The Impact of Breasts and Bras on Physical Activity Amongst Women and Girls: A Systematic Review and Meta-Analysis

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BACKGROUND: Breast motion may cause breast pain in active women, which can negatively impact physical activity. Sports bras are essential pieces of sporting equipment and were designed to help women comfortably participate in sports and engage in physical activity. Thus, the purpose of this systematic review was to summarize how breasts and bras influence physical activity in women and girls.
METHODS: A systematic review was conducted by performing electronic searches of PubMed, Physiotherapy Evidence Database (PEDro), Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Cochrane Central Register of Controlled Trials. Title, abstract, and full text screening were performed by two independent reviewers to identify articles investigating how breasts or bras impact physical activity related outcomes in women or girls. We performed meta-analyses to evaluate the effect of (i) breast size, (ii) bra type, and (iii) breast reduction on (i) breast pain, (ii) physical activity level, and (iii) breast biomechanics. Standardized mean differences and pooled standard deviations of outcome measures were calculated using the DerSimonian-Laird method. All meta-analyses were performed using SPSS Statistics Software.
RESULTS: Of the 323 articles identified, 77 were included in the final analysis. The majority of articles studied participants who were 20-29 years old, identified as white, lived in Western countries, were non-athletes, and weighed between 45-65 kg (BMI: 18.5-29.9), while they were performing a running movement. Very few articles reported household income and ethnicity/race. Key themes investigated by this body of literature were breast biomechanics, breast pain, and physical activity levels. Meta-analyses revealed that women and girls with larger breasts reported more exercise-induced breast pain and experienced greater breast mediolateral velocity and anterior/poster acceleration during physical activity than women and girls with smaller breasts. Meta-analyses revealed that sports bras were associated with less breast pain during physical activity than standard bras.
CONCLUSION: This body of literature largely studied a homogenous population, and there is a need for greater inclusion of women and girls who identify with under-represented minorities, with disability, who are post-menopausal, and who are overweight. Factors such as ethnicity/race and household income, were underreported in the literature, and studies of movement patterns beyond running are needed. Mediolateral breast velocity and anterior/posterior breast acceleration may be contributors to breast pain in women and girls with larger breasts, thus these biomechanical outcomes are of particular interest for future research and for consideration in sports bra optimization.

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INTRODUCTION

Before 1986, women* were largely excluded from clinical trials and research out of concern for impacts on fertility.[1] This exclusion expanded to areas of research that do not put fertility at risk, such as physical activity, and to this day still negatively impacts our understanding of physical activity in females.[2] Indeed, women often have lower levels of physical activity and higher rates of obesity as compared to men.[3-6] This activity gap is even greater for women of color.[7] Although the drivers of these disparities are multifactorial, breast pain and motion are one of the significant barriers to women's participation in physical activity and sport.[8]

In 1978, Haycock et al. first documented how breast motion impacts running and jumping amongst females.[9] Their survey found that 31% of female athletes experienced breast soreness following exercise. Indeed, the breasts can move up to 15 cm during vigorous physical activity, and excessive breast motion is associated with breast discomfort, affecting as many as 56% of females.[10-13] In fact, one study suggested as little as 2 cm of breast motion during exercise is associated with discomfort.[14] Unfortunately, this breast pain often deters women and girls from exercising and participating in sports. In a survey of 249 women in the United Kingdom, 24% reported reducing their physical activity levels to relieve breast pain and 33% reported not meeting physical activity guidelines as a result.[8] Thus, despite the fact that knowledge of breast impacts on physical activity have existed for over 40 years, there are still breast support obstacles for women and girls during physical activity.

In examining components contributing to exercise-induced breast pain, breast size is an important factor. Specifically, females with larger breasts exhibit greater breast motion and report more breast pain during running and jumping activities.[11,13,15] In a survey of over 2,000 adolescent girls in the United Kingdom, 63% of larger-breasted school girls reported their breasts had a negative impact on their participation in sports and exercise, citing excess breast motion as their greatest concern.[16] Similarly, a survey of 438 females in the United States demonstrated that females with larger breasts were significantly more likely to report that concerns of breast support prevented them from participating in physical activity.[17] The impact of large breasts disproportionately affects women who are overweight or obese, and increasing breast size has been found to correlate with a decreasing physical activity cycle, which further contributes to and worsens rates of obesity.[14,18,19,20,21] Therefore, the impact of breasts and bras on physical activity disproportionately affects women and girls with larger breasts and other specific populations.

