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Auditing the Representation of Active Girls, Women, and Female Athletes in Low Energy Availability Research: A Decade-Long Review of the Literature

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BACKGROUND: Low energy availability (LEA), or a mismatch between energy intake and exercise energy expenditure, is a major concern for physically active individuals, particularly females. Although more female athletes are participating in sport today than ever before, they remain underrepresented in sport and exercise science research. However, it remains unclear how well physically active females are considered in research on LEA and LEA-related conditions. This study aimed to (a) evaluate the representation of physically active female in LEA research, and (b) explore the methodological characteristics underpinning LEA research.
METHODS: This review followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Three databases were searched for publications that investigated LEA in active individuals and athletes from 2014-2024. The number of total participants (male/female), title, topic/focus, and methodological characteristics were recorded for each publication. Data were expressed in frequencies and percentages. Chi-square goodness-of-fit tests, independent t-tests, and Chi-square tests of homogeneity (χ^2) were used to compare sex counts across studies, sex-specific studies, and proportions of study population based on methodological characteristics, respectively. Across 296 publications, 34,818 participants were included in analyses.
RESULTS: There was a significant imbalance between the total number of female (n = 28,738; 82.5%) and male participants (n = 6,080; 17.5%) ($\chi^2(1, n = 34{,}818) = 14{,}744.81$, $p < .001$). Overall, 56% of studies included females-only, 22% included males-only, and 22% included both sexes, demonstrating female bias ($t(229) = 2.196$, $p < .001$, $d = .321$). Between 2015 and 2023, mixed-sex cohort publications increased by 800%, female-only cohort publications increased by 420%, and male-only cohort publications rose from 0 to 10, demonstrating substantial growth across all cohorts during this period.
CONCLUSION: A majority of research on LEA is conducted on physically active females, which contrasts with other areas of sports science research.

BACKGROUND

Despite the growing recognition of sex disparities in various aspects of sport, female athletes remain underrepresented in sport and exercise science research. A number of reviews have illustrated a lack of female representation in sport and exercise research, with only 10-34% of all participants identifying as female and just 6-9% of studies employing female-only study designs.[1–3] This lack of representation of females is also demonstrated across a variety of specific sport and exercise research topics, such as sports psychology, carbohydrate intake, resistance training, performance supplementation[9], and heat adaptation.[4-10] Several concerns have been raised regarding not only the quantity, but also the quality of sport and exercise science research in females particularly due to lack of consideration for hormonal profiling.[1–3]

The lack of representation and quality methods of studying females in sport and exercise research has significant implications on the understanding of the unique physiological and psychological challenges faced by physically active females.

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Research that omits female participants and/or fails to consider female-specific topics (e.g., menstrual cycle disturbances, hormonal contraceptive use, pregnancy/postpartum, menopause) not only lacks generalizability, but may even be harmful in some cases.[3,11,12] Moreover, female athletes experience higher rates of certain sports injuries (i.e., concussion, ACL injuries), as well as psychosocial stressors (e.g., disordered eating, depression)[14], compared to male athletes. [13] One issue, in particular, commonly faced by physically active females is under-fueling, also known as low energy availability (LEA), or a mismatch between energy intake and exercise energy expenditure that leaves total energy needs unmet.[15–17] Understanding and working with females' unique physiological and psychological needs can help unlock higher levels of female athlete health and performance.[11,18]

