REVIEW ARTICLE

BMX: A scoping review of the literature

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ABSTRACT

Background: Bicycle Motocross (BMX) has evolved to cater to different styles of riders, including Flatland, Street, Park, and Dirt. BMX culture is characterised by a unique framework of regulations, guidelines, and principles of which a subculture has a pronounced anti-establishment sentiment and embraced do-it-yourself (DIY) practices, contributing to its distinctive identity within the realm of sport. Formal organisations have emerged, leading to the legitimisation of BMX through events such as the Olympics. To the author's knowledge, this is the first attempt to identify and synthesise all academic publications on BMX and describe the emergence of this research. Methods: After adopting the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRIMSA) guidelines 940 studies were identified in the initial search and post screening 87 studies were included. Data was extracted to determine, among other things, the year of publication, methodology adopted, type of BMX and/or BMXers studied, discipline of the study, and focus of inquiry. No date limiter was applied to the search strategy. Results: We identified 87 BMX-related articles for analysis, published between 1982 to 2022. The majority of these studies were conducted within the disciplines of biomechanics and physiology/sports science with a primary focus on performance-enhancing techniques within BMX racing. Most studies have emerged from the UK, with both males and females as their gender sample, using quantitative methodology. Conclusions: This scoping review identified several trends in the history of BMX research. It also identified important gaps and possible avenues for future research to contribute to academic knowledge in this growing field.

Keywords: Bicycle motocross, Olympic sport, Bike riding, Racing, Freestyle.

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INTRODUCTION

For this scoping review, the researchers looked at a wide range of national and international articles regarding BMX bicycles and those who ride them. Literature included reportage of medical research, studies into bicycle mechanics, types of BMX, the evolution of BMX as a sport, rider performance, the culture of BMX riders, places, and spaces where BMX riding takes place, wellbeing of BMX riders, and creativity as expressed in the realm of BMX.

Bicycle Motocross (BMX) bicycles have evolved to cater to different styles of riders, including Flatland BMX for tricks on flat surfaces, Street BMX for urban stunts, Park BMX for skatepark infrastructure, and Dirt/trail riding for aerial stunts on dirt tracks. Freestyle began when BMX racers looked to fill in time between races by informally competing to perform tricks on their bikes and encourage the creation of new tricks (Edwards & Corte, 2009). Freestyle BMX shares similarities with mountain biking, with adaptations for handling loose substrate and performing jumps (Olsen, 2021). Over time, formal organisations have emerged, leading to the legitimisation of Freestyle BMX through events such as the X-Games and the Olympics. While Olympic inclusion may offer economic and cultural rewards for professional athletes in the BMX community. Nevertheless, Olympic exposure has inspired participation and acceptance, especially among women and families, in what has traditionally been a white male-dominated sport (Olsen, 2021; Ding, 2019).

BMX culture is characterised by a unique framework of regulations, guidelines, and principles that distinguish it from more established and regimented sports. Individuals with cultures such as BMX, "*carve out autonomous space for the development and maintenance of alternative forms of culture alongside, and in interaction with, dominant culture producers*" (Honea, 2014, p. 1272). This subculture has a pronounced anti-establishment sentiment and embraced do-it-yourself (DIY) practices, contributing to its distinctive identity within the realm of sport (Ellmer & Rynne, 2022).

The inclusion of BMX in the Olympics has no doubt changed some perceptions of BMX, including those who do not participate in the activity. Ding (2019) notes that for some riders, inclusion in the Olympics is a way to "*legitimise their sport, generate more public awareness, and create new career promises*" (Ding, 2019, p. 362). Further to this, it seems that the prestige associated with the Olympics "*eclipses the risk of participation. BMX status as an elite sport generates hope among the participants that the family may accept their career choice*" (Ding, 2019, p. 158). Conversely, for others, inclusion in the Olympics means that BMX's core anti-mainstream values could be lost (Honea, 2014; Wheaton & Thorpe, 2018).

METHODS

A systematic scoping review of literature was conducted to obtain original and peer reviewed articles for appraisal. The current study was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021).

A scoping review can be defined as a type of systematic and synthesised search strategy that can be used to "*map the literature on a particular topic or research area and provides an opportunity to identify key concepts; gaps in the research; and types and sources of evidence to inform practice, policymaking, and research*" (Daudt et al., 2013, p. 8). This review adopted Arksey and O'Malley's six-stage methodological framework (2005) for conducting scoping reviews. These phases include: (i) identifying the research question; (ii) searching for relevant studies; (iii) selecting studies; (iv) charting the data; (v) collating,

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summarising, and reporting results, and (vi) consulting with stakeholders to inform or validate study findings (optional) (Arksey & O'Malley, 2005).

