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Auditing the Representation of Female Athletes in Sports Medicine Research: Fifth-Metatarsal Fractures

Peter Klug, BS[1*], Jacob Adams, BA[1*], Gordon Lents, MD[2], Rachel Long, BS[2], Ashley Herda, PhD[2,3], Bryan Vopat, MD[2], and Lisa Vopat, MD[2]

Abstract

Background: Female representation within athletics has increased as a result of Title IX, rising popularity, demand for equal compensation, and greater participation in multiple sports. Despite this, gender disparities in sports medicine research are apparent. This project serves to review the literature available on fifth-metatarsal fractures and assess the representation of female athletes in current literature.

Methods: We used a standardized protocol to audit the representation of female athletes in sports science and sports medicine research for fifth-metatarsal fractures. Primary factors included population, athletic caliber, menstrual status, research theme, sample of males and females, journal impact factor, and Altmetric score.

Results: Thirty articles met the inclusion criteria. A total of 472 fifth-metatarsal fractures were identified, with 373 of 472 fractures (79%) occurring in males and 99 of 472 (21%) in females. The majority of studies (18/30, 60%) were mixed cohort, followed by 10 male only (33.33%), 1 female only (3.33%), and 1 male vs female (3.33%). Out of 831 total patients in the 18 mixed-cohort studies, 605 of 831 patients (72.8%) were male and 226 of 831 patients (27%) were female. All 18 mixed-sex cohorts investigated health outcomes. Male-only studies evaluated health outcomes and performance metrics. No studies investigated female performance. The one female-only study investigated health outcomes and was the only study to account for menstrual status. There was a single metatarsal fracture in this study population.

Conclusion: Females are underrepresented in research regarding sports science and sports medicine research for fifth-metatarsal fractures. Research focused on female-only fifth-metatarsal fracture studies exploring the potential impact of female sex–specific factors such as menstrual status in study design are needed.

Keywords: Jones Fracture, foot injury, female sports

Introduction

Female representation within athletics has risen within recent years across the globe. Participation within the Tokyo 2020 Olympic games had 49% of total competitors being female, which increased from 45% in Rio in 2016.[17] Since the enactment of Title IX in 1972, female representation within athletics has increased at the professional and NCAA level in the form of popularity, compensation, and participation in multiple sports.[4,11,17,35] Despite this, female inclusion in sports medicine research has failed to match the rise in

[1]Kansas University Medical Center, Kansas City, KS, USA
[2]Department of Orthopedic Surgery and Sports Medicine, University of Kansas Health System, Kansas City, KS, USA
[3]Department of Health, Sport, and Exercise Sciences, University of Kansas, Lawrence, KS, USA

*Peter Klug, BS, and Jacob Adams, BA, contributed equally to this work.

Corresponding Author:
Peter Klug, BS, Department of Orthopedic Surgery and Sports Medicine, University of Kansas Medical Center, 3901 Rainbow Blvd, MS 3021, Kansas City, KS 66160, USA.
Email: pklug@kumc.edu

participants.[5] An audit of 3 major sports medicine journals conducted by Costello et al[5] included 1400 studies involving 6 million patients, and found women were 39% of the total patients, with 4% to 13% of studies focusing on women as compared to 18% to 34% men within sports participation. Costello et al[5] focused on female population in literature regardless of pathology. Cowley et al[6] examined 6 journals including 12.5 million patients and reported similar findings to Costello et al. This gap in research becomes problematic as applying conclusions drawn from male athletes to female athletes is not adequate because of biological differences that influence performance, fundamental biomechanics, and physiological responses to exercise, potentially affecting the level of medical care.[9,14,29]

Fracture of the fifth metatarsal is the most common foot fracture among athletes, with an annual incidence rate of 6.7 per 100 000 persons.[16,20] Fifth-metatarsal fracture is categorized into distal fracture, which includes the shaft, head, and neck region, and proximal fracture, which is separated into 3 zones: zone 1, tuberosity avulsion; zone 2, Jones; and zone 3, diaphyseal stress.[10] Treatment of the fracture includes immobilization and surgical fixation and depends on location, displacement, and blood supply to the fracture.[10] In a recent systematic review of surgical management of proximal fifth-metatarsal base fractures in elite athletes, a total of 280 patients was found, with only 10 females reported for a representation of 3.57%.[13] Another systematic review performed by Roche and Calder[40] had higher female representation of 154 females of 591 patients, with a representation of 26.05%. Without proper female representation within fifth-metatarsal fracture research, conclusions must be drawn from their male counterparts, which is problematic given sexual dimorphisms and event-specific demands such as sport or training.[42]

Discrepancies within the sports medicine research pool serve as the driving force behind performing a standardized audit of the available literature, which will highlight gaps within the current body of evidence and serve to guide future studies to better serve the female athlete population. Benefits of greater female representation within the sports medicine research field can lead to safer practices and treatment of female athlete patients, greater parity in access to resources and opportunities, and an increase in knowledge and expertise according to Smith et al.[42] Therefore, the purpose of this review was to systematically audit the primary literature available on fifth-metatarsal fractures and assess the representation of female athletes in the current literature.