To try to mitigate some of the breast-motion related barriers to physical activity, in 1977, the first activity-specific bra, known as the "jogbra", was designed.[22 23] Decades later, sports bras have grown into a multibillion-dollar industry and are an essential piece of sporting equipment for many women and girls to be comfortable while being active and participating in sports.[24,25] Although in research studies sports bras appear to reduce breast pain and movement during physical activity, breast pain continues to be a reported barrier to physical activity, even as recent as 2023.[10,12,26,27] Thus, there is a need to synthesize the literature aimed at understanding how breasts and bras impact physical activity to identify potential explanations as to why breast-related barriers to physical activity still exist.

With this background in mind, the purpose of this systematic review was to describe how bras and breasts impact physical activity-related outcomes in girls and women. To be as all-encompassing as possible, we used the World Health Organizations definition of physical activity, defined as all movement including but not limited to exercise, sports, play, and walking.[28] We hypothesized that girls and women with larger breasts would (i) have more pain and discomfort with physical activity, (ii) have more barriers to physical activity, and (iii) be less physically active than women and girls with smaller breasts. We also hypothesized that improper support of breasts during physical activity will lead to (i) improper biomechanics, (ii) more pain during physical activity, and (iii) more injuries than proper breast support.

* While in this review we focus on the impacts of bras and breasts on physical activity in women and girls, we acknowledge that not all women and girls have breasts and that some individuals with breasts do not identify as a woman or girl. Our focus here is largely limited based on the literature that is available, thus, we use the terms "woman" and "girl" to describe individuals who identify as a woman or girl and has breasts.

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METHODS

Systematic Review

Our systematic review was registered on Open Science Framework (OSF) Registries a priori under the title "*The impact of breasts and bras on females' ability to move: a scoping review*". A literature search was performed under the guidance of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement and protocol for systematic reviews (Appendix S1), the Meta-Analysis of Observational Studies in Epidemiology (MOOSE) checklist (Appendix S2), and the Cochrane Handbook for Systematic Reviews of Interventions.[29-32] Studies were not excluded based on the presence of a control group (e.g., case study), age of participants, or year of publications. Studies were excluded if the paper was not published in a peer reviewed journal, not written in English, did not contain human subjects, was not an original research article, studied males only, or focused on breastfeeding/post-partum or breast cancer.

We performed electronic searches of PubMed, Physiotherapy Evidence Database (PEDro), Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Cochrane Central Register of Controlled Trials on March 24, 2023, with search terms outlined in Table S1. Title, abstract, and full-text screening was performed by two independent reviewers (XX, XX). Disagreements were resolved by an independent third reviewer (XX). All screening steps were completed in pre-designed spreadsheets.

Two reviewers extracted study information from the included publications. Specifically, we documented the variables listed under "Study/Participant Demographics Cataloged" in Table S2. If these data were not reported in an included study, we noted so. We then further categorized studies based on intervention type and outcome variables (see Table S2 for specific categories considered).

Meta-analyses

We performed meta-analyses on overlapping outcomes that were reported amongst studies. Specifically, this included evaluating the effect of (i) breast size on breast pain, physical activity level, and breast biomechanics, (ii) bra type on breast pain, and (iii) breast reduction on physical activity level. Breast size was categorized into small breasts (A-C cup) and large breasts (D cup or larger) since this was the most commonly utilized reductionist approach amongst included studies, and bra type was categorized into standard bra and sports bra since these were the two most commonly investigated bra types. Standardized mean differences (SMD) and pooled standard deviations (SD_{pool}) of outcome measures were calculated using the DerSimonian-Laird method.[32] All meta-analyses were performed using SPSS Statistics for Windows (version 28.0, IBM Corp., Armonk, NY, USA).