During the first phase, preliminary scoping of literature consistently showed negligible results in attempting to pair BMX with various other constructs such as "*BMX and wellbeing*" or "*BMX and creativity*". As a result, we broadened our research question considerably, to include an exploration of all academic peer-reviewed publications of BMX from any time, any discipline, and any focus.

The second phase of the framework involved seeking relevant studies; it was conducted via a comprehensive electronic search of five academic journal databases (EBSCOhost, ProQuest, Scopus, Dimensions, and PsycINFO). Once studies were identified, a further search of the reference lists in their corresponding articles was conducted. The literature search was based on as wide a range of concepts involving BMX as possible. The search syntax was endorsed by a liaison librarian at the authors' university and used important keywords in logical combinations. However, all terms were tailored to the thesaurus of each database. Key search terms used in the initial literature search included: *"BMX bikes*", "*bicycle motocross*", "*BMX events*", "*BMX racing*", "*BMX races*", "*BMX riding*", "*field-based bicycle*", "*BMX riders*", "*BMX activities*", "*BMX trails*", "*BMX street*", "*BMX stunt*", "*BMX flatland*", "*dirt jumping*", "*extreme sports*", "action sport", "*informal sport*", "*street sport*", "*lifestyle sport*". For each concept a range of keywords and, where databases permitted, subject headings were used to increase the sensitivity and inclusiveness of the searches. The reviewers considered peer-reviewed articles containing these terms in the title and text.

The third phase involved selecting applicable studies, through designing quality eligibility criteria that were applied to assess the relevance to the research question, firstly to the title and abstract screening process and then to the full text screening stage. Research papers were included if: (i) they were published in an academic journal article; (ii) had undergone a peer review process; (iii) they reported on original research, and (iv) were written in English. Studies were excluded if: (i) they did not contain information on BMX; (ii) they were the wrong publication type e.g., an editorial, thesis, conference proceedings; (iii) they were not original research e.g., a literature review; or (iv) they were written in a language other than English. No publication date range was applied to the search. The eligibility criteria applied to the studies are shown in Table 1.

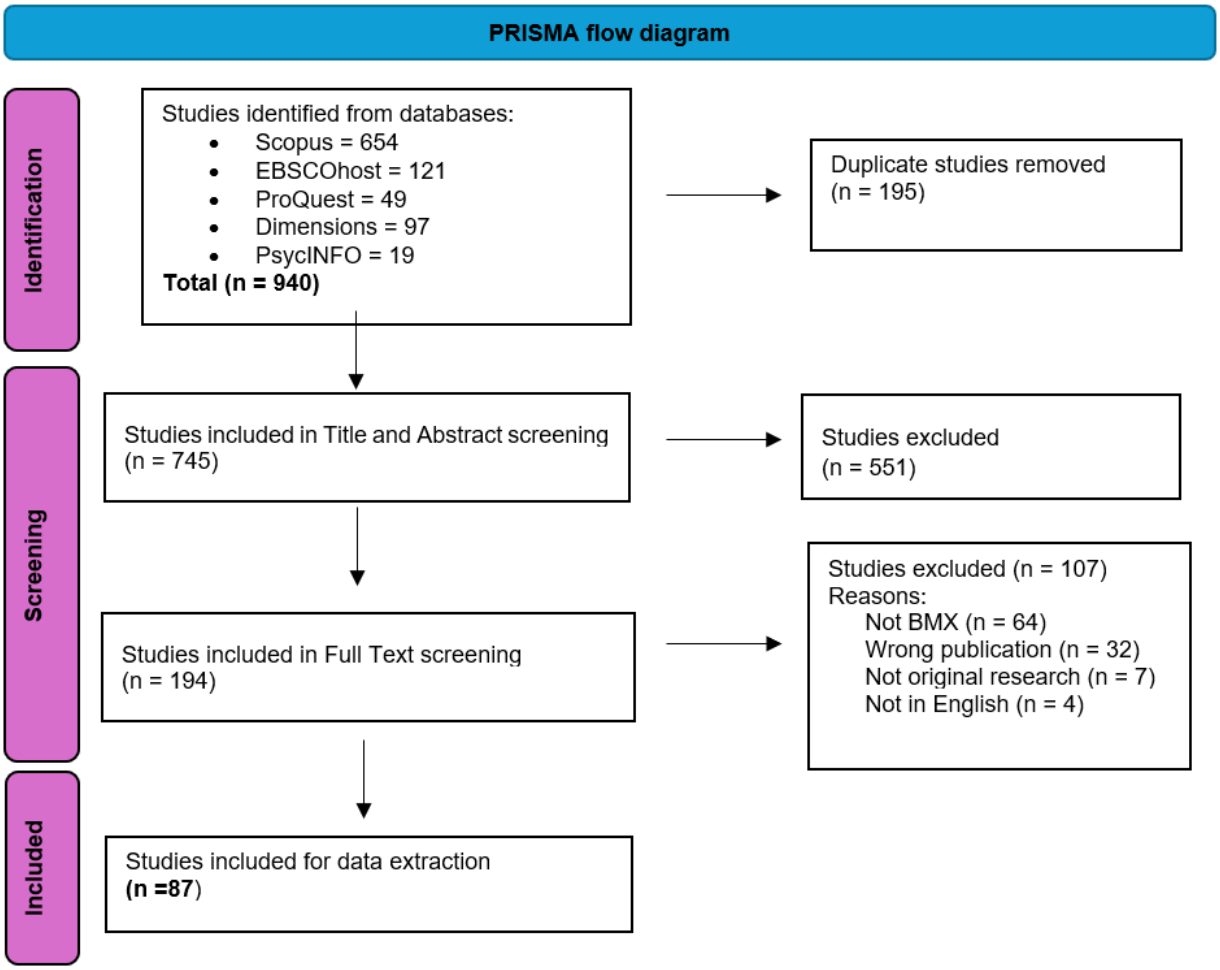
Table 1. Eligibility criteria applied to the research articles.