The Female Athlete Triad was first introduced by the American College of Sports Medicine in 1992 to describe a triad of disorders observed in adolescent and young adult physically active females: disordered eating, amenorrhea, osteoporosis[19]. The Female Athlete Triad position statements have been updated since the initial introduction, and the most recent definition includes a spectrum of three interrelated components: LEA with or without disordered eating, menstrual dysfunction, and low bone mineral density.[20] Approximately ten years ago, the International Olympic Committee expert working group introduced the term 'Relative Energy Deficiency in Sport (REDs)' to provide a broader, more comprehensive term for the Female Athlete Triad[21]. Importantly, the broader syndrome of REDs describes the impaired physiological and/or psychological functioning experienced not only by female athletes, but by male athletes as well. REDs was first proposed in 2014 and has since been updated in 2018 and 2023.[17,22] The expansion beyond the Female Athlete Triad highlighted the complexity of involved body systems and the fact that male athletes are also affected by LEA/REDs.[21] REDs is currently defined as a syndrome of impaired physiological and/or psychological function caused by problematic LEA leading to detrimental health outcomes, including, but not limited to, decreases in energy metabolism, reproductive dysfunction, impaired musculoskeletal health, reduced immunity, which can individually and/or synergistically lead to impaired well-being, increased injury risk, and decreased sport performance.[17] REDs has a high estimated prevalence in female (23-80%) and male (15-70%) athletes across a variety of sport types.[17] The wide range in estimated prevalence is likely due to the lack of a singular diagnosis and standardized research methodology, interchangeable use of LEA and REDs terminology, inaccuracy of energy availability (EA) measurements, and participant volunteer bias, all leading to concerns regarding lack of high quality methods in LEA and REDs research. Furthermore, from 2018 to 2023, an estimated 62% of LEA and/or REDs studies utilized cross-sectional study designs, whereas only 12% used longitudinal interventional study designs.[17,23]

Given its origination as the Female Athlete Triad, it has been suggested that a majority of LEA research has been conducted in females, leaving males underrepresented in LEA research.[23] However, this has yet to be determined systematically in the literature. Therefore, the aim of this review was to assess the representation of physically active females within the LEA literature, and to explore the methodological characteristics of the research conducted from 2014 to 2024. Based on previous research in this area, it is anticipated that a majority of LEA research from the past decade will be conducted in physically active females.

METHODS

This review conforms to the PRISMA statement guidelines (see Electronic Supplementary Material Appendix S1) to identify publications that investigated LEA in active individuals and athletes from 2014-2024.

Study Inclusion and Exclusion Criteria

Population, Intervention, Comparator, Outcomes, and Study design (PICOS) was used to determine the limits in which the review was conducted.

Population

Participants included physically active individuals, regular exercisers, or athletes who were (a) Tier 1 or higher (based on McKay et al.), and (b) free from injury that would affect participation. No restrictions were placed on age.[24]

Intervention

No specific intervention was explored, but EA assessment of some kind was required. All participants were assessed for LEA, Triad, or REDs via EA or energy balance (EB) measurement, EA risk, and/or EA proxy indicators.

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Comparator

No specific comparator was denoted; however, studies may have compared male vs. female participants, at-risk vs. not-at-risk athletes, athletes from different sport types, as well as active vs. non-active controls. Studies that investigated differences between active and non-active controls were retained for analysis.

Outcomes

The primary outcome was study population (i.e., total number, number of physically active female and males, number of female and male non-active controls). The secondary outcome was EA assessment. For the purpose of this review, EA was defined as EA measurement (i.e., energy intake, exercise energy expenditure, and fat-free mass measured), EB measurement (i.e., energy intake and total energy expenditure measured), EA risk (i.e., population-specific questionnaires or clinical interviews), and/or EA proxy indicators (i.e., physiological measurements, such as menstrual cycle irregularities, low BMI, resting metabolic rate ratio). The method of assessment of the primary outcome was explored and also included in this review. Other key outcomes included publication year, research design, age range, athlete tier, sport type, sex in title, sex-specific health topic, lead (first) and senior (last) author gender, country of origin (e.g., research group, study population), and keywords.

Study Design

Experimental studies were considered for analysis if they met the following inclusion criteria: (a) published, in full, in a peer-reviewed journal, (b) had an objective of assessing EA, (c) included physically active individuals, regular exercisers, or athletes as participants, and (d) were published between 2014-2024. As such, case studies, review articles, study protocol papers, and conference proceedings were excluded. Studies that did not involve human subjects were excluded from this review. Only full-text articles that were published in English or had an existing translation were retrieved and examined.

Search Strategy for Identification of Studies

A systematic electronic literature search was conducted by MTL to identify all relevant articles using three databases (PubMed, CENTRAL, and ProQuest). The following standardized search terms and their combinations were used: ("low energy availability" OR "energy deficiency" OR "relative energy deficiency in sport" OR "female athlete triad" OR "male athlete triad" OR "energy availability") AND ("athletes" OR "exercisers" OR "exercise" OR "sport performance" OR "athletic performance"). An example of a full electronic search for one database is available in Electronic Supplementary Material Appendix S2. Databases were searched from May 2014 to May 2024. The reference lists of obtained relevant articles and review articles were hand-searched to identify any further studies and were added in manually.