RESULTS

Literature aimed at studying the impact of breasts/bras on physical activity is largely focused on a homogenous study population

From our systematic literature search, we identified 323 articles studying the effect of breasts and/or bras on physical activity. Following title, abstract, and full text screening, 77 articles were eligible for inclusion in our review (Figure 1).[8,10-14,16-18,20,21,26,33-97] Reasons for exclusion at the full text level are listed in Table S3, with the most frequent reason for exclusion being the article was not an original research study.

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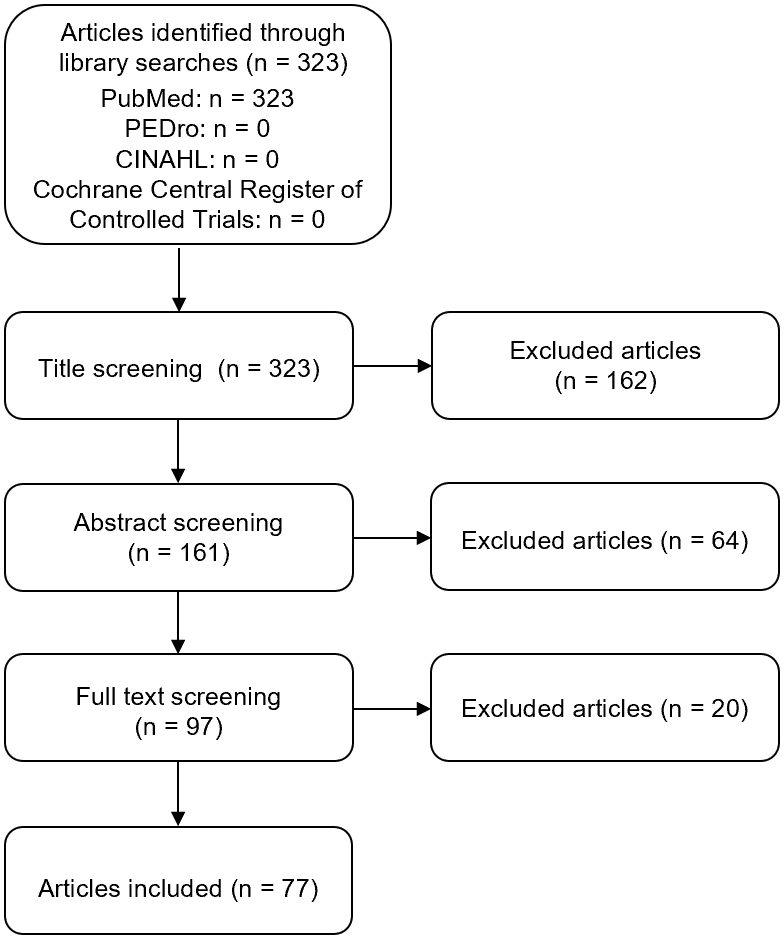

Figure 1. Systematic review workflow. Systematic search of databases, abstract, title, and full text screening resulted in 77 unique articles included in this review
Details on exclusion reasons at the full text level and included article details are available in Tables S3 and S4

Detailed study information was extracted from the included articles and is listed in Table S3. Approximately half of the articles focused on women ages 20-29 (n = 32, Figure 2A), and the majority of articles did not report the ethnicity/race of their participants (n = 73, Figure 2B). Of those that did, most participants were white (70% or more, Table S4). Additionally, only one study reported the household income of participants.[17] Published studies largely took place in Australia, the United Kingdom, or the United States (n = 71, Figure 2C), and included studies mainly focused on non-athletes (n = 62, Figure 2D). Of those that did include athletes, runners were the most commonly studied population (n = 9/17, (two studies included both athletes and non-athletes) Figure 2D). Some studies reported participants' weight (n = 52) or body mass index (BMI) (n = 18), with the mean weight being 45-65 kg and the most investigated BMI being 18.5-29.9; however, a fifth of studies did not report the weight of their participants (n = 14, Figure 2E) and the majority (n = 59) did not report BMI (Figure 2F). There was a wide range of breast sizes represented amongst participants in included studies, with the most common cup size being D (Figure 2G). Most studies were Level III or IV evidence (n = 58, Figure 2H) and focused on biomechanical outcomes (n = 43, Figure 2I). Additionally, the average impact factor of journals from included articles was 4.0 ± 3.4, and 6% of studies were published in female-focused journals (e.g., *The Breast Journal*). Encouragingly, the rate of publication of literature aimed at studying how breasts and bras impact physical activity is increasing exponentially across time (Figure 2J). In examining the specific movement under study, most articles focused on running (n = 41, Figure 2K; Table S4 list movement under study on a per article

