BIASMECHANICS

Does an unconscious bias still persist in biomechanics, positioning males as the default in human research? A meta-analysis on the Journal of Biomechanics 2024 publications

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DOI
10.1016/j.jbiomech.2025.112560

Publication date
2025

Document Version
Final published version

Published in
Journal of Biomechanics

Journal of Biomechanics 181 (2025) 112560

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech

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ARTICLE INFO

Keywords:
Biasmechanics
Bias
Gender
Sex

ABSTRACT

Articles published in the Journal of Biomechanics still reflect bias, with males positioned as the default in human research. This meta-analysis on the 2024 articles reveals a large disparity in female representation. One in four studies showed an imbalance (<30 % female representation) favouring male participants, while only 8 % favoured females. Male-only studies outnumbered female-only studies by over fivefold. Of particular concern is that male-only studies often lack justification for their single-gender focus, whereas female-only studies typically provide clear reasoning. This inconsistency not only lacks accountability but also reinforces the notion that male data is the standard in biomechanics research. I named this issue *bias*mechanics to encourage efforts to address them. While there are valid scientific reasons for focusing on specific gender/sex groups, this should not be the default. Authors must consider sex- and gender-based differences, and reviewers and editors should adopt stricter standards for accepting articles with unjustified imbalances. The *Journal of Biomechanics* could establish standardized guidelines promoting equitable representation in research. Exclusions of any sex or gender must include clear scientific justification in the introduction and methodology sections. The discussion and limitations sections should assess the implications of such exclusions, including their effects on validity, generalizability, and bias. If appropriate, titles and abstracts should clearly indicate single-sex or gender-specific studies to ensure transparency about the research's scope and applicability. By collectively affirming as a scientific community that, except for legitimate scientific justification, we oppose the exclusion of female participants, we can shift the default approach in our research studies.

1. Introduction

Although sex and gender do not fit into a uniform or binary category, distinct differences exist in the physiological systems typically classified as male or female. Today, it is widely recognized in medicine and science that women and men are not simply scaled versions of one another (Cahill, 2006; Clayton and Collins, 2014). Physiological sex differences affect human mechanics, including differences in skeletal structure, musculotendon properties, and mass distribution. Furthermore, other physiological systems, such as cardiac form and function, exhibit sex differences (St. Pierre et al., 2022). Gender can shape daily use of the cardiovascular and musculoskeletal system, for instance, through activities like walking in heels or engaging in different types of sport training. Sex and gender differences are therefore particularly important for the field of biomechanics.

However, as an associate editor for the *Journal of Biomechanics*, I frequently receive manuscripts that generalize findings from single-sex or -gender studies to the entire population, and most often, these studies include solely male participants. This recurring pattern raised a question: does an unconscious bias still persist in biomechanics, positioning males as the default in human research?

Rather than revisiting the historical oversight of sex and gender underrepresentation, I conducted a meta-analysis of all articles published in the *Journal of Biomechanics* in the past year, 2024, to understand if unconscious bias manifests in our most recent biomechanics research. The aim of this analysis is not to criticize authors or hold them responsible, but to foster awareness and encourage reflection on this issue. The aim is to look forward, proposing "from-now-on" best practices for authors, reviewers, editors, and publishers in the field of Biomechanics.

2. Method

2.1. Data extraction

All articles published in the *Journal of Biomechanics* between January and December 2024 (Volumes 162–177) were collected for analysis. Articles that included human participants or specimens were selected for further examination. Using an AI language processor (NotebookLM, Gemini 1.5), essential information was extracted from each article, including titles, authors, total number of participants, number of female participants, and number of male participants. Since most articles did not clearly distinguish between sex and gender, I used the combined term "gender/sex" throughout this letter. This choice is not intended to diminish the importance of recognizing the distinction between the two. In cases where the language processor did not explicitly identify gender/sex information, I conducted a manual review to address any omissions. This was mostly the case for studies where gender/sex data was presented in abbreviated formats (e.g., labeled as "4M/5F"), which the language processor did not interpret accurately.

https://doi.org/10.1016/j.jbiomech.2025.112560
Accepted 30 January 2025
Available online 31 January 2025

2.2. Gender/sex balance

The gender/sex distribution among participants in the analyzed articles was assessed to evaluate representation. This involved comparing the total number of male and female participants as well as examining the gender/sex balance within each study. Studies with a gender/sex disparity, defined as having less than 30 % representation of either gender/sex, were classified as "severely imbalanced".