Selection of Studies

Initial screening was conducted by one reviewer (MTL) independently reviewing the titles, abstracts, and full-text papers of the identified articles for inclusion and any duplicates were removed using Rayyan systematic review software (https://www.rayyan.ai/) (Cambridge, MA). All searches followed a two-phase screening strategy. Phase one assessed the eligibility of the title and abstract of every manuscript generated from the electronic searches and hand-searches against the predetermined inclusion and exclusion criteria. Studies that either clearly did not meet the inclusion criteria or met at least one exclusion criterion were excluded during this phase. In phase two, the full-text manuscript was retrieved for the articles identified in phase one and assessed against the predetermined inclusion and exclusion criteria. Any conflicts between the reviewers related to study eligibility were resolved in consensus meetings (AEF, AVV, and MTL).

Data Extraction and Synthesis

Data extraction was conducted by two members of the review team (AEF and AVV) and independently verified by one reviewer (MTL). Any discrepancies were resolved by reviewing the original article and consensus was achieved by discussion during consensus meetings (AEF, AVV, and MTL). Data extracted from studies included the following methodological characteristics: publication year, journal, sex in title, sex-specific health topic, topic in title, lead and senior authorship gender, purpose, EA assessment and method, research design, study timeline, participant counts (i.e., total number, number of physically active female and males, number of female and male non-active controls), age range, athlete tier, sport type, country origin (e.g., research group, study population), and keywords. Authorship gender was determined via manual

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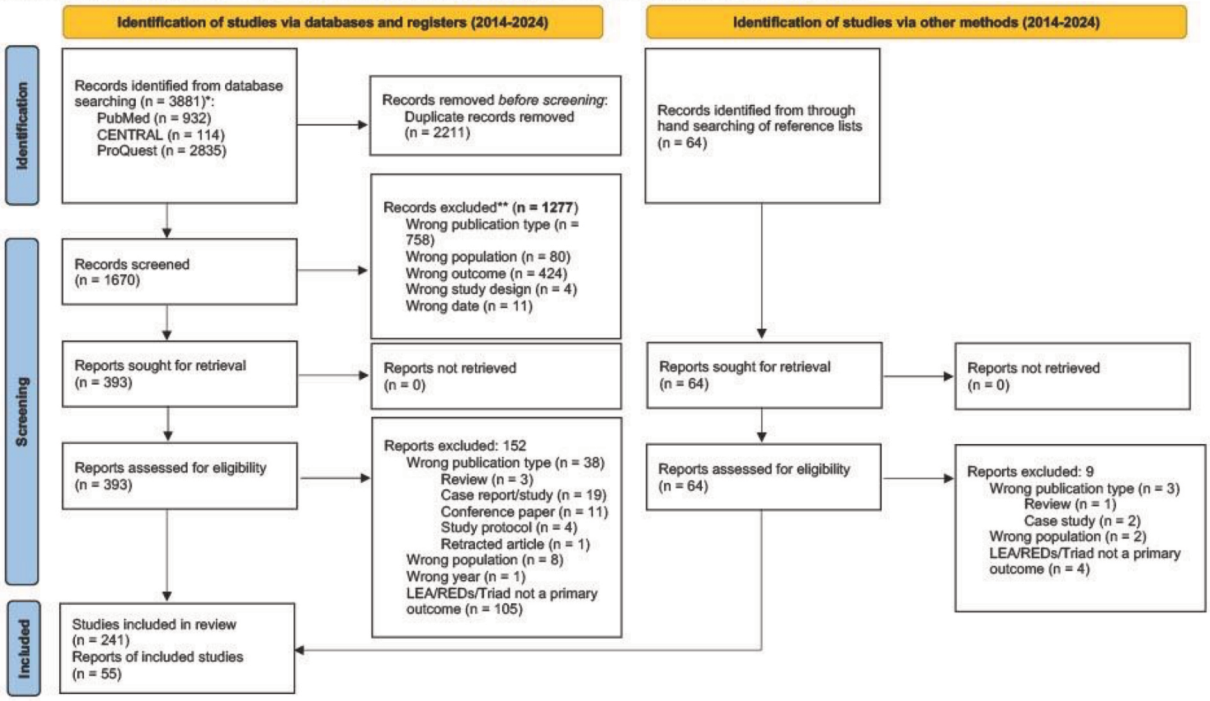

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines flow chart for new systematic reviews and study selection[25]

inspection of publicly available online profiles and institutional webpages (e.g., pronouns). If author gender was unable to be identified, gender was classified as unidentified. Duplicate participant samples were identified by comparing cohort names, recruitment sites, enrollment periods, sample sizes, and key participant characteristics across publications to determine whether multiple publications reported data from the same underlying study population. When duplicate samples were identified, they were classified as originating from a single cohort.