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basis). Many studies' independent variable was bra type (n = 37), while 23 studies focused on breast size, and 24 studies were descriptive in nature (Figure 2L). The most common outcome variables studied in this body of literature were related to breast biomechanics (n = 31) and breast pain (n = 31, Figure 2M).

Meta-analyses revealed that breasts and bras impact physical activity level and breast pain during physical activity

Meta-analyses revealed that women with larger breasts reported more breast pain with physical activity than women with smaller breasts (Figure 3A). Despite this, however, there was no detectable effect of breast size on physical activity level (Figure 3B). Interestingly, sports bras were reported to cause less breast pain during physical activity than standard bras (Figure 3C), and women reported more physical activity post-breast reduction than pre-breast reduction (Figure 3D).

Women with larger breasts experienced greater mediolateral velocity and anterior/posterior acceleration of their breasts during physical activity than women with smaller breasts

When examining the effect of breast size on breast displacement, we found no effect in the vertical, mediolateral, or anterior/posterior directions (Figure 4A-4C). While there was no effect of breast size on vertical and anterior/posterior velocity (Figure 4D, 4F), women and girls with larger breasts experienced greater mediolateral velocity than women and girls with smaller breasts (Figure 4E). Conversely, while there was no effect of breast size on vertical and mediolateral acceleration (Figure 4G-4H), women and girls with larger breasts experienced greater anterior/posterior acceleration than women and girls with smaller breasts (Figure 4I).

DISCUSSION

This systematic review provides a comprehensive summary of the existing literature aimed at understanding the impact of breasts and bras on physical activity amongst women and girls. While there is a large body of literature reviewing non-breast related physical activity outcomes amongst females, to our knowledge, there are only three published reviews focused specifically on breasts and physical activity outcomes.[98-109] Two of these reviews specifically examine methodology for studying breast biomechanics, while the most recently published review analyzed how bra fit relates to sports participation.[110-112] Here, we build on this body of literature by more broadly examining how breasts and bras impact physical activity and performing meta-analyses on how these factors impact breast pain, physical activity levels, and breast biomechanics.

Encouragingly, the body of literature aimed at studying the impact of breasts and bras on physical activity is growing exponentially and is being published in journals geared toward the entire exercise/sports/rehabilitation community. Indeed, we found that the number of publications on this topic increased more than 3-fold from 2003-2012 to 2013-2022. Additionally, we found that 94% of studies were published in general sports/exercise/rehabilitation journals, while only 6% of studies were published in female-specific journals. These findings are of particular interest, given the consistently reported lack of studies on female athletes relative to male counterparts and more generally challenges with publishing studies that include women compared to studies that include men.[113,114]

The literature revealed homogenous subject populations, with the majority of articles examining participants who were 20-29 years old, identified as white, lived in Western countries, were non-athletes, and weighed between 45-65 kg. Encouragingly, however, many studies included a wide range of breast sizes (Figure 2F). In future studies, greater attention should be paid to the inclusion of older women, women with disabilities, underrepresented minorities, and overweight or obese women. Interestingly, race and ethnicity, along with household income and other social determinants of health, were not reported by many studies. When studies did report race, the vast majority of participants identified as white. As of 2023, all but six studies were conducted in predominantly white countries including Australia, the United Kingdom, and the United States. As sports bra-wearing habits and perceptions of the breasts likely vary in different communities of women, the results gathered in this review may not be generalizable to other populations, and greater attention to including diverse populations is critical for future research.

