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Research article

The Occurrence, Causes and Perceived Performance Effects of Breast Injuries in Elite Female Athletes

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Abstract
Female breasts are vulnerable to direct blows or frictional injuries during sport; however, little research has investigated breast injuries experienced by female athletes. This study aimed to investigate the occurrence, causes and perceived performance effects of breast injuries in elite female athletes across a wide range of sports. A custom-designed survey was distributed to female athletes aged over 18 years who were competing nationally or internationally in their chosen sport. The survey included questions about breast injuries sustained during training and competition and any perceived performance effects of these injuries. 504 elite female athletes from 46 different sports completed the survey. 36% of participants (n = 182) reported experiencing breast injuries and 21% (n = 37) perceived that their breast injury negatively affected their performance. Contact breast injuries were reported by significantly more athletes involved in contact or combat sports and by athletes with larger breasts or a higher body mass index. Frictional breast injuries were reported by significantly more older athletes or those with larger breasts. Less than 10% of participants who experienced breast injuries reported their injury to a coach or medical professional and only half used any prevention strategies. Athletes, coaches and medical professionals associated with women's sport need to be made aware of the occurrence and potential negative effects of breast injuries. It is critical to normalise conversations around breast health so that athletes can be encouraged to report and, when necessary, receive treatment for breast injuries. Further research is also required to better understand factors that affect breast injuries in sport in order to develop evidence-based breast injury prevention strategies.

Key words: Surveys and questionnaires, contact injury, friction injury, athletic injuries, breast, sporting performance.

Introduction

Due to their location on the anterior chest wall, limited anatomical support and lack of musculoskeletal protection, female breasts are vulnerable to injury, particularly from direct blows during contact sports (Greydanus et al., 1998; Jiang and Ni, 2013; Loud and Micheli, 2001). The extensive superficial capillary networks within breasts also increase the likelihood of contusions and haematomas from direct contact (Haycock, 1987; Holschen, 2004). Despite this vulnerability to injury, there is a paucity of published research investigating breast injuries sustained during sport. One of the few published studies in this field was a survey completed by athletic training staff of injuries sustained by female collegiate athletes in 1975, which revealed that breast injuries were the least common injury for this cohort (Gillette, 1975). Possibly because breast injuries were not considered problematic in this study, injuries to the breast or chest have seldom since been included in research that has documented injuries sustained by female athletes (Hägglund et al., 2009; Hilibrand et al., 2015; Langeveld et al., 2012; McCarthy et al., 2013; Peck et al., 2013; Zelisko et al., 1982).

In sports injury research, investigators traditionally record injuries that have been reported by athletes to coaches or athletic trainers (Dönmez et al., 2018; Gillette, 1975; Schiff et al., 2010) or that have been diagnosed by team physiotherapists or physicians (Giza et al., 2005; Peck et al., 2013; Wik et al., 2019). These methods of recording sports injuries, however, are unlikely to capture reliable information on breast injuries because female athletes are often reluctant to report injuries they sustain to their breasts or chests (Smith et al., 2018), particularly to male athletic staff (Drummond et al., 2007). Furthermore, there is no widely accepted medical classification for breast injuries sustained during sport and no information about breast injuries was included in the most recent iteration of the Team Physician Consensus Statement on Female Athlete Issues, a publication specifically designed to educate team doctors about injuries which female athletes might sustain (Team Physician Consensus Statement, 2018). As such, the most reliable method of recording these sensitive and unclassified breast injuries is through a direct survey of female athletes.

Most sports injury researchers also use a narrow definition of injury (Clarsen and Bahr, 2014), recording only injuries that result in time-loss from training or matches (Dönmez et al., 2018; Engström et al., 1991; Schick et al., 2008) or that necessitate medical attention (Giza et al., 2005; Holland et al., 2018; Peck et al., 2013). It is unknown, however, whether breast injuries are severe enough to remove an athlete from sport or require medical attention, or whether female athletes seek medical attention for their breast injuries. It is therefore possible that a narrow definition of a sports injury might systematically exclude breast injuries from being recorded, even though these injuries could negatively affect athletic performance. To better understand the scope of breast injuries sustained in sport and whether these injuries affect performance, it is necessary to adopt an "any physical complaint" injury definition (Clarsen and Bahr, 2014) and record all occurrences of breast injuries during sport, irrespective of severity.