Statistical Analysis

Statistical analyses were performed in IBM SPSS Statistics (Macintosh V.29), with statistical significance set at $p < .05$ *a priori*. Chi-square goodness-of-fit tests were performed to compare the sum of sex counts across all studies to an expected equal distribution, using both participant counts across all publications (n's with duplicate participants) and counts excluding duplicates (n's without duplicate participants, reflecting only participants counted once across the same underlying study population). Independent t-tests were used to compare the number of LEA publications that included female-only and male-only study populations. Chi-square tests of homogeneity (χ^2) analysis were used to compare the proportions of study populations (e.g., female-only, male-only, both) based on sex in title, sex-specific health topic, as well as lead and senior author gender. Bonferroni adjustments were applied for multiple Chi-squared tests.

RESULTS

Literature Search

The literature search and selection of studies are presented in Figure 1. Relevant methodological characteristics of all included publications are outlined in Table 1.

Sex Disparity in LEA Research Participants

A total of 296 LEA publications including 34,818 participants were reviewed from 2014 to 2024. Physically active females (n = 28,081; 81%) and males (n = 5,824; 17%), as well as control participant females (n = 657; 2%), and males (n = 256; 1%) comprised the total number of participants in LEA publications. A chi-square analysis of participant sex counts indicated a significant imbalance in the representation of female (28,738, 82.5%) and male (6,080, 17.5%)) participants across LEA publications ($\chi^2(1, n = 34,818) = 14,744.81, p < .001$).

Duplicate participants were excluded from

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Table 1. Study characteristics for lea publications

Study Characteristics	*Category*	*No. of Articles*
EA Assessment	EA measured	162
	EA risk	105
	EA proxy indicators	64
	EB measured	29
Research Design	Cohort	10
	Cross-sectional	188
	Longitudinal, observational	62
	Longitudinal, intervention	24
	RCT	34
	Survey-based	31
Age Category	<18	85
	18-29	266
	30-44	129
	45-64	15
	>65	3
Average Athlete Tier	High	68
	Middle	26
	Low	67
	Mixed	132
	N/A	2
Sport Type	Endurance	107
	Aesthetic	29
	Weight	2
	Ball/team	34
	Anti-gravitational	1
	Power/strength	5
	Mixed	72
	Active	28
	Tactical	13
	Combat	3

EA measured was determined based on objective energy intake (EI), exercise energy expenditure (EEE), and fat-free mass (FFM) measurements; EB measured was determined based on objective EI and total daily energy expenditure (TDEE); EA risk was determined based on administration of population-specific questionnaire or clinical interviews; EA proxy indicators were determined based on objective physiological indicators consistent with low energy availability (LEA). Average athlete tier was determined based on the following criteria: high (tier 4 or higher); middle (tier 3); low (tier 2 or lower); mixed (crosses multiple tier levels), based on McKay et al.[24] Number of articles counted was indicated if this category was met by the article (total count of articles may exceed 296).
EA, energy availability; EB, energy balance; RCT, randomized controlled trial