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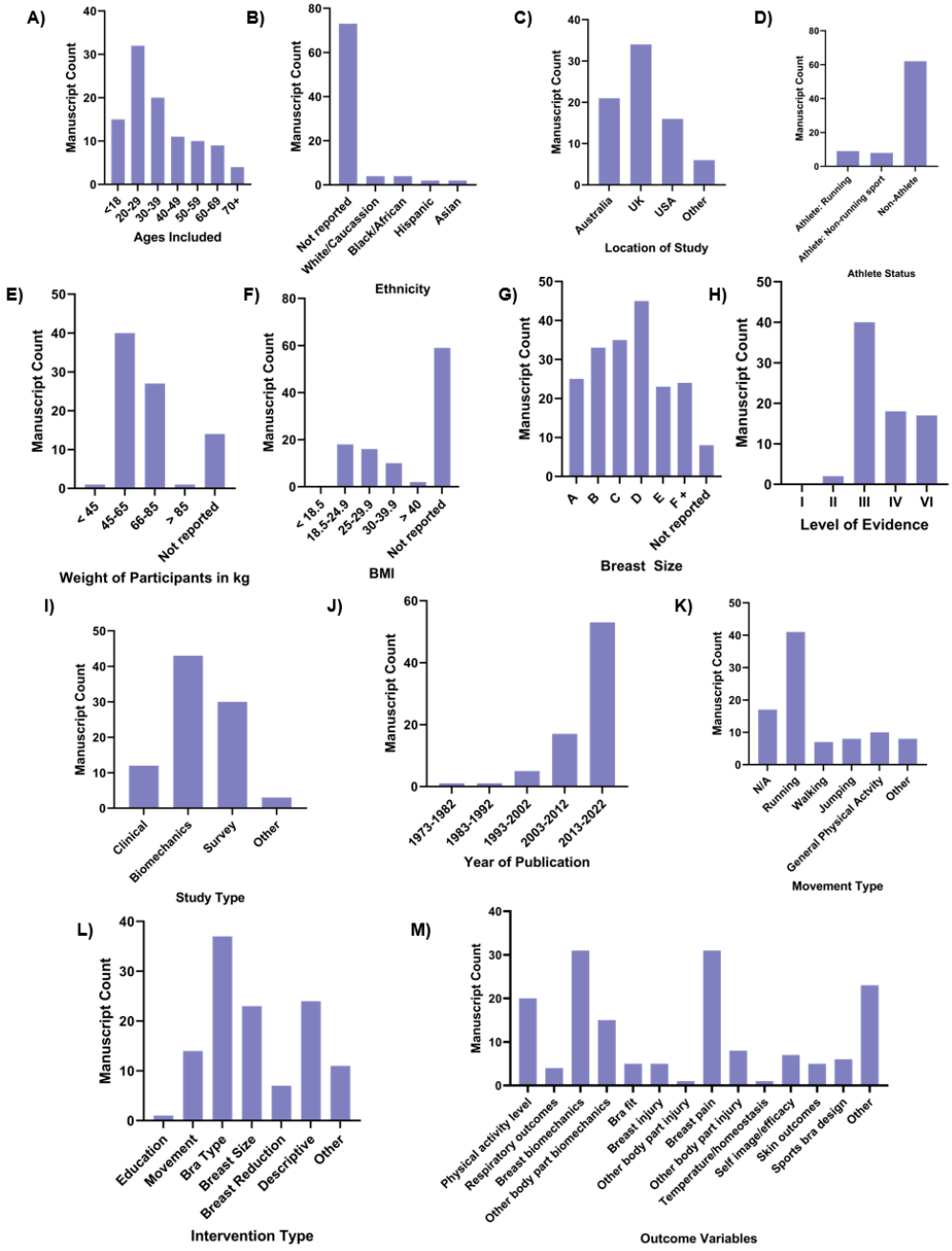

