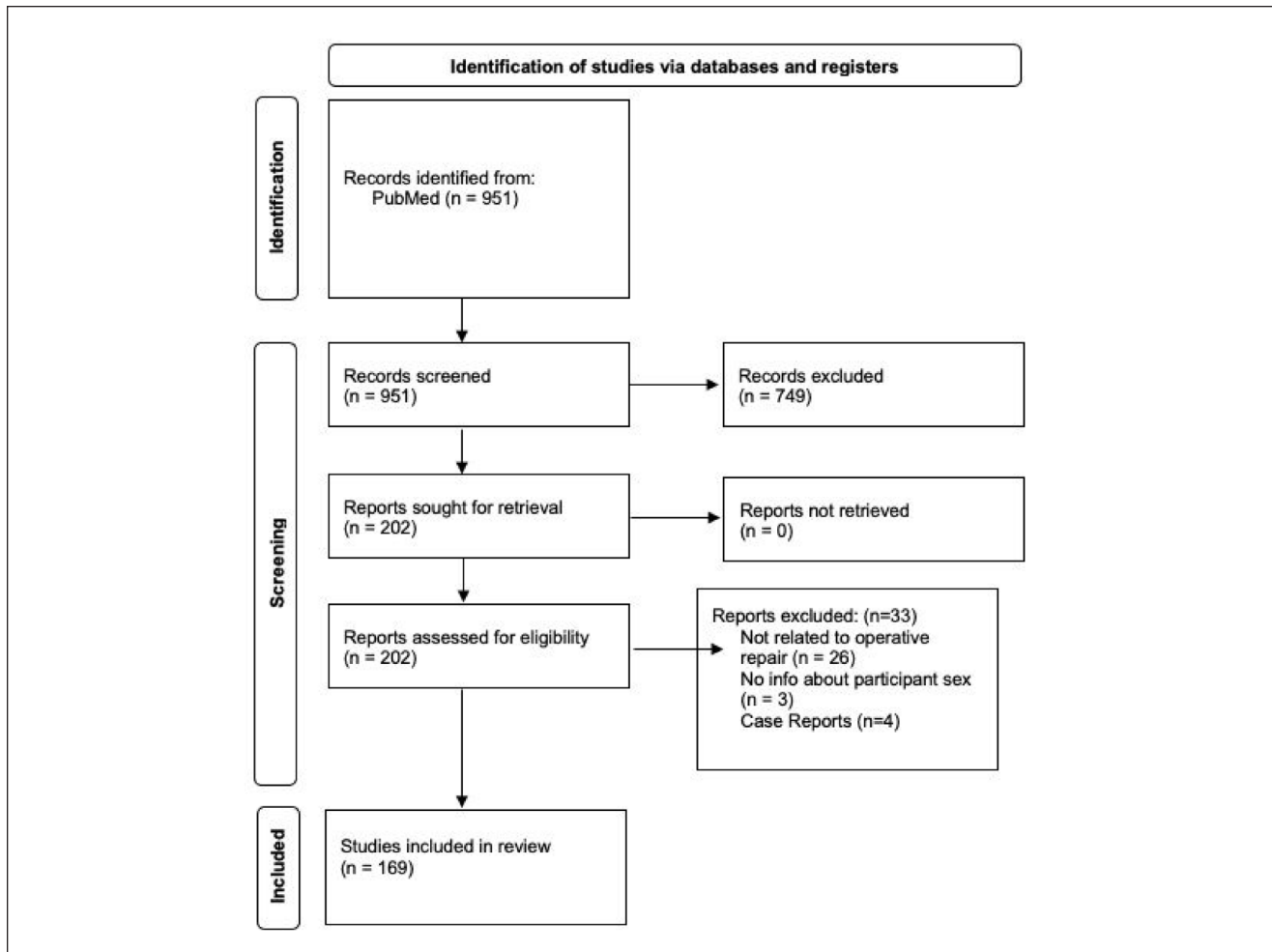


Figure 2. Flow chart of search results.¹⁹

sex, or being single-patient case reports, leaving 169 articles for inclusion in this review.

Across all 169 articles, 10 673 subjects were represented, with further classification found in Figure 2. Female representation across all studies was 1783 of 10 673 subjects (16.71%). Composition of included studies was predominantly mixed-sex cohorts with 132 of 169 (78.1%) included studies. Within mixed-sex cohort studies, the total representation of female athletes was 1654 of a total of 8792 participants (18.9%). Thirty-two studies were male-only cohorts constituting 1540 participants whereas 3 studies were female-only cohort studies composed of 86 athletes (17.9:1 male-female athlete ratio in sex-specific cohort literature). Two of the included studies were categorized as male vs female subanalysis, with study characteristics of these and the female-only studies found in Table 1.