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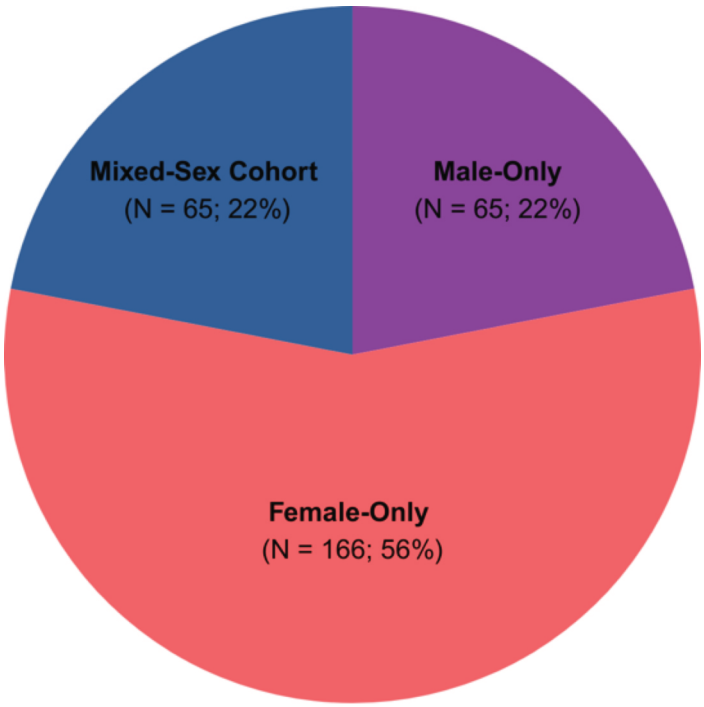

Figure 2. Sex of study population across all publications (N = 296)

total counts, which resulted in a total of 24,532 participants, including physically active females (n = 18,476), physically active males (n = 5,172), female control participants (n = 628), and male control participants (n = 256). The significant imbalance in sex counts ($\chi^2(1, n = 24{,}532) = 7{,}624.04$, $p < .001$) between the total number of female (19,104; 78%) and male (5,428; 22%) participants remained imbalanced after excluding duplicate participants.

Sex Disparity in LEA Publications

The majority of studies included female-only populations (56%, N = 166), whereas 22% (N = 65) included male-only populations and another 22% (N = 65) included data from both sexes (Figure 2). There was a significant difference between the number of LEA publications that included females only and males only, with a considerable number of single-sex studies with a female bias ($t(229) = 2.196$, $p < .001$, $d = .321$). Figure 3 illustrates the distribution of study population in LEA publications by year, demonstrating an overall increase in the number of LEA publications over the past decade. Across the 12-month calendar years from 2015 and 2023, there was an 800% increase in LEA pbulications with mixed-sex cohorts (from 2 to 18), a 420% increase in LEA publications including female-only populations (from 5 to 26), and an increase from 0 to 10 in LEA publications including male-only populations.

Sex Disparity in LEA Publication Titles

Overall, 48% of studies mentioned only females in the publication title, 13.2% mentioned only males in the title, 5.1% mentioned both sexes, and 33.8% of studies did not use sex in the title. There was a significant association between sex in title and sex of study population ($X^2(6, 296) = 358.014$, $p < .001$) (Table 2).

Disparity in Sex-Specific LEA-Related Research

Sex-specific health topics (e.g., menstrual cycle, birth control, menopause for female-specific health topics; testosterone deficiency for male-specific health topics) were identified in 27.7% of all studies. There was a significant association between sex-specific health topic and sex of study population ($X^2(2, 296) = 58.610$, $p < .001$) (Table 2).

Authorship Gender in LEA Research

Women authors are similarly well-represented in LEA research. A majority of lead and senior authors of LEA publications were women (69% lead, 55% senior), followed by men (28% lead, 43% senior), and unidentified author gender (3% lead,