2.3. Single gender/sex studies

The analysis then focused on studies that exclusively examined a single gender/sex. Studies with fewer than three participants were excluded from this analysis. For these studies, the stated reasons for adopting a single-gender/sex approach were reviewed, with an emphasis on evaluating the clarity and transparency of the authors' explanations. The titles, abstracts, methods, discussion and conclusion sections were analysed to determine whether they clearly indicated a gender/sex-specific focus and provided a well-articulated rationale for this choice. While a similar approach could be applied to studies labelled as *severely imbalanced*, I have excluded this from consideration to avoid debate over the threshold for gender/sex balance.

3. Results

In the analysis of articles published in the *Journal of Biomechanics* in 2024 (N = 432), 75 % (N = 323) were experimental studies involving human participants or specimens (Fig. 1). Among these, 11 % (N = 36) did not specify the gender/sex of participants. 33 % of the studies were labelled as *severely imbalanced* (N = 107): 8 % (N = 25) had fewer than 30 % male participants, while 25 % (N = 82) had fewer than 30 % female participants. Overall, 14 % of all 2024 publications (N = 46) were classified as single-gender/sex studies, of which 83 % (N = 38) focusing exclusively on male participants and 17 % (N = 8) exclusively on female participants.

3.1. Transparency and clarification for single-gender/sex studies

A clear difference was observed in how female-only versus male-only studies reported their participant focus (Table 1). Among the female-only studies, 5 out of 8 explicitly noted this focus in their titles, and 5 out of 8 emphasized it in their abstracts. Additionally, nearly all (7/8) provided a scientific rationale for studying only women. This rationale was outlined either in the introduction and methods sections (Dick et al., 2024; Gerstle et al., 2024; Oliviero et al., 2024; Small and Neptune, 2024; Wheatley et al., 2024) or in the discussion section (Levine et al., 2024). Only one study did not include a specific reason for its female-only focus, though it clearly articulated this focus in both the title and abstract (Ng et al., 2024b).

In contrast, male-only studies mostly lacked transparency regarding their single-gender/sex focus, and the rationale for studying only men was often vague or insufficiently communicated. Only 3 out of 38 studies included "male" or "men" in the title, two of which noted in the article plans to recruit female participants for a follow-up study, which may have prompted the specific title choice (González-García et al., 2024; J. M. Liu and Zaferiou, 2024). Another 12 studies articulated the male-only focus in the abstract (Table 1). However, only one out of the 38 studies offered a scientific reason for excluding women, clearly articulating this in the methods section and appropriately limiting the study's conclusions to males (Brouwer et al., 2024). For the majority of male-only studies (31 out of 38), no justification was provided for the exclusion of female participants; two studies mentioned plans for follow-up studies involving females choice (González-García et al., 2024; Liu and Zaferiou, 2024), while three studies offered questionable justifications, citing "convenience", "minimal variations", or "social constraints" as reasons for the male-only focus (Althomali, 2024; Dunn et al., 2024; Yang et al., 2024). Although 20 of the 38 studies acknowledged the exclusion of women as a limitation, fewer than half of them (8 out of 38) discussed how results might differ for women in the discussion section, with only one study arguing that gender/sex would not impact the findings (Daroudi et al., 2024). Aside from Brouwer et al. (2024) and Schmid et al. (2024), none of the studies explicitly stated in their conclusions