In a direct survey of female collegiate athletes, the authors of a 2018 study found that breast injuries affected

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nearly 48% of collegiate basketball, soccer, softball and volleyball athletes in America (Smith et al., 2018). Only 10% of female athletes in this study reported their breast injuries to medical personnel (Smith et al., 2018), which supports the notion that breast injuries are likely to have been under-represented in previous sports injury research. This study also broadly classified breasts injuries as any trauma to the breast including contusions, bruising, hematomas, oedema and pain (Smith et al., 2018), irrespective of time-loss or medical attention, which might explain the higher prevalence of injuries recorded in this study compared to the 1975 survey (Gillette, 1975). Although this 2018 study revealed that nearly half of the female athletes had sustained a breast injury during sport, the participants only included college-aged basketball, soccer, softball and volleyball players. Given the wide variety of sports that female athletes participate in (Brisbine et al., 2019a) and the growing popularity of contact sport (Huxley, 2016; Navaratnam, 2017; Roberts, 2017; Rubgy Australia, 2018), there is a need to investigate the occurrence, causes and perceived performance effects of breast injuries sustained across a greater diversity of sports.

In addition to the breasts being vulnerable to trauma, skin around the upper torso and breast is also sensitive to potential injury from repetitive contact with an athlete's sports bra or uniform, which might result in chafing or lacerations from rigid bra components (Haycock, 1987; Loud & Micheli, 2001). "Runner's nipple" (also known as "jogger's nipple") is a chafing injury that has been extensively reported in both female and male runners, the occurrence of which has been associated with running distance (Purim and Leite, 2014), body mass index (BMI) (Helm et al., 2012) and infrequent sports bra use in female athletes (Mailler and Adams, 2004). It is therefore possible that female athletes who train for several hours, have a higher BMI or use a sports bra less frequently might be susceptible to frictional breast injuries. Larger breast size might also contribute to frictional breast injuries in female athletes, because overweight men have been found to sustain frequent chafing injuries due to increased "jiggling" of breast tissue and a resultant increase in friction between the breast and their shirt (Helm et al., 2012). Although numerous studies have investigated chafing injuries in runners (Adams, 2002; Loud and Micheli, 2001; Mailler and Adams, 2004; Mailler-Savage and Adams, 2006), no research was located that specifically investigated frictional breast injuries across a range of sports or how these injuries might affect sporting performance.

This study aimed to investigate, through a direct survey and the use of a broad injury definition, the occurrence and causes of breast injuries reported by elite female athletes from a wide range of sports and whether the athletes perceived these breast injuries to affect their sporting performance. These aims address the crucial first phase of the Team-sport Injury Prevention framework by evaluating the current breast injury situation in sports (O'Brien et al., 2019). This exploratory research is necessary to inform future specific breast injury research and the development and implementation of evidence-based breast injury prevention strategies. It was hypothesised that:

H1: elite female athletes would experience breast injuries during sport;

H2: breast injuries would be caused by direct contact or friction between breast skin and an athlete's bra or uniform during sport; and

H3: elite female athletes would perceive that breast injuries negatively affected their sporting performance.

Methods

Survey design and implementation

Although sports injury research traditionally relies on surveillance by coaches or medical staff, the sensitive nature of breast injuries, the absence of standardised breast injury definitions and the lack of breast injury reporting necessitated a survey to directly ask female athletes about the occurrence, causes and performance effects of breast injuries. An anonymous 42-question survey was therefore designed to gather data on breast issues sustained by female athletes, aged 18 years or older, currently competing nationally or internationally (i.e. representing their state or country) in any sport. Full details of how the survey was developed and implemented are described in a previous publication (Brisbine et al., 2019a); in brief, the survey was initially developed using focus groups comprised of female athletes from a range of sports. The survey was then distributed as an electronic link or a hard copy to sporting organisations, coaches, medical professionals and sports teams throughout Australia via email, social media, standard mail and in-person. The survey was presented in four sections: *About You, About Your Bra, Your Breast Pain* and *Your Breast Injuries.* Only relevant data from each section was reported in this paper. The University of Wollongong Human Research Ethics Committee (HREC 2017/009) and the Australian Institute of Sport Ethics Committee (20170610) approved the survey design and implementation procedures.