Methods

The audit for this project was conducted according to the methodology outlined by Smith et al.[42] A search was conducted within PubMed in May 2023 with the following terms: athlete OR sport OR healthy AND ("5th" OR "Metatarsal Fracture" OR "Jones Fracture" OR "Avulsion Fracture" OR "Stress Fracture" OR "Non-Union" OR "Delayed Union") AND (exercise OR performance OR endurance OR aerobic OR strength OR power OR anaerobic OR speed OR skill OR tactics) NOT ("animals" [mesh] NOT "humans" [mesh]) NOT ("Review" [Publication Type] OR "Case Reports" [Publication Type]). All results were uploaded into the software Rayyan for title and abstract screening by the 2 reviewers P.K. and J.A. All included articles were extracted into an Excel sheet for data collection.

Eligibility Criteria

All articles were screened by previously set inclusion and exclusion criteria. Included articles must have met one of the following criteria: focus on the fifth metatarsal, patients must have been male or female, studies must be reported in the English language, studies must center around humans, and studies conducted in the United States or another country offering similar treatment. All levels of evidence were included within this audit. Articles excluded may have met one of the following: editorials, animal studies, cadaver studies, narrative reviews, scoping reviews, systematic reviews, case reports, studies' full text not available, populations with lifestyle diseases, studies where fifth metatarsals were not the primary focus of the study, studies failing to explicitly state sex, studies looking at older women or postmenopausal population, and biomechanical studies.

Screening and Selection

Studies were screened for inclusion and exclusion criteria by title and abstract screening by the 2 reviewers. Identified articles' reference sections were also screened for additional studies missed by our search terms. Any conflicts were resolved by a third reviewer or the overseeing physician. On selection, all articles were exported to an Excel spreadsheet for data extraction through manual full-text review.

Data Extraction

Included articles were reviewed by full body text. The data extracted as described by the Smith et al protocol included population, athletic caliber, menstrual status, research theme, journal impact factor, article mean Almetric score, and sample size. All fifth-metatarsal fractures, regardless of region or type, were included in this study. Population looked at the overall participants within each study, including male-only, female-only, mixed-sex cohort, male-vs-female subanalysis, and male-vs-female design features. Athletic caliber investigated athletics on a 6-tier system from sedentary tier 0 to world class athletes in tier 5.[28] Menstrual status involved a 2-tiered approach ranking

studies on 4 categories of menstrual status and then ranking based on ovarian hormonal profiles provided. Research theme involved ranking studies based on performance focus, health focus, or both. Study impact score and Altmetric score were used to investigate the impact each study had on the scientific community and highlight disparities within the literature and publishing landscape. Sample size involved looking at the specific populations within each study and separating by sex. Our audit also evaluated healing rate (HR), nonunion rate (NUR), delayed union rate (DUR), return to sport rate (RTS), or refracture rate (RFR) to investigate sexual differences in outcomes of fifth-metatarsal treatment.

Results

The initial search was performed in June 2023, from which 2037 articles were extracted from the PubMed database for title and abstract screening. All 2037 articles were unique studies and screened for inclusion and exclusion criteria, and 1944 articles were excluded. A total of 113 articles went on to full-text review and data extraction in which 84 articles were excluded. Twenty-nine articles were included in this audit. A single article was included from references within the included articles. These articles were broken down into categories as outlined by Smith et al including population, athletic caliber, menstrual status, research theme, study impact, and sample size as illustrated by the flowchart in Figure 1.

Population

Within the 30 studies, 10 were male-only representing 33.33% (10 of 30)[1,20-22,24,25,38,43-45]; 1 was female-only, representing 3.33% (1 of 30)[41]; 1 had male-vs-female design features, representing 3.33% (1 of 30)[15]; and 18 were mixed-sex cohorts, representing 60% (18 of 30).[2,3,7,8,18,19,23,26,27,30-34,36,37,39,46] There was no male-vs-female subanalysis available.