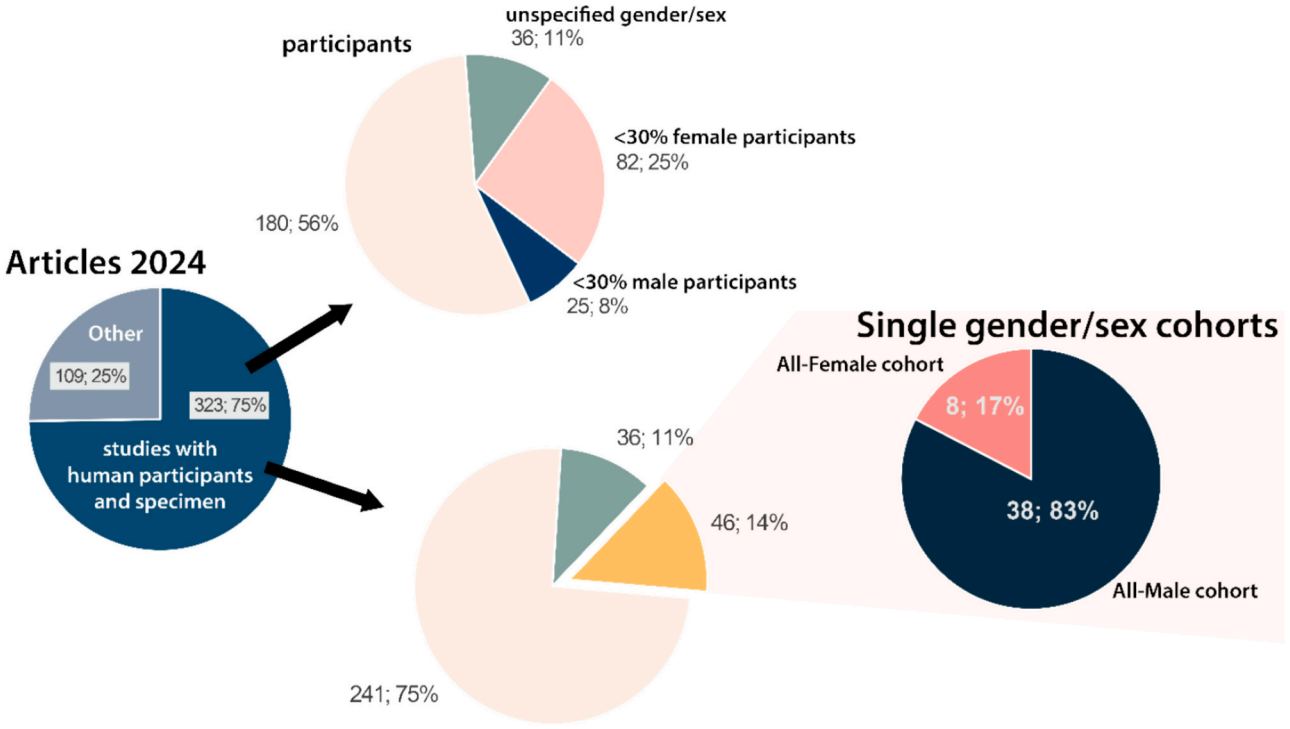

Fig. 1. Articles published in the Journal of Biomechanics 2024 (volumes 162–177). 75 % of the articles were experimental studies involving human participants or specimen. One quarter of the studies were severely imbalanced towards males; half of those studies included only males.

Table 1
Overview of studies published in the 2024 Journal of Biomechanics that utilized a single-gender/sex cohort, including indications of where the singular focus is addressed within each article.