Analytical variables

Age: Participants recorded their date of birth, which was then used to calculate their age at the date they completed the survey. Age was recorded as a continuous numerical variable.

Breast size: Participants were asked to report the bra band size and cup size (e.g. 8B, 32DD) that they most often wore. Previously published data on bra size and breast volume (Coltman et al., 2014; Coltman et al., 2017a; McGhee and Steele, 2011) were then used to assign a breast size score to each participant based on their approximate breast volume (Brisbine et al., 2019b): Breast volume < 350 ml, score = 1 (small breasts); breast volume 350-700 ml, score = 2 (medium sized breasts), breast volume 701-1200 ml, score = 3 (large breasts); breast volume > 1200 ml, score = 4 (hypertrophic breasts) (Coltman et al., 2017a). These ordinal breast size scores were then treated as continuous numerical data, whereby a score closer to "1" represented a smaller mean breast size and a score closer to "4" represented a larger mean breast size.

Body mass index: Participants reported their estimated height in centimetres and body mass in kilograms. Each participant's body mass index (BMI) was then calculated by dividing her mass by her height, squared (kg/m^2). BMI was represented as a continuous numerical variable.

Frequency of sports bra use: The participants were asked how frequently they wore any form of sports bra (either a compression crop top, an encapsulation sports bra or a "hybrid" combination of an encapsulation bra with a compressive outer layer) during training and competition on a five-point Likert scale ranging from "always" (score = 1) to "never" (score = 5). These ordinal scores were treated as continuous numerical data, whereby a score closer to "1" represented a higher mean frequency of sports bra use and a score closer to "5" represented a lower mean frequency of sports bra use.

Weekly training: Participants were asked to estimate their weekly in-season training hours. Where a range of numbers was given, an average was calculated to produce a continuous numerical variable.

Sport type: The participants recorded their sport and position/event. This response was then used to classify each participant into one of three sports categories: (i) "contact sports" – in which contact between players is an inherent aspect of the sport (e.g. contact football codes), (ii) "combat sports" – in which athletes engage in one-on-one combat with an opponent and contact is an inherent aspect of the sport (e.g. boxing, taekwondo), and (iii) "non-contact sports" – in which extensive contact between players does not usually occur (e.g. running, swimming). Due to a high frequency count of "non-contact sports", the categories "contact sports" and "combat sports" were later combined into a single group ("contact/combat sports") for analysis. Sport type was therefore represented as a dichotomous independent variable ("contact/combat sports" and "non-contact sports").

Occurrence of breast injuries: Participants were asked "Have you ever had a breast injury during training or competition (e.g. a bruise to your breast from a direct blow, a cut from a piece of sporting equipment, a scrape, chafing of the nipples, etc.)?", to which they could respond either "yes" or "no".

Causes of breast injuries: If a participant answered "yes" to ever having a breast injury, she was also asked to specify which cause(s) of injury she had experienced. Options (developed through the focus groups) were: "direct blow from another athlete (e.g. elbowed/kicked in the chest)"; "direct blow from sporting equipment (e.g. soccer ball, hockey stick, etc.)"; "direct contact with a surface (e.g. falling onto chest)"; and "contact from my sports bra/uniform (e.g. chafing of nipples, cut from underwire, etc.)". The former three responses (another athlete, sporting equipment and surface) were grouped together as "contact breast injuries" and the response "sports bra/uniform" was considered a "frictional breast injury".

Perceived performance effects: Participants were asked whether breast injuries had a perceived negative effect on their sporting performance during training or competition, with possible responses "yes" or "no".

Injury reporting: Participants were asked whether they consulted anyone about their breast injury, with the response options being: "parent"; "team mate"; "coach"; "doctor"; "physiotherapist"; "sport scientist"; "I did not seek advice about the injury"; or "other", where space was given to write a free response. Responses of reporting to a coach, doctor, physiotherapist or sport scientist were grouped collectively as "coach or medical professional".