Eligible/Included	**Ineligible/Excluded**
About BMX[1]	Does not include BMX
An academic journal article	Not an academic article/paper e.g., editorial, conference proceedings, thesis
Original research	Not original research e.g., literature review
Has undergone a peer-review process	No peer-review is evident
Written in English	Written in a language other than English
Any time period	

Included articles were retrieved, imported, and stored within EndNote X9. Duplicate articles were identified and removed with the EndNote function, and then again manually by one of the review authors conducting a visual inspection to check and confirm duplicates before removal. Remaining articles were imported into the Covidence program, a screening and data extraction tool, where further duplicates were identified and removed.

[1] *The high initial count is due to research into an enzyme (**Cytoplasmic tyrosine-protein kinase BMX**) that in humans is encoded by the BMX gene.*

Articles underwent a double-blind screening of title and abstract by six independent researchers. Conflicts were discussed and resolved. Subsequently, full text articles were retrieved to determine whether the eligibility criteria were observed. These articles underwent double-blind screening of the full text by the researchers, again with conflicts discussed and resolved. For both stages of screening, articles were allocated to reviewers randomly by Covidence software and each article was reviewed by two of the researchers. The full review process comprising the number of studies included at each phase is reported with a PRISMA flow chart (Page et al., 2021), (See Figure 1).



Note. Retrieved from: Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

Figure 1. PRISMA flow chart.

Phase four involved charting the data whereby extraction and synthesis took place regarding pre-agreed data characteristics. Data were extracted from the final included articles using Covidence. Extracted data from articles included name of first author, year of publication, article title, journal, country study was conducted, aims, outcomes, study design, methodology, methods, survey instrument used, reliability/validity of instrument, sample, gender, sample size, setting, types of sport analysed, type of BMX analysed, focus of inquiry, discipline of inquiry, key findings, limitations. Data from each article was extracted blindly by two of the researchers and any conflicts were discussed until consensus was reached.

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Phase five of Arksey and O'Malley's framework involves collating, summarising, and reporting results which is explained in the following "*Results*" section.

The sixth phase of Arksey and O'Malley's methodological framework, consulting with stakeholders to inform or validate study findings, is labelled as optional. This phase is designed to provide opportunities for consumer and stakeholder involvement to suggest additional references and provide insights beyond those in the literature. However, engaging consumers and stakeholders was beyond the scope of this review.

RESULTS

This scoping review identified 87 BMX-related articles for inclusion and analysis. The included articles in the scoping review were published between 1982 to 2022, with a significant concentration in the years 2012 and 2021. The majority of these articles were conducted within the disciplines of biomechanics and physiology/sports science. These studies primarily focused on performance-enhancing techniques within BMX racing, with the first emerging in 2008 (Zabala et al., 2008).