	Title	Abstract	Introduction	Limitations	Conclusion	Clarification	Implications
Female-only studies							
(Wheatley et al., 2024)	X	X	X	n.a.	X	Introduction (higher incidence females)	
(Gerstle et al., 2024)	X	X	X	n.a.	X	Introduction (higher incidence females)	
(Dick et al., 2024)	X	X	X	n.a.	X	Introduction (higher incidence females)	
(P. T. T. Ng et al., 2024)	X	X	X				
(Small & Neptune, 2024)	X		X	n.a.		Introduction (women-event only)	
(Levine et al., 2024)		X		X		Discussion (higher incidence females)	X
(Oliviero et al., 2024)			X	X		Introduction (menopausal)	
(Sommers & Davis, 2024)						Method (higher incidence females)	
Male-only studies							
(González-García et al., 2024)	X	X	X	X		Method & Discussion (convenience)	
(Liu & Zaferiou, 2024)	X	X		X		Discussion (convenience)	
(Krbavac et al., 2024)	X		X				
(Brouwer et al., 2024)		X		X	X	Method (scientific setup)	X
(Schmid et al., 2024)		X		X	X		
(Sasajima & Kubo, 2024)		X		X			X
(Dunn et al., 2024)		X		X		Discussion (convenience)	X
(Eyre et al., 2024)		X		X			
(Wang et al., 2024)		X		X			
(Kovács et al., 2024)		X		X		Discussion (resources)	
(Lu et al., 2024)		X		X			
(Stefaniak et al., 2024)		X					
(Pimenta et al., 2024)		X					
(Liu et al., 2024)		X					
(Slater et al., 2024)		X					
(Motomura et al., 2024)			X				
(Althomali, 2024)				X		Discussion (social constraints)	
(Hosseini & Arjmand, 2024)				X			
(Yu et al., 2024)				X			X
(Mohseni et al., 2024)				X			X
(Xiang et al., 2024)				X			X
(Wenghofer et al., 2024)				X			
(Shirai et al., 2024)				X			
(Daroudi et al., 2024)				X			X
(Deignan et al., 2024)				X			
(Matsumoto et al., 2024)				X			X
(Yang et al., 2024)						Discussion (min. variations)	
(Ng et al., 2024a)							
(Toussaint & Schepens, 2024)							
(DeVol et al., 2024)							
(Julia et al., 2024)							
(Job III et al., 2024							
(Zappalá et al., 2024)							
(Ebisch et al., 2024)							
(Augustus et al., 2024)							
(Ghezelbash et al., 2024)							
(Ma et al., 2024)							
(Vaz et al., 2024)							

that the results applied solely to male participants. This lack of transparency in reporting implicitly positions men as the default population.

4. Discussion

This meta-analysis highlights a disparity in the representation of females in Journal of Biomechanics research studies published in 2024, with a higher prevalence of studies imbalanced towards male participants. Specifically, one in four research articles exhibited an imbalance (<30 % representation of either gender/sex) favouring male participants, compared to only 8 % favouring females. Half of the male-skewed studies excluded women entirely, the number of male-only studies was over five times greater than that of female-only studies. However, of particular concern is the lack of transparency in male-only studies, where mostly no clear rationale is provided for the single sex or gender focus. In contrast, the reasoning is explicitly articulated in female-only studies. This inconsistency not only highlights a troubling lack of accountability but also reinforces the perception that male data serves as the default standard in biomechanics research.

While there are legitimate scientific reasons for focusing on specific gender/sex groups—such as studying conditions that predominantly affect one gender/sex—this should not be the default approach. There is no scientific justification for the large imbalance between male-only and female-only studies in the 2024 articles. If valid scientific rationale had been provided in the articles, it would imply that the topics studied in our field are male-dominated, which could be partially accurate and might highlight part of the problem. However, the issues explored in the male-only studies in Table 1 generally affect all sexes.

Just as research on fall prevention among the elderly would require justification if conducted with only young participants, studies on issues that are not inherently specific to a single gender or sex must clearly justify any single-gender or single-sex focus in the introduction and methods sections. In the absence of such justification, articles ideally should not be accepted for publication. The guiding assumption should be that men are not automatically representative of women, nor are women automatically representative of men. If a study's participant pool is limited by resources, necessitating a choice between gender/sex, researchers must acknowledge and communicate that the findings are

not representative of the general population and discuss the implications of this. To ensure scientific accuracy, it is imperative that studies with single gender/sex participant pools amend their titles and abstracts to clearly indicate that the results cannot be unconditionally generalized to the entire population. Such transparency would foster a more critical evaluation of the literature, helping readers interpret findings in the correct context. Biomechanics research aims to inform public health and clinical practices. Misrepresenting the applicability of results risks undermining the reliability of the field and could have consequences for health outcomes across diverse demographics.

Several of the reasons provided for male-only studies cited reasons of convenience, such as the particular population readily available for research. However, to address gender/sex bias, we need to go beyond convenience. Male populations are often easier to study, due to factors like higher numbers of male students at (engineering) universities, and a combination of a male dominated research field with sometimes social and cultural barriers for males to conduct experiments with female participants in a motion capture lab. However, this does not justify defaulting to male-only studies. Social and cultural barriers can mostly be addressed by ensuring gender/sex diversity within the research team, making it easier to accommodate and conduct experiments involving participants of different sexes in the lab. And if resources are limited and there is no strong rationale for excluding either gender/sex, why not make the effort to conduct female-focused studies, without generalizing results to the broader population? Such an approach would help balance the historically skewed data availability.