Athletic Caliber

Within the male-only studies, there were 8 studies looking at elite/international level (Tier 4) athletes with a rate of 80% (8 of 10), 1 study investigating highly trained/national level athletes (Tier 3) with a rate of 10% (1 of 10), and 1 study investigating trained/developmental athletics (Tier 2) with a rate of 10% (1 of 10). In the single female-only study, they investigated trained/developmental (Tier 2) female military personnel with a rate of 100%. Within the mixed-sex cohorts, 1 study investigated world-class athletes (Tier 5) with a rate of 5.56% (1 of 18), 10 studied elite/international level athletes (Tier 4) with a rate of 55.56% (10 of 18), 2 studied highly trained/national level (Tier 3) with a rate of 11.76% (2 of 18), 3 studied trained/developmental athletes (Tier 2) with a rate of 16.67% (3 of 18), 1 study focused on a sedentary population (Tier 0) with a rate of 5.56% (1 of 18), and 1 study failed to mention athletic status, making the unclassified rate 5.56% (1 of 18). The single study with male-vs-female design investigated the bone structures of sedentary populations to assess for stress fracture risk for a rate of 100%.

Menstrual Status

Within the single female-only population, the study described a mixed menstrual status and was categorized as silver classification for methodologic control including age at menarche, delayed menarche, menses during past year, secondary amenorrhea during past year, and oral contraception use. All 18 mixed-sex cohorts failed to mention menstrual status or hormonal contraception use and were considered unclassified, making them ineligible for further classification.

Research Theme

Within the male-only studies, there were 5 articles focusing on performance such as minutes, scoring, and assists in multiple sports with a representation of 50% (5 of 10). This was followed by 4 studies investigating health outcomes such as HR, NUR, and RTS time for a representation of 40% (4 of 10). Finally, there was a singular study with indirect associations with health and performance where National Football League (NFL) players underwent multiple radiographs that were read by 2 reviewers, and morphology was correlated with proximal fifth-metatarsal fracture (1 of 10). In the singular female-only study, a focus was placed on exercise, menstruation, and activities with comparison to stress fractures suffered by a set military population. Within the only study with male-vs-female design properties, indirect associations were made with the cross sections of male and female metatarsals and hypothesized risk of stress fracture. Within the mixed-sex cohorts, all 18 studies focused on health outcomes including HR, DUR, and NUR, and RTS.

Journal Impact Factor

The male-only studies appeared in 6 journals with a mean 4-year journal impact factor (IF) of 3.807. Many of these studies (80%, 8 of 10) had an Altmetric score, with the mean being 27.88 (Table 1). The singular female-only study had a 4-year impact factor of 5.997 appearing in the *American Journal of Sports Medicine* and had an Altmetric score of 9. The study with male-vs-female design appeared in *Bone* with a 4-year IF of 4.635; however, as it was published in 2005, no Altmetric score was available. Finally,