Figure 2. Descriptors of publications aimed at studying the effects of breasts and bras on physical activity in women and girls. A) Ages included, B) Race/Ethnicity, C) Location of study, D) Athlete status, E) Weight of included participants, F) Body mass index (BMI) of participants, G) Breast size of participants, H) Level of evidence, I) Study Type (i.e., what types of data were collected/what was the format of the study), J) Year of publication, K) Movement type under study, L) Intervention type or independent variable of the study, M) Outcome variables or dependent variables in study

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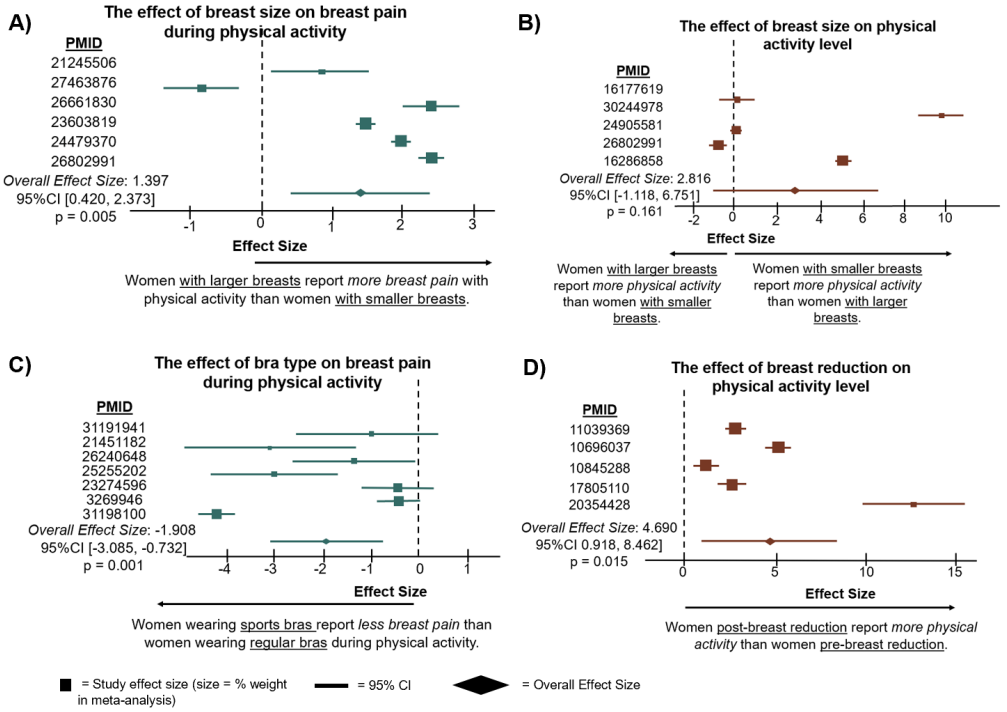

Figure 3. The effects of breasts and bras on breast pain during physical activity and physical activity level

Meta-analyses were performed to assess the following relationships: (A) the effect of breast size on breast pain during physical activity, (B) the effect of breast size on physical activity level, (C) the effect of bra type on breast pain during physical activity, and (D) the effect of breast reduction on physical activity level.

Few studies were specifically focused on athletes. When they did, most articles analyzing athletes included only runners, and the most common movement-related intervention was running. Only two of the included studies examined breast outcomes amongst athletes in contact sports. In a survey of 504 elite female athletes representing 46 different sports, participants in contact sports reported a significantly greater number of breast injuries (47.3%) than participants in non-contact sports (33.7%).[82] Another study reported that amongst collegiate-level female basketball and soccer players, 48.8% and 46.7%, respectively, had experienced a breast injury while playing their sport.[80] While the data is limited, these studies suggest that athletes, especially those in contact sports, experience high rates of breast injuries. Future research on this topic could focus on understanding the causes and types of breast injuries experienced by contact sport players.

In addition to breast injuries amongst athletes, exercise-induced breast pain presents a significant burden to physical activity. In a survey of elite female athletes in Australia, 44% reported experiencing exercise-induced breast pain, with 32% reporting this pain negatively affected performance in their sport.[115] Of the few studies that have examined other modalities of physical activity, results suggest breast biomechanics and perceptions of breast impacts on physical activity vary considerably between walking, running, and jumping.[86,110] Thus, our understanding of the impact of breasts and bras on athletes and in sports/movements outside of running, especially in contact sports, is limited and is a needed focus area of future research.