A total of 81 articles (47.9%) gave information relative to the athletic caliber of the study participants. Within those articles, the maximum athletic caliber (Table 2) represented

in each study according to the classification system outlined by McKay et al¹⁴ and participant breakdown by sex is summarized in Table 2.

The research theme of included articles was as follows: 94 articles focused on health (55.6%), 19 focused on performance (11.2%), and 56 had an indirect association with performance or health (33.1%). Included mixed-sex cohort studies were predominately related to health (65.9%), whereas male- or female-only studies generally investigated performance or indirect associations with performance.

The mean journal impact factor was found to be the highest in the mixed-sex cohort studies at 3.67 ± 1.55 , whereas the mean Altmetric Score, a value weighting the breadth of distribution of research across various platforms, including news outlets, citations, and social media, was found to be the highest in male-only studies at 28.09 ± 46.38 . Female-only studies were found to have the lowest mean journal impact factor and mean Altmetric Score with 2.51 ± 1.01 and 1 ± 0.0 , respectively.

Table 1. Female-Only Cohort and Male-vs-Female Subanalysis Studies.

Author	Study Design	Participant Characteristics	Athletic Caliber	Outcome Variables	Main Findings
Hodgens et al, ⁹ 2021	Female-only cohort study	Athletes in the WNBA who had sustained Achilles tendon rupture and underwent surgical repair N = 17	5	Age, BMI, basketball position, mechanism of injury, performance statistics for the year prior to injury and 2 seasons after with calculation of PER	Average age of rupture was 28y, average time in WNBA at the time of rupture was 6.5y, players who were able to return (13/17) played significantly fewer minutes ($P < .01$) and had a significant decrease in PER ($P = .024$)
Kobayashi et al, ¹¹ 2023	Female-only retrospective cohort study	Collegiate gymnasts who had experienced Achilles tendon rupture 42 NCAA programs, N = 71 Achilles ruptures	4	Antecedent symptoms, mechanism of injury, return to sport	46% experienced antecedent pain, 95% of ruptures occurred performing floor exercises, 61% were able to return to competition, of the athletes returning 59% achieved comparable performance to preinjury metrics
Tramer et al, ²⁴ 2021	Female-only cohort study	Athletes in the WNBA who had sustained Achilles tendon rupture N = 12	5	Player characteristics, game utilization, PER (postinjury career compared with preinjury baseline)	10/12 players returned to play with a mean of 12.5 mo from injury, Athletes played significantly fewer minutes ($P < .05$), players with Achilles repair had significantly shorter careers and postinjury PER compared with uninjured controls ($P < .01$ and $P = .02$, respectively)
Saxena et al, ²¹ 2021	Cohort study with male-vs-female subanalysis	Patients who had sustained Achilles tendon rupture and subsequent repair N = 188 (M: 149; F: 39)	Unclassified	RM score, single-leg heel raise, calf atrophy, return to sport	No difference for return to sport ($P = .54$) or RM score ($P = .69$) observed between male and female participants
Yang et al, ²⁸ 2023	Cohort study with male-vs-female subanalysis	Patients with acute Achilles tendon rupture treated with primary repair or augmented repair with a gastrocnemius turn-down flap N = 68 (M: 64; F: 4)	Unclassified	VAS, AOFAS score, VISA-A score, ATRS, Tegner, postoperative calf circumference	Sex significantly correlated with VISA-A scores ($P = .009$); authors conclude that female athletes tended to have poorer outcomes but complete seal of paratenon and short leg cast correlated with higher AOFAS score ($P = .031$) and ARTS score ($P = .006$) respectively

Abbreviations: AOFAS, American Orthopaedic Foot & Ankle Society Ankle-Hindfoot score; ATRS, Achilles Tendon Total Rupture Score; BMI, body mass index; F, female; M, male; PER, Player Efficiency Rating; RM, Roles and Maudsley; VAS, visual analog scale; VISA-A, Victorian Institute of Sport Assessment–Achilles; WNBA, Women’s National Basketball Association.

Table 2. Sex-Specific Breakdown and Female Representation by Studies Where Athletic Caliber Could Be Determined.

Max Athletic Caliber Classification ⁹	Male Participants (n)	Female Participants (n)	Female Representation (%)
Tier 1: Recreationally Active (48 studies)	1759	413	19.01
Tier 2: Trained or Developmental (7 studies)	587	97	14.18
Tier 3: Highly Trained or National Level (2 studies)	39	9	18.75
Tier 4: Elite or International Level (11 studies)	974	124	11.29
Tier 5: World Class (13 studies)	556	29	4.96
TOTAL (n=81 studies)	3915	674	14.69

Of the included studies that were either mixed-sex cohorts or female-only cohorts, none collected any data or information related to menstrual status and its potential relationship to Achilles rupture or postoperative outcomes.