Prevention strategies: The participants were asked to select all breast injury prevention strategies that they used, with options "wear a padded sports bra"; "wear a protective bra"; "strap my breasts to my chest using tape or bandages"; "modify my movements to prevent breast injury"; "limit activities that might cause breast injury"; "protect my breasts with my hands during sport"; "I do not use any strategies to prevent breast injury"; and "other", where space was given to write a free response. Participants were also asked to report whether they had ever used specific breast padding, with responses "yes" or "no".

Statistical analyses

Descriptive statistics: Basic frequency counts were used to calculate the overall percentage of participants who reported experiencing any breast injuries, contact breast injuries and frictional breast injuries, as well as the percentage of participants who reported that their breast injury had a negative effect on their sporting performance. Data were also reported for the percentage of participants who used various breast injury prevention strategies and those who reported their breast injury.

Chi-squared Test of Independence: The SPSS Crosstabs procedure was used to generate a contingency table, summarising the distribution of participants in this study who reported that they had experienced breast injuries in each sport type (contact/combat sports and non-contact sports). Statistical significance of the relationship between sport type and breast injury ("yes" vs. "no") was assessed using a Chi-squared Test of Independence.

Mann-Whitney U-test: A series of Mann-Whitney U-tests was used to compare participants who did and did not report: (i) any breast injuries, (ii) contact breast injuries and (iii) frictional breast injuries, classified by age, BMI, breast size, frequency of sports bra use and average weekly training hours. This test was chosen as a non-parametric alternative to an independent samples *t*-test and for its robustness with regard to significant outliers in the data. Although multiple statistical tests were conducted, increasing the chance of incurring an error, no adjustment to the alpha level was deemed necessary given the exploratory nature of the study and the low cost associated with incurring an error. Differences in the mean rank between groups were considered statistically significant at $p < 0.05$. All statistics were performed in SPSS (Version 23, IBM Statistics, Chicago, USA).

Results

Participants

Five hundred and four female athletes (mean age 25.7 ± 9.5 years; height 1.69 ± 0.08 m; body mass 65.6 ± 10.8 kg; BMI 23.0 ± 3.3 m/kg^2) competing in 46 different sports (see Figure 1) completed the survey. Participants reported bra sizes ranging from 8A to 20G (Australian bra sizing) (McGhee and Steele, 2006) and mean weekly training hours of 12.1 ± 8.4 hours. Ninety percent of participants reported always wearing a sports bra during training and competition.

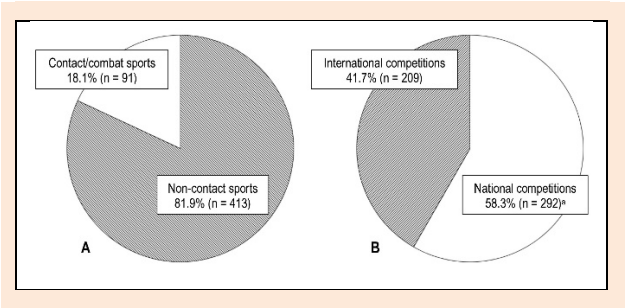

Figure 1. The percentage of participants competing: (A) in contact/combat sports or non-contact sports and (B) in national or international competitions. [a] Three participants did not specify whether they competed at a national or an international level.

Occurrence of breast injuries

Breast injuries were reported by 36% (n = 182) of the participants. Only 10% of these participants (n = 18) reported their breast injury to a coach or medical professional (i.e. a doctor, physiotherapist, athletic trainer).

Causes of breast injuries

Participants reported that breast injuries were caused by direct contact with another athlete, with sporting equipment or with the ground (contact breast injury; reported by 29% of participants) or by friction from a bra or uniform rubbing or chafing the skin of their breasts (frictional breast injury; reported by 20% of participants). There was a statistically significant association between sport type and both the occurrence of any breast injuries and the occurrence of contact breast injuries. That is, a significantly greater percentage of participants from contact/combat sports reported any breast injuries ($\chi^2(1) = 5.975$) and contact breast injuries ($\chi^2(1) = 12.715$; see Table 1) compared to participants from non-contact sports.

Table 1. Percentage of participants from non-contact sports and contact/combat sports who reported contact breast injuries, frictional breast injuries and any breast injuries.