Of the studies included in our review, five specifically studied bra fit, though not in a manner we could specifically compile into a meta-analysis. When asking non-athlete young women with C-E breast size about their experience with bra fitting, 87% reported having never been fitted professionally.[63] In addition, 83% of female athletes

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at the Olympics and Paralympics wore improperly fitted bras.[94] Another study reported that bra fit discomfort increases during running when a standard sports bra is used, and Wakefield-Scurr et al. reported that sports bra fit changes after 25 wash/dry cycles. [47,95] Given this current literature, there is an essential need for more access to bra fitting and educational initiatives, for athletes and non-athletes alike, on appropriate bra fit as well as descriptive studies geared at understanding how much inappropriate bra fit, access to sports bra, and poor sports bra design are barriers for physical activity.

Interestingly, our meta-analyses did not detect an effect of breast size on physical activity level. This lack of effect may be due to missing confounders, such as information on bra fit or type. We did, however, identify that larger breasts were associated with both more breast pain and altered breast biomechanics. Specifically, we found women and girls with larger breasts presented with more mediolateral velocity and anterior/posterior acceleration of their breasts compared to women with smaller breasts. This correlation between breast biomechanics and pain puts forth the hypothesis that increased mediolateral velocity and anterior/poster acceleration of the breasts may contribute to breast pain. However, similar to the meta-analysis on breast size and physical activity level, these data are also limited by incomplete reporting of bra fit and type, which may affect the conclusions drawn by this dataset.