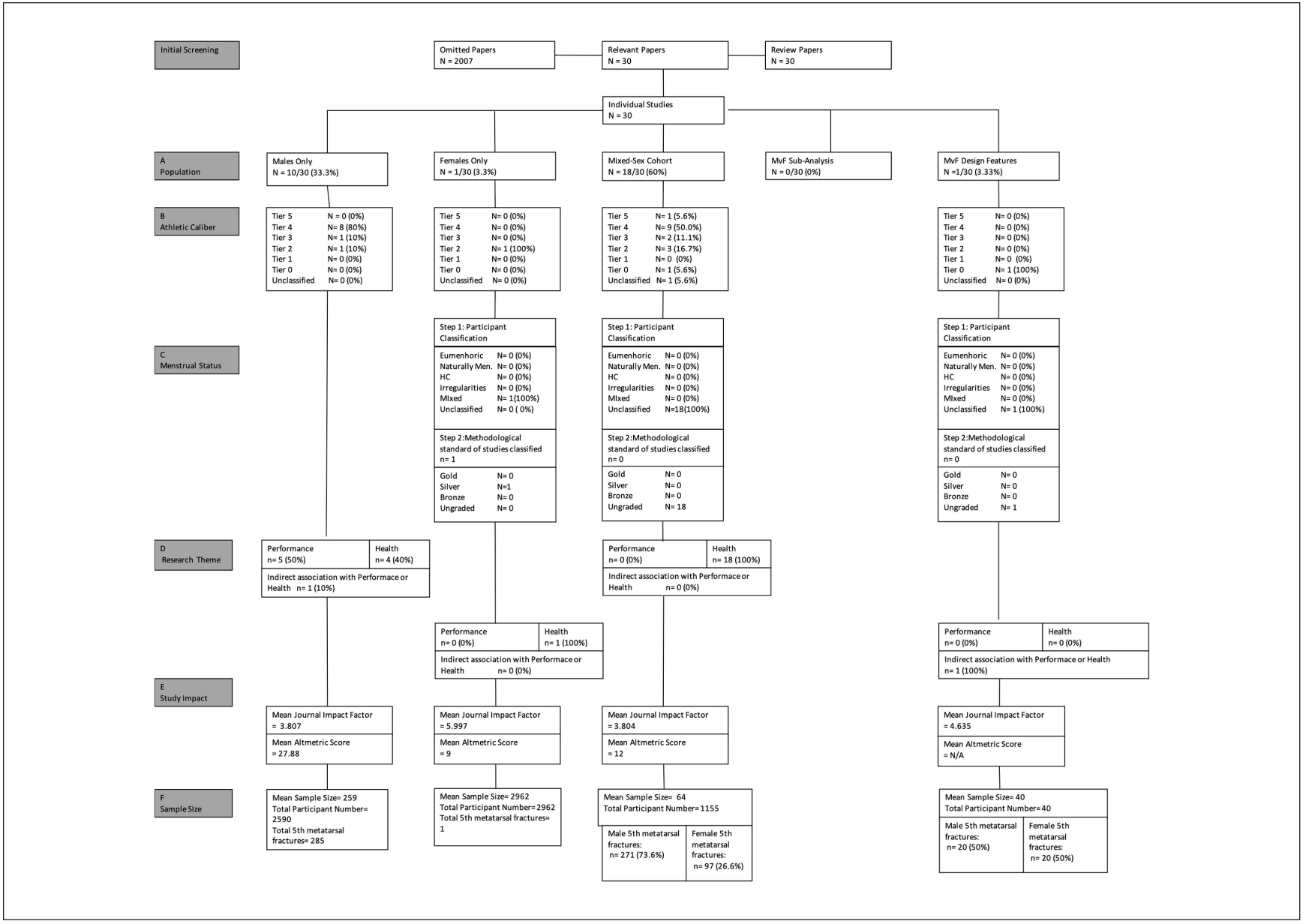

Figure 1. Article inclusion flowchart with population, athletic caliber, menstrual status, research theme, and study impact.

Table 1. Journal Impact Factor, Altmetric Score if Available, Healing Rate (HR), Delayed-Union Rate (DUR), Nonunion Rate (NUR), Refracture Rate (RFR), and Return to Sport Rate (RTS).

Author	4-y IF	Altmetric	HR, %	DUR, %	NUR, %	RFR, %	RTS Rate, %
Tu et al[45]	2.987	–	97.60	0.00	2.40	–	–
Begly et al[1]	3.366	24	81.00	–	–	19.00	85.00
Bucknam et al[2]	2.987	22	100	–	–	–	100
Chuckpaiwong et al[3]	2.208	1	93.50	–	6.50	–	100
Deelee et al[7]	5.997	–	100	–	0.00	–	100
Demel et al[8]	0.414	–	87.50	–	–	–	100
Ritchie et al[38]	5.997	2	100	–	–	–	100
Griffin et al[15]	4.635	–	100	–	–	–	–
Hulkko and Orava[18]	2.661	–	63.60	–	36.40	–	100
Hunt and Anderson[19]	5.997	17	100	–	–	–	100
Japjec et al[20]	2.801	–	88.00	–	12.00	–	100
Karnovsky et al[21]	2.987	2	–	–	–	–	100
Kavanaugh et al[22]	4.197	3	47.80	52.20	–	–	–
Khan et al[24]	3.366	132	–	–	–	–	57.10
Kc et al[23]	0.536	–	94.10	0.00	5.80	–	100
Lareau et al[25]	2.987	22	100	0.00	0.00	12.00	100
Lee et al[26]	5.997	–	87.60	0.00	12.30	8.20	100
Lombardi et al[27]	1.55	–	90.00	0.00	10.00	10.00	100
Mindrebo et al[30]	5.997	–	100	0.00	0.00	0.00	100
Murakami et al[31]	1.55	–	97.40	0.00	2.50	1.30	100
Murawski and Kennedy[32]	5.997	–	96.00	4.00	0.00	4.00	92.30
O'Malley et al[33]	5.997	13	96.00	4.00	0.00	4.00	100
Orava and Hulkko[34]	5.997	–	50.00	0.00	50.00	–	–
Pećina et al[36]	5.997	–	–	–	–	–	100
Reese et al[37]	5.997	–	100	6.60	–	–	100
Roberston et al[39]	1.707	–	–	–	–	–	–
Shaffer et al[41]	5.997	9	–	–	–	–	–
Spang et al[43]	3.095	25	–	–	–	–	–
Stone et al[44]	5.997	13	100	0.00	0.00	22.20	95.00
Watson et al[46]	3.095	7	100	0.00	0.00	4.00	100

the mixed-sex cohort studies appeared in 9 journals and had a mean 4-year IF of 3.93, with 6 studies having an Altmetric score available with a mean score of 10.5.