Injury Type	Non-contact sports (n = 413)	Contact/ combat sports (n = 91)	*p*-value
Contact breast injury	25.6	44.4	<0.001
Frictional breast injury	20.0	21.1	0.456
Any breast injury	33.7	47.3	0.011

Contact breast injuries were also significantly associated with breast size and BMI, whereby participants who experienced contact breast injuries had larger breasts and a higher BMI compared to participants who did not experience contact breast injuries. In contrast, frictional breast injuries were significantly associated with age and breast size, whereby participants who experienced frictional breast injuries were older and had larger breasts compared to participants who did not experience frictional breast injuries (see Table 2 and Figures 2 and 3).

Perceived performance effects of breast injuries

Twenty one percent of the participants (n = 37) reported that they perceived their breast injury to negatively affect their sporting performance. Across all sports, 43% of participants (n = 76) reported that they had no breast injury prevention strategies and only 3% of participants (n = 14) reported wearing any breast padding during training or competition. Thirteen of these participants played combat sports in which breast padding was either mandatory or actively encouraged (e.g. boxing and fencing) and one played ice hockey. Other injury prevention strategies used by participants who reported experiencing breast injuries (n = 182) included wearing a sports bra (29%), modifying their movements to prevent injury (e.g. altering running style; 9%), limiting specific activities that might result in injury (e.g. avoiding a tackle; 6%), physically placing their hands in front of their breasts to prevent injury (6%) or strapping or bandaging their breasts (3%).

Discussion

This is the first study to specifically investigate the occurrence, causes and perceived performance effects of breast injuries in elite female athletes across a wide range of sports. More than one in three of these elite athletes reported experiencing an injury to their breasts during training or competition. Despite 21% of the participants perceiving that these breast injuries negatively affected their sporting performance, very few participants reported their injury to a coach or medical professional and only a few participants reported using any breast injury prevention strategy. The implications of these unique findings are discussed below.

Occurrence of breast injuries

As hypothesised (H1), elite female athletes (36%) reported experiencing breast injuries during their sport. Although this finding was in contrast to previous research that reported breast injuries as an uncommon injury for female athletes (Gillette, 1975), it was somewhat consistent with recent findings that reported a high occurrence (48%) of breast injuries among female basketball, soccer, softball and volleyball athletes in America (Smith et al., 2018). These data highlight the need to directly and specifically ask athletes about their experience with breast injuries, rather than assuming that all injuries will be reported to

Table 2. Mean ± standard deviation of age, breast size, body mass index (BMI) frequency of sports bra use and training hours between participants who did not report (no injury) and did report (injury) contact breast injuries and frictional breast injuries.

Variable	Contact breast injuries			Frictional breast injuries		
	No injury	Injury	p-value	No injury	Injury	p-value
Age (years)	25.5 ± 9.2	26.1 ± 9.7	0.578	25.0 ± 8.8	28.3 ± 11.0	0.011
Breast size (rank) *	1.2 ± 0.5	1.5 ± 0.6	<0.001	1.2 ± 0.5	1.6 ± 0.6	<0.001
BMI (kg/m2)	22.6 ± 3.0	24.1 ± 3.8	<0.001	22.8 ± 3.0	23.8 ± 4.1	0.123
Sports bra use (rank) #	1.1 ± 0.5	1.2 ± 0.6	0.098	1.2 ± 0.5	1.2 ± 0.7	0.951
Training (hours)	12.2 ± 7.8	12.1 ± 9.8	0.257	11.9 ± 8.1	13.3 ± 9.6	0.211

*Breast size ranked from 1 (small breasts, < 350 ml per breast) to 4 (hypertrophic breasts, > 1200 ml per breast). # Frequency of sports bra use ranked from 1 (always) to 5 (never).

athletic or medical staff. Indeed, 90% of participants in the current survey indicated that they did not report their breast injury to a coach or medical professional. Similar low levels of reporting of breast injuries were documented by Smith et al. in the 2018 survey of American collegiate athletes (Smith et al., 2018). These findings support the notion that breast injuries are likely to have been under-represented in previous sports injury research (Gillette, 1975) due to infrequent reporting by athletes. This incorrect assumption related to a low occurrence of breast injuries in sport is likely to have contributed, in turn, to a general lack of breast injury awareness amongst coaches, medical professionals and the athletes themselves. As more than one in three participants reported sustaining a breast injury, it is crucial that athletes, coaches and medical professionals associated with women's teams are educated about the risk of athletes incurring a breast injury during training or competition to increase overall awareness so that athletes can be encouraged to report and, if necessary, receive treatment for these injuries.