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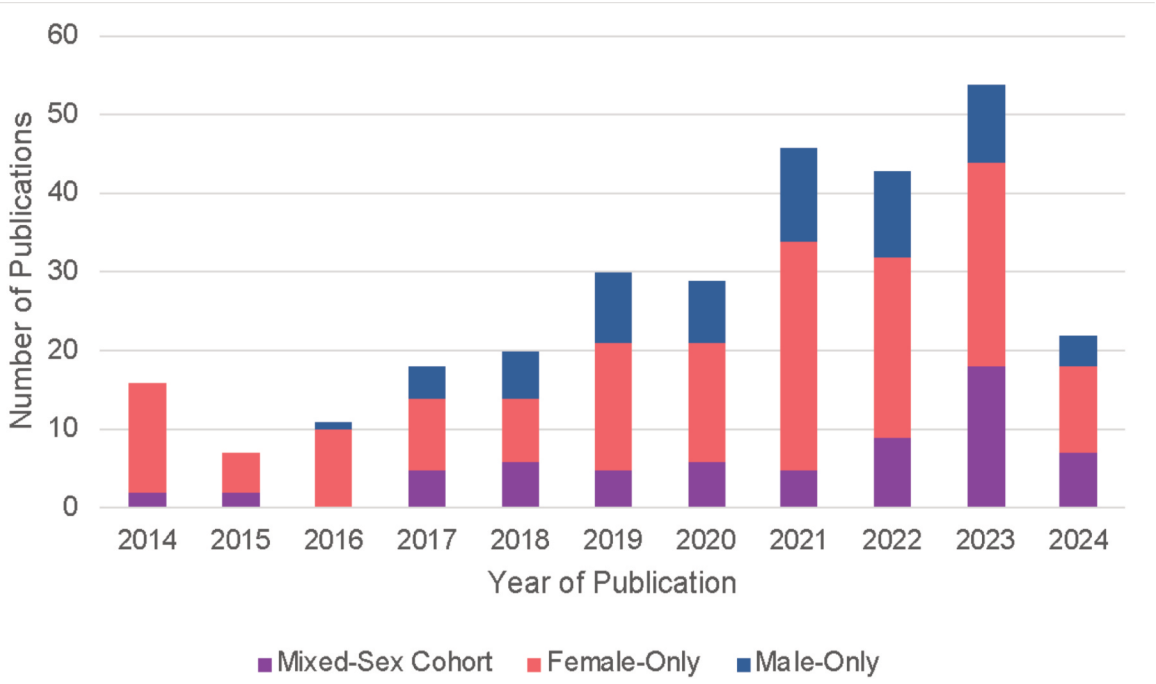

Figure 3. Study population by year. Databases were searched from May 2014 to May 2024; therefore, the data presented for 2014 and 2024 do not capture the 12-month calendar year, unlike the other years from 2015 to 2023.

2% senior). Despite a significant difference in proportions between gender of lead author and sex of study population ($X^2(4, 296) = 12.363$, $p = .015$), there was no difference between gender of senior author and sex of study population (($X^2(4, 296) = 6.864$, $p = .143$) (Table 3).

DISCUSSION

The present study evaluated the representation of physically active females in LEA research conducted between 2014 and 2024. Females represent a majority (~80%) of the participants in LEA research to date and female-only LEA studies were more common (56%). Nonetheless, the sex data gap is evident over the past decade across various other topics in sport and exercise science research. Female representation in LEA research was greater than that previously observed in other areas of sport and exercise research, demonstrating that the current findings are the exception to the rule. Furthermore, the homogenous nature of current methodological characteristics and general lack of high quality methods (e.g., a majority of studies were cross-sectional, mixed athlete tiers, primarily endurance sports) underpinning LEA research preclude further insights into LEA in physically active females over time and across various life stages, in a variety of sport types and competition levels, and in response to specific interventions, as well as any potential sex-based differences to LEA.

Sex Gap in Sport and Exercise Research

Overall, the representation of female participants in sports and exercise medicine research has not changed from 2011 to 2021. Costello et al. were the first to investigate the ratio of male and female participants in sports and exercise medicine research.[26] In a review of 1,382 exercise medicine and sports science articles from 2011-2013 involving a total of 6,076,580, 39% of the participants identified as female, and 4-13% of the articles included female-only samples.[26] Cowley et al. (2021) provided an updated review on the sex data gap in sport and exercise science research between the years 2014 to 2021.[3] In a review of six major journals, 5,261 publications were identified with a total of 12,511,386 participants, of which 34% of participants identified as females.[3] Only 6% of the sports science studies included female-only study designs, demonstrating a lack of improvement from 2011 to 2021.[3] Most recently, a systematic review by Paul et al. of 669 sports medicine research studies from six top sports

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Table 2. Disparities in sex-specific titles or topics of LEA publications

Sex/Gender in Title	*Female-only N of studies (%)*	*Male-only N of studies (%)*	*Both N of studies (%)*	*p-value*
No	24 (24%)	26 (26%)	50 (50%)	< .001
Female	142 (100%)	0 (0%)	0 (0%)	
Male	0 (0%)	39 (100%)	0 (0%)	
Both	0 (0%)	0 (0%)	15 (100%)	
Sex-Specific Health Topic	***Female-only N of studies (%)***	***Male-only N of studies (%)***	***Both N of studies (%)***	***p-value***
No	91 (42.5%)	59 (27.6%)	64 (29.9%)	< .001
Yes	75 (91.5%)	6 (7.3%)	1 (1.2%)	

Sex/gender in title was determined based on whether female/male, women/men, or some combination was mentioned in the research article title. Female-specific health topics include the menstrual cycle, birth control, menopause, etc., and male-specific health topics include testosterone deficiency, etc.