In the field of medicine, studies examined the injuries sustained by riders. Among the most common injuries studied were head injuries, abdominal injuries, urological complications such as urethral injuries and testicular calcifications, and musculoskeletal injuries. Over a period spanning 1982 to 1989, six articles were published, all with a focus on various aspects of injury.

The majority of studies regarding BMX have emerged from the United Kingdom (19), followed by the United States (14), Spain (12), Australia (11), France (10), and New Zealand (7). The number of BMX studies by country is depicted in Figure 2. It is important to note that the country refers to where the study took place, not the country of publication. Also of note, the numbers do not add to 100% as some studies took place in multiple countries.

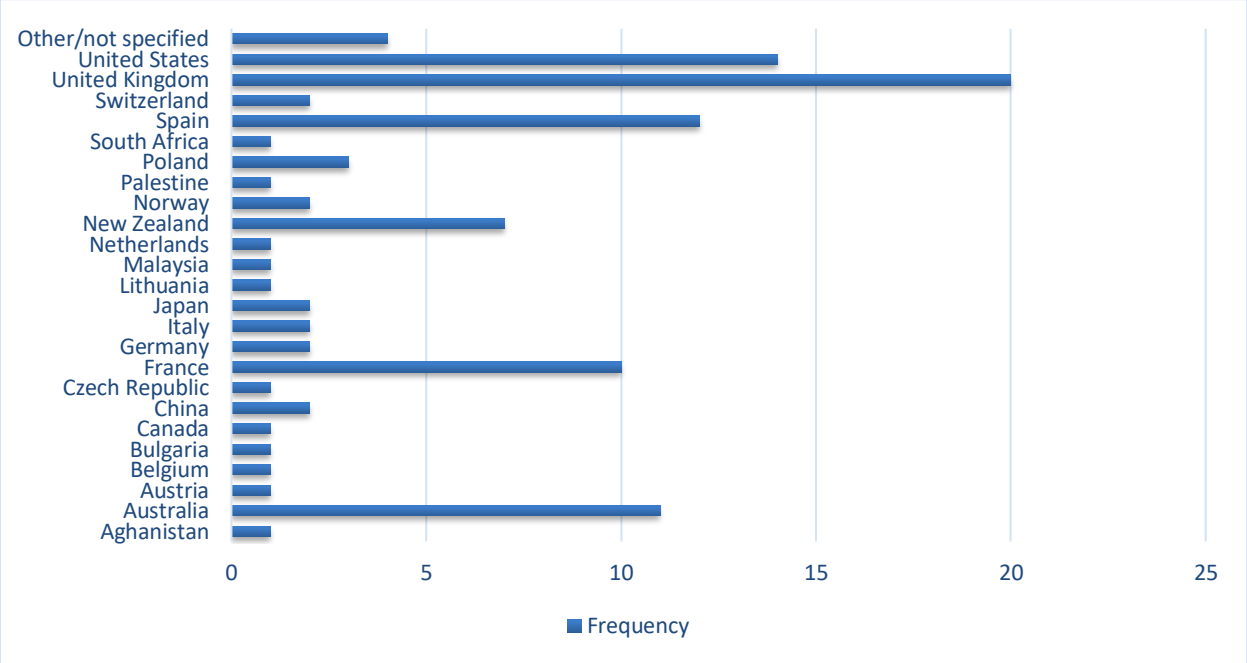

Figure 2. Frequencies of the country of BMX study.

The majority of studies published about BMX had both males and females as their gender sample (39), followed by males only (31), and one study with a focus of a female only sample. The large majority of the type of BMX riding studied was Racing (45), followed by Freestyle (18), with Racing and Freestyle combined (11), and then all other types (13). Table 2 shows the style of BMX studied by gender sample.

Table 2. Type of BMX style by gender sample.

		Gender				Total
		Male	Female	Female and Male	Other	
Type of BMX	Freestyle	8	0	10	0	18
	Racing	22	1	18	4	45
	Freestyle and Racing	1	0	5	5	11
	Other	1	0	6	6	13
Total		**32**	**1**	**39**	**15**	**87**

Quantitative methodology was employed in the majority of BMX studies (48), followed by mixed methods (23), and then qualitative methodology (13), with three studies falling in the Other/Not specified category. The number of studies by methodology adopted is depicted in Figure 3.