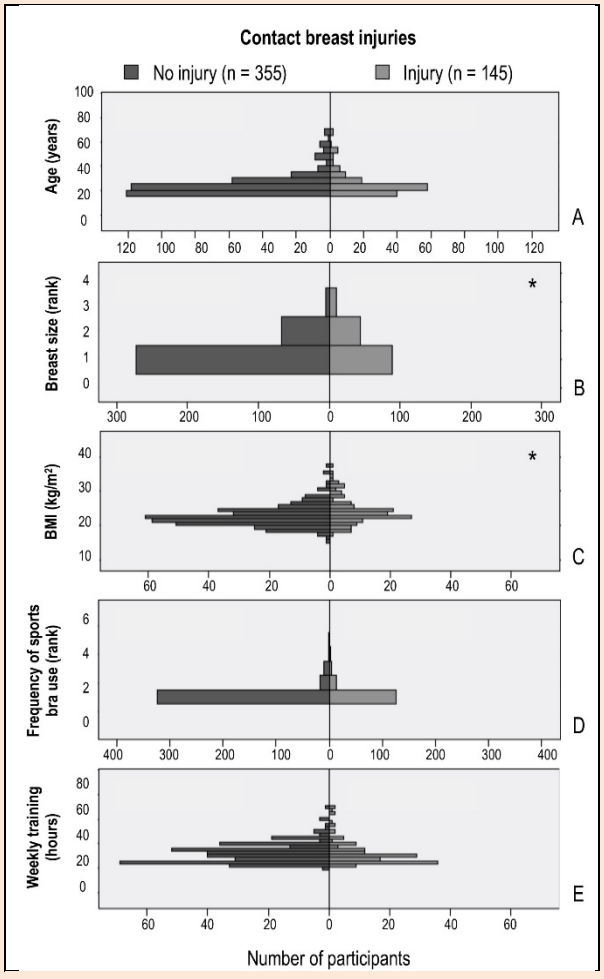

Figure 2. The frequency distribution of (A) age, (B) breast size[a], (C) BMI, (D) frequency of sports bra use[b], and (E) weekly training for participants who did not report (no injury) and did report (injury) contact breast injuries. * indicates significant difference ($p < 0.05$) between participants who did not report and did report contact breast injuries.[a] Breast size ranked from 1 (small breasts, < 350 ml per breast) to 4 (hypertrophic breasts, > 1200 ml per breast).[b] Frequency of sports bra use ranked from 1 (always) to 5 (never)