Sample Size

Within the male-only studies, there were a total of 2590 males included. A total of 285 fifth-metatarsal fractures were identified and treated at a rate of 11% of the population. The mean sample size for the male-only studies was 259 patients. The female-only study had 2962 women included that were screened for risk of stress fractures, of which only a single female within the study suffered a fifth-metatarsal stress fracture at a rate of 0.03% of the study population. The only study with male-vs-female design features included 40 patients with equal representation of male and female. Within the mixed-sex cohorts, there were a total of 1155 patients. The mean sample size of the mixed-sex cohort studies was 64 patients. One study failed to explicitly state the sex of its 324 patients; however, this study included the breakdown of the number of stress fractures within each sex at 271 males and 97 females.[18] These patients were omitted, leaving the total number of patients at 831 for statistical analysis. Males made up 72.8% of total patients (605 males), whereas females represented 27.20% of total patients (226 females). Within all studies, there were 620 fifth-metatarsal fractures examined in total. One study failed to differentiate the sex of the fifth-metatarsal fracture patients, leaving the total number of fifth-metatarsal fractures for statistical analysis by sex to be 472.[39] Of the 472 fifth-metatarsal fractures, 373 were suffered by males for a representation of 79.03% and 99 were suffered by females for a representation of 20.97%.

Healing Rate, Nonunion Rate, Return to Sport Rate

Twenty-six of 34 articles mention HR, NUR, DUR, RTS, and RFR, which are reported along with 4-year journal impact factor, and Altmetric score for each individual study (Table 1).

A single study failed to determine the HR, DUR, and RTS rate of fifth-metatarsal fractures within its analysis and was removed from the average within our calculations. The average HR across the 25 articles was 89.79%. The average DUR was reported in 14 studies excluding the single study with an average rate of 4.78%. RFR was mentioned within 10 articles included within this audit and had an average rate of 8.47%. The average RTS rate was 97% across a total of 23 articles. Articles did not differentiate between sex, so we were unable to analyze male-vs-female secondary outcomes regarding HR, DUR, NUR, RFR, and RTS.

Discussion

Popularity for female athletics has risen, and the evidence has supported a necessity for female-specific, evidence-based research. This audit serves to evaluate whether the lower representation rate of females within sports medicine research specifically applied to the science involving fifth-metatarsal fractures. Costello et al found that females accounted for 39% of patients within sports medicine research.[5] Our audit showed greater disparity with female representation, with only 20.97% of patients suffering confirmed fifth-metatarsal fractures. Although this is greater than the 3.57% reported by Goodloe et al,[13] it is below the 26.05% female representation rate reported by Roche and Calder[40] regarding fifth-metatarsal fracture. All studies differentiated sex of patients, yet many failed to differentiate DUR, RFR, and NUR regarding sex. Lack of data within these key health outcomes makes it difficult to rely on the research available when treating female patients because of their biological differences. Combined with the overall lack of methodological control regarding menstrual status, the mean complication rates could be overestimated within all studies. Although there was a single female-only study within our audit, the overall representation of fifth-metatarsal fractures was poor, with a single participant suffering a fifth-metatarsal fracture.[41] This study was performed in military recruits and may not be generalizable to other female sport patients. It did include menstrual irregularities, oral contraception use, and menstrual activity; however, it failed to run hormone panels and track the menstrual cycle, therefore being classified in silver tier according to Elliott-Sale et al.[3,12,41,42] Without proper control for the menstrual cycle and reporting of negative health outcomes by sex, medical guidelines cannot be formulated for the benefit of both male and female athletes.