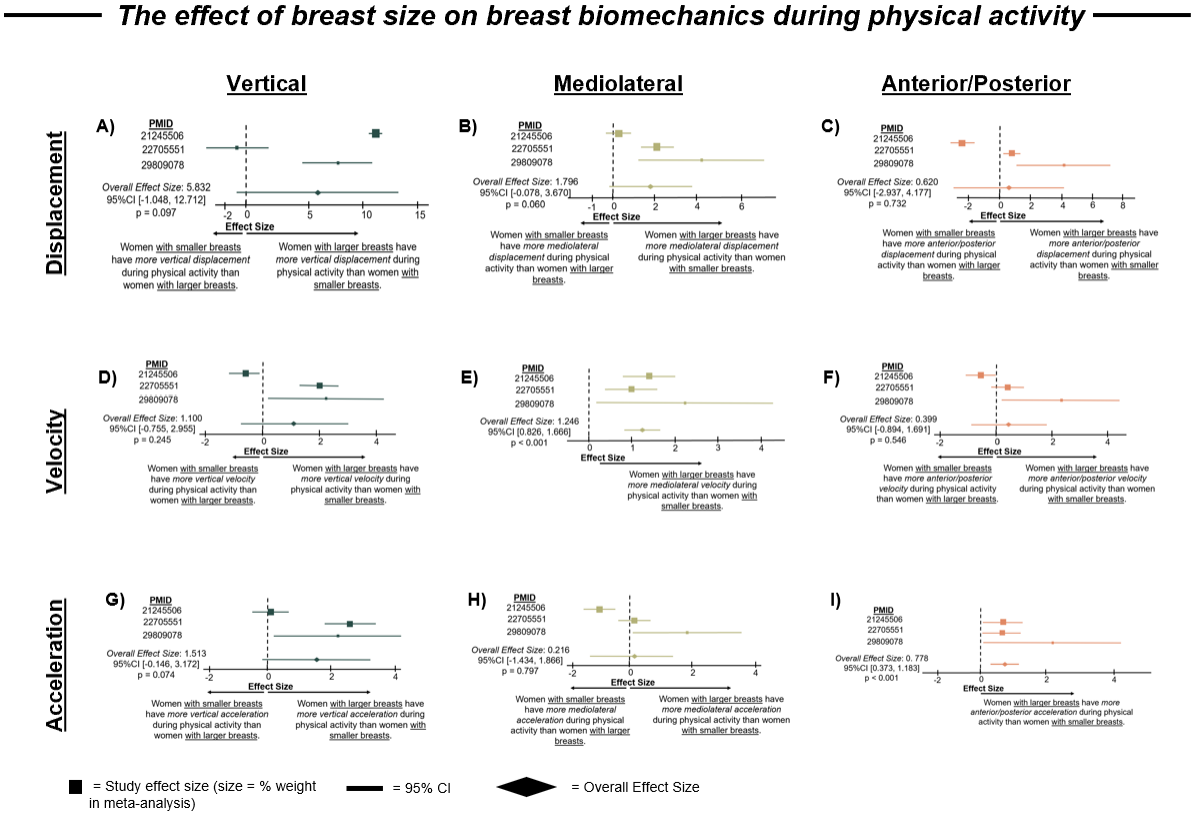

Figure 4. The effects of breast size on breast biomechanics during physical activity. Meta-analyses were performed to assess the effect of breast size on breast: A) vertical displacement, B) mediolateral displacement, C) anterior/posterior displacement, D) vertical velocity, E) mediolateral velocity, F) anterior/posterior velocity, G) vertical acceleration, H) mediolateral acceleration, and I) anterior/posterior acceleration

Our meta-analyses indicate that a standard sports bra is sufficient at reducing breast pain during physical activity in comparison to a regular bra. While this does not negate the importance of

continued improvement on sports bra design, it does raise into question why breast pain continues to be such a prominent problem for females, both athletes and non-athletes, during physical activity.[8] Indeed, many studies have suggested that wearing a properly fitted sports bra can reduce breast movement by 59% and decrease pain in 85% of cases.[10,116] As aforementioned, there is evidence that access to bra fitting and/or education on the importance of bra fitting is missing amongst women included within these studies. There is also anecdotal evidence that access to sports bras, appropriately fitted or not, is a central barrier to particular communities of women to physical activity, and there are many organizations aimed at increasing sports bra accessibility (for example, The Sports Bra Project and Bras for Girls).[117-122] However, this is a poorly reported and studied area of the literature, and only one study in our review addressed this head on.[17] Therefore, understanding how access to sports bras impacts breast pain during physical activity and improving said access is an important area of continued research and outreach efforts.

Although this study adds to a growing body of literature, it does exist with limitations. As described previously, the study populations and movement patterns examined in the literature are largely homogenous, thus generalizability to other populations and movements are limited. Additionally, given the limited types of physical activity studied, we were not able to stratify data by activity type. The included studies also sparsely reported baseline activity level, BMI, bra type*, bra fit*, accessibility of sports bras, and other health risk factors that may have confounded results; thus, we were not able to adequately control for these features (*unless these were the specific independent/dependent variables). Another limitation of our analyses is that these studies were published over a wide range of time (1973-2023), and bra design and support has changed over this time period in a way that we have not controlled for here. As mentioned at the onset of our study, these analyses exclude people who have breasts but do not identify as women/girls, and there is a need for specific research aimed at targeting this population. Our meta-analyses were limited by a small sample size and presented with high heterogeneity ($I^2 > 0.9$ for all), thus the lack of effects may be due to underpowered analysis or confounding factors rather than a true lack of effect. Additionally, we did not perform risk of bias or rigor and reproducibility analyses.

CONCLUSION

This systematic review and meta-analysis studying the impact of breasts and bras on physical activity in women and girls. We found that the literature is biased towards a homogenous population, and greater inclusion of under-represented minorities, post-menopausal, and overweight women will increase the generalizability of studies. In addition, there is a need for this body of literature to better report confounding factors, such as race/ethnicity and household income, and study other types of movement beyond running. Our meta-analyses revealed that larger breasts were associated with both more breast pain, more mediolateral breast velocity, and more anterior/posterior breast acceleration. Thus, prospective studies should focus on these biomechanical outcomes in sports bra design to further determine if these altered mechanics have a causal relationship with breast pain.

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Conflict of Interest Statement

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