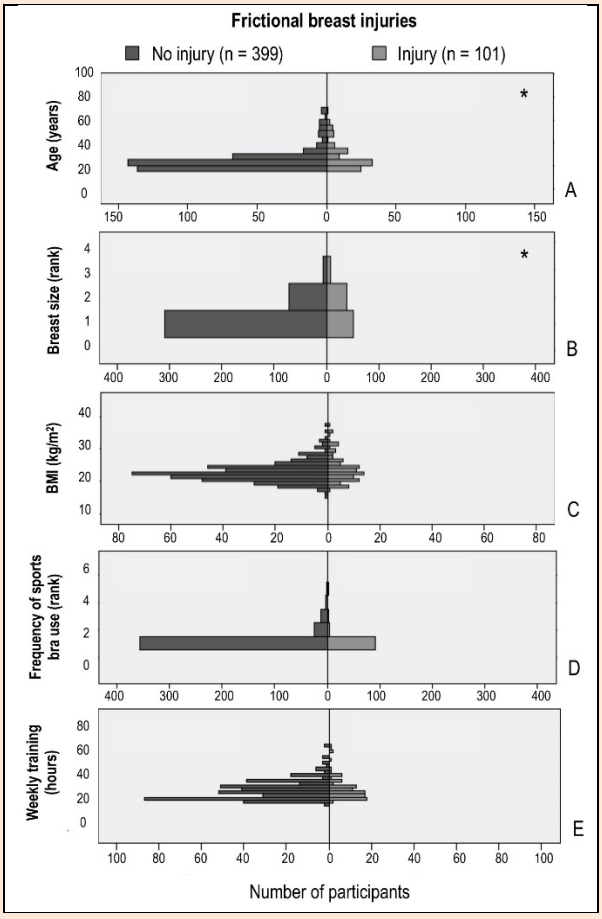

Figure 3. The frequency distribution of (A) age, (B) breast size[a], (C) BMI, (D) frequency of sports bra use[b], and (E) weekly training for participants who did not report (no injury) and did report (injury) frictional breast injuries. * indicates significant difference ($p < 0.05$) between participants who did not report and did report frictional breast injuries. [a] Breast size ranked from 1 (small breasts, < 350 ml per breast) to 4 (hypertrophic breasts, > 1200 ml per breast). [b] Frequency of sports bra use ranked from 1 (always) to 5 (never)

Causes of breast injuries

Consistent with our second hypothesis (H2), two main types of breast injuries were self-reported by the participants: (i) contact breast injuries, caused by a direct blow from another athlete, a piece of equipment or the ground, and (ii) frictional breast injuries. Although some medical professionals have reported observing contact injuries to the breast (Haycock, 1987), this is the first study to report on the specific causes of these contact breast injuries in a diverse cohort of elite female athletes. A greater occurrence of contact injuries was reported compared to frictional injuries and these injuries were primarily related to direct contact with another athlete. Unsurprisingly, significantly more contact/combat athletes reported contact breast injuries compared to non-contact athletes, supporting the assertion made by Haycock that "traumatic" breast injuries are more common in contact sports (Haycock, 1987). As female participation numbers rise in sports such as Australian Rules Football (AFL), Rugby League and Rugby Union (Huxley, 2016; Navaratnam, 2017; Roberts, 2017; Rubgy Australia, 2018), an increasing number of

athletes are likely to incur contact breast injuries. Therefore, strategies to prevent and manage breast injuries in the contact football codes are likely to be necessary.

Participants who experienced contact breast injuries also had larger breasts, on average, compared to participants who did not experience contact breast injuries. This association is likely because larger breasts have a greater surface area for potential contact and they usually protrude farther from the chest wall, increasing their vulnerability to direct contact. Additionally, BMI was significantly associated with contact breast injuries, such that participants who reported contact breast injuries had a higher BMI compared to participants who did not report contact breast injuries. As BMI is closely associated with breast size in the general female population (Brown et al., 2012; Coltman et al., 2017a), it is likely that the greater susceptibility to contact breast injuries in participants with a larger BMI is partially due to their larger breast size. Therefore, strategies to prevent and manage contact breast injury should be developed specifically for athletes from contact and combat sports, as well as athletes with a larger BMI or larger breasts. Given the wide range of physical characteristics reported by participants who sustained contact injuries, however, prevention strategies must also be developed to cater for a diverse range of elite female athletes, not only those with larger breasts.

Previous research has documented long-distance runners reporting specific chafing injuries such as "runner's nipple" (Helm et al., 2012; Mailler-Savage and Adams, 2006; Purim and Leite, 2014). However, this was the first study to report that elite female athletes from a wide variety of sports, and not just long-distance runners, experience lacerations or chafing caused by frictional forces generated between their sports bra or uniform and breast skin. Although no significant difference was found between participants who did and did not report frictional breast injuries in terms of training hours, BMI or frequency of sports bra use, participants who reported experiencing frictional breast injuries had significantly larger breasts than participants who did not report frictional breast injuries. This finding is consistent with previous breast biomechanics research that has associated larger breast mass with greater three-dimensional breast motion (Lorentzen and Lawson, 1987; McGhee et al., 2013; Wood et al., 2012), which is, in turn, likely to increase friction between the breast skin and the sports bra.