One interesting study within this audit was the male-vs-female study investigating the morphology of male and female metatarsals regarding bone pressure and cross-sectional area. It was supported within their discussion that females were at increased risk of stress fracture within all metatarsals because of the morphology of their bone structure with CA/BM 0.0063, Zx/(BM*BL) being 0.0087, and Zy/(BM*BL) being 0.004 in the fifth metatarsal when comparing male and females.[15] These statistical ranges suggest males tend to have greater pressure distribution across the metatarsal because of a greater surface area compared with females.[15] They hypothesize that in combination with factors such as bone structure properties and level of activity, females could be at significantly higher risk of fracture compared with their male counterparts. This supports the statement that females have different biological considerations than their male counterparts, and without proper evidence-based medicine there could be an increase in poor outcomes in the treatment of fifth-metatarsal fractures within females.[42] Investigating the effect of female differences on health outcomes could serve to better prevent female athlete injury, and lower overall complication rate in all populations.

The distinct lack of female-only studies serves as a reminder that most of the guidelines practitioners use within their practice are male-based. The single female-only study included only a single patient with a fifth-metatarsal fracture, whereas 10 of the 30 studies included in this audit were male-only studies examining almost exclusively the fifth metatarsal. Additionally, although 18 of the 30 articles were mixed-sex cohorts, males made up a total of 605 of the 831 patients included within those 18 studies. These results demonstrate more effort and resources need to be directed toward female representation within the literature of fifth-metatarsal fractures. Although increased risk of injury and negative outcome may not affect all individuals, elite and international athletes are a different story. Most of the world-class, international, elite, and national athlete studies were male only, or included predominantly male patients.[1,7,21,24,25,38,43-45]

A potential limitation of this study is the lack of focus on incidence rates of fifth-metatarsal fractures between males and females in the literature. It is possible that female athletes experience different rates of fifth-metatarsal fractures than men, which may influence their inclusion in the literature; however, this point was not discussed within the literature included in this study. Another potential limitation of this study is the lack of data regarding vitamin D levels, calcium levels, bone health status, or comorbidities. These factors may play a significant role in fracture risk and incidence in any population, but they were not discussed in the literature. Additionally, the dates of publication for included articles range from 1978 to 2023. It is possible the lack of representation could be due to the inclusion of older articles, as it may be likely that more recent publications focus more heavily on including female athletes. Further studies are needed to determine the difference in incidence rates of fifth-metatarsal fractures and biomechanical and metabolic differences that could contribute to them.

The purpose of this audit was to highlight the representation rate of female athletes within the sports medicine research

community. The limited representation of female athletes suggests further studies must be conducted to better understand fifth-metatarsal fractures and healing patterns regarding sex. Although studies between male and female athletes at all levels of competition help us better understand the nuances that biological differences have on healing potential, more resources need to be placed on female-only studies to optimize the treatment of fifth-metatarsal fractures within this population. We also recommend further resources be spent on methodological menstrual control within female-only studies to better comprehend the effects it can have specifically on fifth-metatarsal fractures. Increased mixed-sex cohorts with improved methodological control would assist in the treatment of female athletes and better investigate their male counterparts based on their biological differences as well.

Conclusion

Despite recent increases in participation of female athletes in sports, research focused on their athletic performance and recovery remains limited. This study helps to highlight the disparity of female vs male representation in sports medicine literature, specifically female representation in literature focused on fifth-metatarsal fractures. Female representation in fifth-metatarsal fracture-related literature was found to be lower than that found in previous sports medicine audits. Because of the heavy male focus in sports medicine, many guidelines are based on male-dominated data, which fails to account for biomechanical differences and has the potential to affect recovery and performance of female athletes. The results of this study suggest a need for more research and focus on fifth-metatarsal fracture injury and recovery.

Ethical Approval

Ethical approval was not sought for the present study as all health-sensitive information was removed by the articles included within this systematic audit.

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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ORCID iD