Discussion

To our knowledge, this is the first review auditing the representation of female athletes in research related to operative repair of Achilles tendon rupture. Despite previous studies indicating sex-hormone-specific impacts on tendon pathologies and collagen turnover rates, female athletes were consistently underrepresented in the studies included in our review, with only a 16.7% total female representation rate across the 169 included studies. The gap in representation found in our study is even broader than that found by Costello et al.⁷ Although this number may be close to differences in relative rates of injury, it is important in mixed-sex cohort studies to aim for equivalent representation of stratified analysis to allow for potentially significant differences in outcomes by sex to be determined. Additionally, substantial knowledge gaps in our understanding of the most appropriate treatment recommendations for female athletes in the setting of Achilles rupture will persist unless additional work is done focusing on female-only cohorts, particularly with high-caliber athletes.

The knowledge gap presented by underrepresentation makes it challenging to understand sex-specific differences in mechanism of injury, operative management, postoperative rehabilitation and complications, and prevention of recurrence. No study in our review collected data related to menstrual status of female participants despite several authors discussing that sex-specific hormone differences may be related to the difference in incidence of Achilles tendon rupture between male and female athletes reported as ranging from 5:1 to 6:1.^{20,24,26} Bryant et al⁵ found that long-term estrogen exposure reduced overall Achilles tendon strain and attritional wear likely because of its negative effect on collagen synthesis. This indicates a potential predisposition to Achilles injuries in aging females that fluctuates based on estrogen levels. Therefore, studies assessing sex-specific hormone status, particularly estrogen, in the perioperative Achilles repair window might improve operative and nonoperative management of male and female athletes.

Female athletes were not only underrepresented in studies using mixed-sex cohort design studies but were also underrepresented when comparing the bulk of male-only to female-only literature (32 studies compared to 3 studies respectively). Even within female-only cohort studies, information about menstrual status or sex-specific hormones and their relationship to Achilles tendon rupture were not collected. Further research into Achilles injury and the relationship to menstrual status/timing needs to be conducted. Additionally, of studies indicating the athletic caliber of athletes, female athlete representation declined with increasing athletic tier, with only a 5.0% representation rate among studies with athletes of tier 5 caliber (world class). The growth of women's sport participation and popularity in recent years is creating a knowledge gap that continues to widen as research does not keep up with these changes.²³ The importance of understanding sex-specific injury risk factors, treatment, and rehabilitation is even more important in this group because of the high demands required for elite-level participation in sport.

Average Altmetric scores were highest for male-only studies, indicating a broader sharing of the results of these studies. This is likely related to the high proportion of these studies, including the high athletic caliber of the included male athletes. However, this also indicates that among the studies included in this review, the most widely shared articles had no female representation, potentially leading to suboptimal treatment recommendations for high-level female athletes. Several studies assessing hormonal impact on tendinous injuries have found differences between pre- and postmenopausal women as well as potential differences in injury risk within different phases of a female athlete's menstrual cycle, highlighting the need for improved research and female athlete-specific recommendations.^{15,27}

Future work should focus on increasing female athlete representation within the body of research related to Achilles tendon rupture to clarify the understanding of sex-specific hormone differences in tendon injury and recovery. Moving forward, accounting for position in menstrual cycle (ie, date of last period, regular vs irregular periods) as well as hormonal contraceptive use or amenorrheic status are a few places to begin accounting for a confounding variable historically present in sports medicine research.⁸ There is a combination of physical and psychological/perceived

factors present related to menstrual status that can allow us to improve our methodology of female research.¹⁷ This can allow us to improve our understanding of female performance, ultimately improving our ability to maximize female athlete performance and limit injury risk.^{1,6}

Limitations

This study is not without limitations. The first limitation is the adjustment of the audit itself, which was designed for sports science research (ie, nutritional pre-event strategies, altitude training, recovery strategies, etc) rather than a specific sports medicine injury.²² This limited our ability to apply the methodology to all studies, and specific decisions mostly regarding research theme, were up to the authors' interpretations of the original article. Another limitation is the limited data extrapolation of the 169 included studies. Because this study was meant to provide a broad audit of the literature, the result was significant heterogeneity between studies and their outcomes. Therefore, a summary of the findings regarding male vs female outcomes was not feasible. Further studies assessing specific treatment strategies and gender-specific outcomes can continue to improve our understanding of the gender gap in sports medicine research.

Conclusion

To our knowledge, this is the first review auditing the representation of female athletes in research related to Achilles rupture and surgical repair. Mixed-sex cohort studies consistently underrepresented female athletes and male-only cohort studies were more common than female-only cohort studies. These findings indicate a need for increased representation of female athletes as well as acknowledgment of menstrual status in research related to Achilles tendon rupture. Future studies should focus on representation of female athletes as well as data collection related to sex-specific hormones, hormonal contraceptive use, and menstrual status to improve recommendations and treatment of Achilles tendon ruptures for female athletes.

Ethical Approval

Ethical approval was not sought for the present study because it was not required for this review of available published Achilles repair literature.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. Disclosure forms for all authors are available online.

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