Table 3. Authorship of lea research based on study population

Lead Author	*Female-only N of studies (%)*	*Male-only N of studies (%)*	*Both N of studies (%)*	*p-value*
Women	128 (62.4%)	38 (18.5%)	39 (19.0%)	.015
Men	34 (41.0%)	24 (28.9%)	35 (30.1%)	
N/A	4 (50.0%)	3 (37.5%)	1 (12.5%)	
Senior Author	***Female-only N of studies (%)***	***Male-only N of studies (%)***	***Both N of studies (%)***	***p-value***
Women	101 (61.6%)	32 (19.5%)	31 (18.9%)	.143
Men	63 (50.0%)	30 (23.8%)	33 (26.2%)	
N/A	2 (33.3%)	3 (50.0%)	1 (16.7%)	

N/A = gender of author was unidentifiable

medicine journals between 2017-2021 illustrated that only 20.5% of studies included both male and female athletes and just 8.8% isolated female athletes.[1] This is further compounded by other topics in sport and exercise research, such as sports psychology (46% female participants, 7% female-only studies), carbohydrate intake (11-16% female participants, 4-6% female-only studies), resistance training (31-54% adult female participants, 11-16% female-only), performance supplementation (23% female participants, 0-8% female-only), and heat adaptation (6% female-only).[4,5,7-9,27] However, one area of particular emphasis that has focused primarily on female athletes is supplements to manage diagnosed micronutrient issues (71% female participants, 31% female-only).[28] Current findings on the representation of female participants in LEA research are not in line with other reviews exploring the sex data gap in sport and exercise science research topics, such as sport psychology, carbohydrate intake/guidelines, performance supplements, resistance training, and heat adaptation, with the exception of micronutrient supplementation to manage micronutrient issues.[3–5,7,9,10,26,28]

Despite the introduction of the REDs framework, which was intended to broaden the scope of LEA beyond the Female Athlete Triad, males remain markedly underrepresented in LEA research.[23,29–31] One factor contributing to this imbalance may be diagnostic ambiguity; many clinical indicators historically used to define REDs deficiency (e.g., menstrual dysfunction) are female-specific, and male biomarkers lack universally accepted cut-offs, complicating both clinical identification and research inclusion.[23,30,32,33] Recruitment bias also likely plays a role; research has disproportionately sampled female athletes

from aesthetic, endurance, and weight-sensitive sports, leaving male athletes from other sporting backgrounds underexamined.[17,23,30,32] Finally, lower clinical awareness of REDs presentations in males may reduce screening, diagnosis, and subsequent research participation, perpetuating a cycle of underrepresentation in the literature.[31] Together, these issues underscore the need for targeted research strategies to ensure that male athletes are adequately represented in LEA research.

Authorship Gender

While a majority of authors of LEA publications were women, the significant difference in proportions of lead author gender and study population sex became insignificant when exploring the senior author gender and study population sex. Women authors are generally underrepresented in sport and exercise science research with 25-33% of lead and 17-33% of senior authors being women.[2,34] A 2023 study by Cowan et al. demonstrated a linear relationship between the number of women authors (i.e., women as lead and/or senior) and the proportion of female participants.[2,34] In female-only research studies, women researchers make up more lead author positions compared to men (55% vs. 45%) yet still hold fewer senior author positions (38% vs. 52%).[35] Women lead authors were associated with 8.5X more female participants, which may help explain the higher proportion of female participants in LEA research illustrated here.[2]

Methodological Quality and Recommendations for Future Research

The representation of physically active females is alive and well in LEA research, which highlights a gap in the current understanding of LEA in physically active males. Cumulative findings from the current review highlight the need for more high-quality studies to address unanswered questions – particularly concerning male participants – to improve the health, well-being, and performance of all active individuals. As the number of LEA publications has increased over the past decade, future research should prioritize more high-quality methods involving female participants, alongside the evaluation of sex-based differences in the response to LEA. Such efforts are necessary to ensure the needs of both active females and males have been considered in current protocols involving sports nutrition and underfueling specifically.