Peter Klug, BS https://orcid.org/0009-0009-1153-6162

References

1. Begly JP, Guss M, Ramme AJ, Karia R, Meislin RJ. Return to play and performance after Jones fracture in National Basketball Association athletes. *Sports Health*. 2015;8(4):342-346.
2. Bucknam RB, Scanaliato JP, Kusnezov NA, Heida KA, Dunn JC, Orr JD. Return to weightbearing and high-impact activities following Jones fracture intramedullary screw fixation. *Foot Ankle Int*. 2020;41(4):379-386.
3. Chuckpaiwong B, Queen RM, Easley ME, Nunley JA. Distinguishing Jones and proximal diaphyseal fractures of the fifth metatarsal. *Clin Orthop Relat Res*. 2008;466(8):1966-1970.
4. Claus L. Why gender equal pay is so hard to achieve in sport. 2020. Accessed July 3, 2023. https://www.mgmt.ucl.ac.uk/news/gender-equality-sports-%E2%80%93-why-gender-equal-pay-so-hard-achieve-sport
5. Costello JT, Bieuzen F, Bleakley CM. Where are all the female participants in Sports and Exercise Medicine research? *Eur J Sport Sci*. 2014;14(8):847-851.
6. Cowley ES, Olenick AA, McNulty KL, Ross EZ. "Invisible sportswomen": the sex data gap in sport and exercise science research. *Women Sport Phys Act J*. 2021;29(2):146-151.
7. Delee JC, Evans JP, Julian J. Stress fracture of the fifth metatarsal. *Am J Sports Med*. 1983;11(5):349-353.
8. Demel J, Planka L, Stichhauer R, et al. 5th metatarsal Jones fracture - to treat conservatively, or surgically using headless double-threaded Herbert screw? *Acta Chir Orthop Traumatol Cech*. 2023;90(1):53-58.
9. Devries MC. Sex-based differences in endurance exercise muscle metabolism: impact on exercise and nutritional strategies to optimize health and performance in women. *Exp Physiol*. 2016;101(2):243-249.
10. Dini M, Parks CB. Fifth metatarsal fracture. In: Papadakis MA, McPhee SJ, Rabow MW, McQuaid KR eds. *Current Medical Diagnosis & Treatment*. McGraw-Hill Education; 2023.
11. Douglas L. The rise of women's sports. 2018. Accessed July 3, 2023. https://www.nielsen.com/wp-content/uploads/sites/3/2019/04/the-rise-of-womens-sports.pdf
12. Elliott-Sale KJ, Minahan CL, de Jonge XAKJ, et al. Methodological considerations for studies in sport and exercise science with women as participants: a working guide for standards of practice for research on women. *Sports Med*. 2021;51(5):843-861.
13. Goodloe JB, Cregar WM, Caughman A, Bailey EP, Barfield WR, Gross CE. Surgical management of proximal fifth metatarsal fractures in elite athletes: a systematic review. *Orthop J Sports Med*. 2021;9(9):23259671211037647.
14. Green DJ, Hopkins ND, Jones H, Thijssen DH, Eijsvogels TM, Yeap BB. Sex differences in vascular endothelial function and health in humans: impacts of exercise. *Exp Physiol*. 2016;101(2):230-242.
15. Griffin NL, Richmond BG. Cross-sectional geometry of the human forefoot. *Bone*. 2005;37(2):253-260.
16. Herterich V, Baumbach SF, Kaiser A, Bocker W, Polzer H. Fifth metatarsal fracture—a systematic review of the treatment of fractures of the base of the fifth metatarsal bone. *Dtsch Arztebl Int*. 2021;118(35-36):587-594.