I recognize the geopolitical restrictions that limit some researchers, but I strongly believe that geopolitical or cultural factors should never be used as justification for excluding female participants, or anyone, from research studies. Accepting such exclusion sends a concerning message to women, one that we, as a community, should avoid to be sending. Women have an universal right to be included as subjects of research (right to health) and to engage in research (right to education) (Assembly, 1949; CEDAW et al., 1995). In my opinion, we must oppose the exclusion of female participants from biomechanics research unless there are scientifically valid reasons to do so. This stance can also empower researchers in challenging environments to advocate for meaningful change, while staying within cultural and religious boundaries

A final consideration was whether the composition of the author team had any correlation with the population focus. This analysis was conducted based on the authors' best interpretation of the first names, interpreting them based on whether they were culturally or socially associated with a particular gender. This showed that all but one of the female-only studies seem to have female first authors (7 out of 8). In contrast, 11 out of 34 male-only studies (with the genders of 4 authors undetermined) had female first authors. This suggests that authorship did not directly align with the gender/sex of the participants studied, indicating that merely including a diverse research team does not directly solve this unconscious bias. While diversity among researchers is important, especially in human experimental research, so that participants of all genders and sexes feel at ease in the lab, it does not automatically eliminate the unconscious biases that can influence study design and participant selection.

I would like to reiterate that the goal of this analysis is not to criticize the referenced authors or assign blame. This analysis exclusively examines studies published in the Journal of Biomechanics in 2024 where gender/sex was explicitly mentioned, and the actual issue is probably wider than what this meta-analysis portrays. I also want to acknowledge that this meta-analysis was conducted by a single individual, which may introduce the potential for misinterpretation of authors' intentions and rationales for justification. Where gender/sex was not specified (11 % of articles), it was impossible to determine whether the conclusions drawn about the human population were based on a diverse sample, potentially masking additional hidden biases that are not captured in this analysis. Furthermore, intersex and nonbinary individuals were not represented in any of the articles examined. Simulation studies were also excluded from this analysis, though our recent research (Maarleveld et al., 2024) underscores the need to address the male bias in musculoskeletal simulations

5. Call for action

Sex- and gender-specific differences in the human physiological systems affect human mechanics, and thus biomechanics. This meta-analysis highlights a large disparity in female representation within *Journal of Biomechanics* studies published in 2024, a concern I term *biasmechanics* to encourage efforts to address it. Historical analyses of biomechanics conference abstracts (Bach et al., 2015; Sebastian et al., 2024) indicate that this issue has persisted over time and requires call for action. I therefore urge authors to be mindful of sex- and gender-differences, and for reviewers and editors to adopt stricter standards in accepting articles that exhibit an unjustified gender or sex imbalance. Furthermore, I encourage the *Journal of Biomechanics* to take an active role in addressing this issue by adopting standardized guidelines to promote equitable representation in research. To foster awareness and encourage reflection on this important issue, I propose the following:

- **Scientific Justification for Gender or Sex Exclusion**
  A specific sex or gender can only be excluded from the study, when a clear and concise scientific justification is provided for this choice. This should be articulated in the introduction and methodology sections to inform readers of the rationale behind the study design.
- **Discuss Scientific Implications in the Discussion and Limitations Section**
  In the discussion and limitations section of the article, it is important to provide a scientific analysis of the implications resulting from the exclusion of a particular sex or gender. This should include an exploration of how such exclusions may affect the validity and generalizability of the findings, as well as potential biases that may arise in the interpretation of the results.
- **Indicate Single-Sex or Gender Focus in the Title and Abstract**
  If the study is single-sex or gender-specific and there is reasonable doubt about the generalizability to other sexes/genders, the gender/sex focus should be clear from the title and abstract. This transparency allows readers to immediately understand the focus of the research and its applicability to different populations.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author utilized NotebookLM (Gemini 1.5) to extract information from articles, and ChatGPT to enhance English grammar. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This publication is part of the project COMPensate of the research programme Veni which is financed by the Dutch Research Council (NWO) under the grant 18145. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. I extend my gratitude to Martine van der Does (Fordham University's Institute of International Humanitarian Affairs) for providing valuable insights on the discussion of geopolitical concerns.

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