Importantly, the interpretation of existing findings is limited by the methodological quality of current LEA literature. Common limitations include small sample sizes, predominantly cross-sectional study designs, reliance on survey-based data, heterogeneous outcome measures for EA assessment, broadly defined study populations, and failure to account for sex-specific factors. Further methodological challenges in the assessment of female participants include not properly defining menstrual status, failing to confirm hormonal profiling, ill-defined athletic caliber, lack of dietary control or intervention-based protocols, and an abundance of cross-sectional or survey-based work.[3–5,7,9,10,26,28] Although a detailed investigation into the quality of methods underpinning LEA research is beyond the scope of this paper, several recommendations can be suggested to improve the quality of LEA research and allow for the exploration of sex-based differences in the future:

Define the training and performance caliber of participants across all sexes/genders according to the classification framework proposed by McKay et al. [24]

Investigate and appropriately consider/report the potential impact of menstrual cycle phase and/or menstrual cycle status, as well as appreciate the potential role of hormonal contraceptives on study outcomes utilizing operationalized methodology outlined by Elliott-Sale et al.[36]

Consider the in-depth methodological recommendations for assessment of EA status (including proper assessment of energy intake, exercise energy expenditure, and fat-free mass), REDs components, and/or REDs risk explored by Ackerman et al.[23]

Potential Sex-Based Differences

The exploration of potential sex-based differences in LEA research is essential to meet the needs of physically active males and females. However, not all health outcomes associated with LEA pertain across sexes/genders (i.e., menstrual cycle disturbances, hormonal contraceptive use, pregnancy/postpartum, menopause). As such, these sex-specific outcomes cannot be explored in a singular study design, which may explain the significant association between sex-specific health topics and sex of study populations observed in LEA research. Nonetheless, when exploring non-sex-specific health and performance outcomes, it is important to not only include female and male participants, but also consider hormonal status

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(e.g., menstrual cycle phase or hormonal contraceptive use) to effectively evaluate any potential sex- or hormonal milieu-based differences (i.e., EA thresholds, carbohydrate metabolism).

Strengths and Limitations

There are several notable strengths and limitations of the present review. A large number of participants were included in the analyses (> 30,000 participants), with standardized PRISMA guidelines. Publications were included from within the past ten years, as it was not until 2014 that it was widely recognized in the literature that males also experience adverse outcomes related to LEA. However, this decade-long review does not fully represent the history of all LEA research since 1992. Additionally, the dichotomy of research participants into female and male groups does not represent the full range of gender expression and lacks further exploration of a more nuanced model including participants along a gender spectrum. The binary model only allows for a better understanding of the representation of females and males in research. There is also a possibility of publication bias, as our search terms, particularly those containing "female athlete triad", may have preferentially identified studies focused on female participants. Further, the determination of author gender via manual inspection of publicly available information (e.g., author pronouns) introduces the possibility of errors and does not account for gender identities that are not publicly disclosed. However, to avoid misclassification, authors whose gender could not be determined from available sources were classified as "unidentified", and no assumptions were made in such cases. Future research should aim to determine how sex-based differences (e.g., menstrual cycle phases, birth control use) are accounted for and controlled in study designs. By doing so, this will provide a greater quantity of high-quality LEA research specific to physically active females and allow for a more appropriate comparison of the current literature available in females.

CONCLUSION

To the authors' knowledge, the current study is the first to assess the sex data gap in participants within sport and exercise science research on LEA. These insightful data demonstrate that females are more likely to be represented, than males, within LEA research. Females account for ~80% of the total number of participants included in LEA research, and 56% of total publications were conducted exclusively on females. This review also identified a lack of robust methodology to investigate LEA in female and male participants. Future research should seek to achieve an equal understanding of both sexes in the context of LEA/REDs, with a particular focus on male participants and understanding potential sex-based differences. Efforts should also address methodological quality to ensure both sexes are adequately represented, and that sex-specific risks and needs are understood.

Conflict of Interest Statement

The authors declare no conflicts of interest with the contents of this study.

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