17. Houghton EJ, Pieper L, Smith M. *Women in the 2016 Olympic and Paralympic Games: An Analysis of Participation, Leadership, and Media Coverage*. Women's Sports Foundation; 2017.
18. Hulkko A, Orava S. Stress fractures in athletes. *Int J Sports Med*. 1987;8(3):221-226.
19. Hunt KJ, Anderson RB. Treatment of Jones fracture nonunions and refractures in the elite athlete: outcomes of intramedullary screw fixation with bone grafting. *Am J Sports Med*. 2011;39(9):1948-1954.
20. Japjec M, Staresinic M, Starjacki M, Zgaljardic I, Stivicic J, Sebecic B. Treatment of proximal fifth metatarsal bone fractures in athletes. *Injury*. 2015;46(suppl 6):S134-S136.
21. Karnovsky SC, Rosenbaum AJ, DeSandis B, et al. Radiographic analysis of National Football League players' fifth metatarsal morphology relationship to proximal fifth metatarsal fracture risk. *Foot Ankle Int*. 2019;40(3):318-322.
22. Kavanaugh JH, Brower TD, Mann RV. The Jones fracture revisited. *J Bone Joint Surg Am*. 1978;60(6):776-782.
23. Kc KM, Marahatta SB, Niroula A, Kc A, Pangeni RB. Comparative study between operative versus non-operative treatment for base of fifth metatarsal fractures in young adults. *Kathmandu Univ Med J (KUMJ)*. 2021;19(74):190-194.
24. Khan M, Madden K, Burrus MT, et al. Epidemiology and impact on performance of lower extremity stress injuries in professional basketball players. *Sports Health*. 2017;10(2):169-174.
25. Lareau CR, Hsu AR, Anderson RB. Return to play in National Football League players after operative Jones fracture treatment. *Foot Ankle Int*. 2016;37(1):8-16.
26. Lee KT, Park YU, Young KW, Kim JS, Kim JB. The plantar gap: another prognostic factor for fifth metatarsal stress fracture. *Am J Sports Med*. 2011;39(10):2206-2211.
27. Lombardi CM, Connolly FG, Silhanek AD. The use of external fixation for treatment of the acute jones fracture: a retrospective review of 10 cases. *J Foot Ankle Surg*. 2004;43(3):173-178.
28. McKay AKA, Stellingwerff T, Smith ES, et al. Defining training and performance caliber: a participant classification framework. *Int J Sports Physiol Perform*. 2022;17(2):317-331.
29. McNulty KL, Elliott-Sale KJ, Dolan E, et al. The effects of menstrual cycle phase on exercise performance in eumenorrheic women: a systematic review and meta-analysis. *Sports Med*. 2020;50(10):1813-1827.
30. Mindrebo N, Shelbourne KD, Van Meter CD, Rettig AC. Outpatient percutaneous screw fixation of the acute Jones fracture. *Am J Sports Med*. 1993;21(5):720-723.
31. Murakami R, Sanada T, Fukai A, et al. Less invasive surgery with autologous bone grafting for proximal fifth metatarsal diaphyseal stress fractures. *J Foot Ankle Surg*. 2022;61(4):807-811.
32. Murawski CD, Kennedy JG. Percutaneous internal fixation of proximal fifth metatarsal jones fractures (Zones II and III) with Charlotte Carolina screw and bone marrow aspirate concentrate: an outcome study in athletes. *Am J Sports Med*. 2011;39(6):1295-1301.
33. O'Malley MJ, Hamilton WG, Munyak J. Fractures of the distal shaft of the fifth metatarsal: "dancer's fracture." *Am J Sports Med*. 1996;24(2):240-243.
34. Orava S, Hulkko A. Delayed unions and nonunions of stress fractures in athletes. *Am J Sports Med*. 1988;16(4):378-382.
35. Oxley S. Prize money in sport: what can football learn from cricket? 2021. Accessed July 3, 2023. https://www.bbc.co.uk/sport/56240686
36. Pećina M, Bojanić I, Dubravčić S. Stress fractures in figure skaters. *Am J Sports Med*. 1990;18(3):277-279.
37. Reese K, Litsky A, Kaeding C, Pedroza A, Shah N. Cannulated screw fixation of Jones fractures: a clinical and biomechanical study. *Am J Sports Med*. 2004;32(7):1736-1742.
38. Ritchie JD, Shaver JC, Anderson RB, Lawrence SJ, Mair SD. Excision of symptomatic nonunions of proximal fifth metatarsal avulsion fractures in elite athletes. *Am J Sports Med*. 2011;39(11):2466-2469.
39. Robertson NB, Roocroft JH, Edmonds EW. Childhood metatarsal shaft fractures: treatment outcomes and relative indications for surgical intervention. *J Child Orthop*. 2012;6(2):125-129.
40. Roche AJ, Calder JD. Treatment and return to sport following a Jones fracture of the fifth metatarsal: a systematic review. *Knee Surg Sports Traumatol Arthrosc*. 2013;21(6):1307-1315.
41. Shaffer RA, Rauh MJ, Brodine SK, Trone DW, Macera CA. Predictors of stress fracture susceptibility in young female recruits. *Am J Sports Med*. 2006;34(1):108-115.
42. Smith ES, McKay AKA, Ackerman KE, et al. Methodology review: a protocol to audit the representation of female athletes in sports science and sports medicine research. *Int J Sport Nutr Exerc Metab*. 2022;32(2):114-127.
43. Spang RC, Haber DB, Beaulieu-Jones BR, et al. Jones fractures identified at the National Football League scouting combine: assessment of prognostic factors, computed tomography findings, and initial career performance. *Orthop J Sports Med*. 2018;6(8):2325967118790740.
44. Stone JA, Miranda AD, Gerhardt MB, Mandelbaum BR, Giza E. Outcomes of surgically treated fifth metatarsal fractures in Major League soccer athletes. *Am J Sports Med*. 2021;49(11):3014-3020.
45. Tu L-A, Knapik DM, Sheehan J, Salata MJ, Voos JE. Prevalence of Jones fracture repair and impact on short-term NFL participation. *Foot Ankle Int*. 2017;39(1):6-10.
46. Watson S, Trammell A, Tanner S, Martin S, Bowman L. Early return to play after intramedullary screw fixation of acute Jones fractures in collegiate athletes: 22-year experience. *Orthop J Sports Med*. 2020;8(4):232596712 0912423.