Participants who reported frictional breast injuries were also significantly older than participants who did not report frictional breast injuries. We attributed this finding to the age-related changes in skin elasticity that have been observed in the breast and chest skin after the age of 25 years (Coltman et al., 2017b). These skin changes substantially reduce anatomical support to the breasts, permitting greater breast motion and, in turn, increased friction between the breast skin and the bra. Breast skin thickness also decreases with ageing (Coltman et al., 2017b), which might make older breasts more vulnerable to chafing and lacerations. Frictional breast injuries were reported by many elite female participants (20%) in this study. It is therefore crucial that athletes, coaches and medical professionals receive education about frictional breast injuries and that evidence-based strategies are developed to prevent and manage these injuries, with special consideration for older athletes and those with larger breasts. However, as participants who reported frictional breast injuries were diverse in terms of age, breast size and BMI, it is imperative that any future prevention or management strategies cater for the variety of female athletes who sustain frictional injuries.

Perceived performance effects of breast injuries

In support of our third hypothesis (H3), approximately one in five of the participants who experienced a breast injury perceived that their breast injury negatively affected their sporting performance. These findings are also consistent with the survey of American collegiate female athletes, which found that 18% of basketball, soccer, softball and volleyball players reported decreases in their sports performance or participation as a result of their breast injury (Smith et al., 2018). It is therefore imperative that athletes, coaches and medical professionals are aware of the potential for breast injuries to hinder sporting performance and that conversations around breast injuries are normalised in female sport.

Despite the potential negative effects of breast injuries on sporting performance, nearly half of the participants in this study reported that they had no strategies to prevent breast injuries. Of the strategies that were used, numerous participants reported modifying the way they ran/played or limiting specific activities (e.g. avoided a tackle) as their primary means of preventing breast injuries. Several participants also stated that they physically placed their hands in front of their breasts while playing to avoid contact breast injuries. Regardless of how effective or ineffective these actions might be in preventing a breast injury, it is likely that many of these strategies could further impede sporting performance, either due to being distracting or contributing to improper technique. Development of viable, evidence-based strategies to prevent breast injuries occurring is therefore critical. However, before any recommendations can be made with regard to specific injury prevention strategies, further research is needed to understand the reasons why athletes choose to or choose not to use existing strategies that could prevent breast injuries in sport (O'Brien et al., 2019). It is also necessary to investigate the attitudes and suggestions of coaches and medical professionals with respect to breast injury prevention strategies because these staff will be critical in the successful implementation of any future breast injury prevention or management strategies (O'Brien et al., 2019).

Study limitations

As the results of the present study are based on data collected from a survey, it is necessary to acknowledge the inherent limitations associated with subjective, self-reported data such as breast size, BMI and frequency of sports bra use. Directly assessing participant characteristics, specifically breast characteristics, and quantifying other factors that might be associated with breast injuries, such as bra fit, is therefore recommended for future research in this field. Due to the exploratory nature of this research, we did not anticipate some relevant follow-up questions

(e.g. *how* breast injuries are perceived to affect performance). Therefore, additional research is also encouraged to further explore the causes of breast injuries in different cohorts of female athletes and how these injuries affect performance.

Conclusion

Over one-third of elite female athletes reported experiencing either contact or frictional breast injuries during sport. Despite a fifth of these elite athletes perceiving breast injuries to negatively affect their sporting performance, most of the athletes had never reported their breast injury to a coach or medical professional. It is therefore imperative that athletes, coaches and medical professionals associated with women's sport are made aware of the occurrence and potential negative effects of breast injuries. It is critical to normalise conversations around breast health so that athletes can be encouraged to report and, when necessary, receive treatment for these injuries. Further research is also required to better understand factors that affect breast injuries in sport in order to develop effective evidence-based breast injury prevention strategies.

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Key points

- Elite female athletes experience contact breast injuries and frictional breast injuries during their sport.
- Contact breast injuries were reported by significantly more athletes involved in contact/combat sports (e.g. contact football codes, martial arts) and by athletes with a larger BMI or with larger breasts.
- Frictional breast injuries were reported by significantly more older athletes or those with larger breasts.
- Breast injuries were perceived to negatively affect performance in 21% of athletes who reported experiencing a breast injury.
- Only 10% of athletes reported their breast injury to a coach or medical professional and many athletes had no strategy to prevent breast injuries during their sport.

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