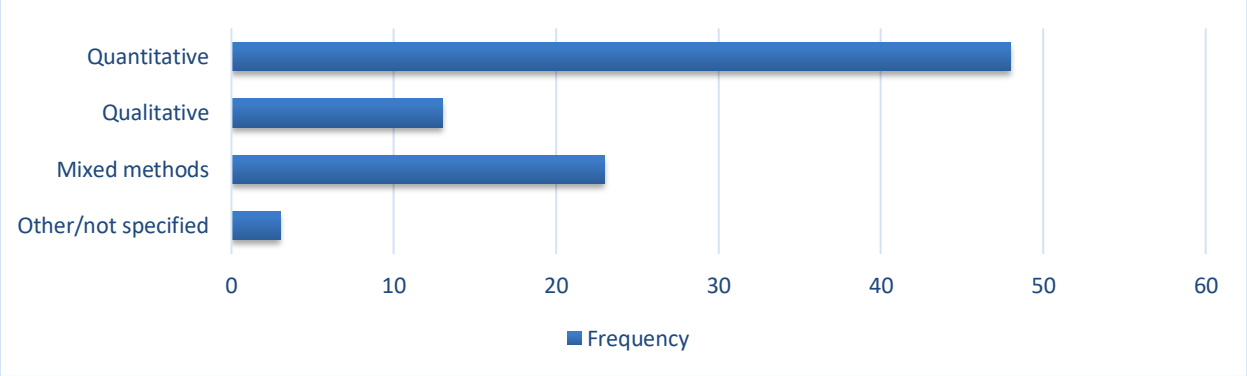

Figure 3. Number of studies by methodology.

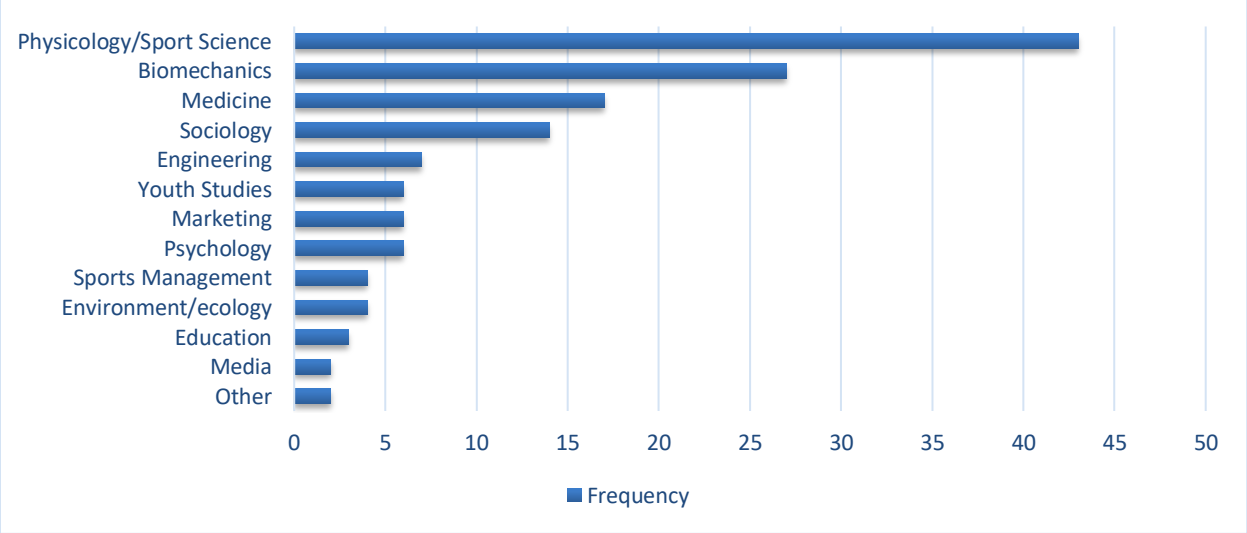

Figure 4. Number of studies by discipline.

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From the scoping review it became apparent that BMX research has predominantly emerged from the discipline of physiology/sports science (43), followed by biomechanics (27), medicine (18), sociology (15), engineering (7), with psychology, marketing, and youth studies each producing 6 studies each. Other disciplines that have published BMX content include environment/ecology (4), education (4), sports management (4), and media (2). The number of studies by discipline is displayed in Figure 4. In the figure below the numbers do not add to 100% due to some studies belonging in more than one discipline.

Another key finding of the scoping review is that the focus of inquiry of BMX studies has largely centred around performance (49), followed by injuries (16), equipment such as bikes and helmets (13), risk taking (10), belonging (7), marketing/commercialisation (7) and wellbeing (6). Other focus areas have included tourism (5), creativity (3), media (3), and education (1). The number of BMX studies by focus of inquiry is displayed in Figure 5. In the figure below the numbers do not add to 100% due to some studies including more than one focus of inquiry.

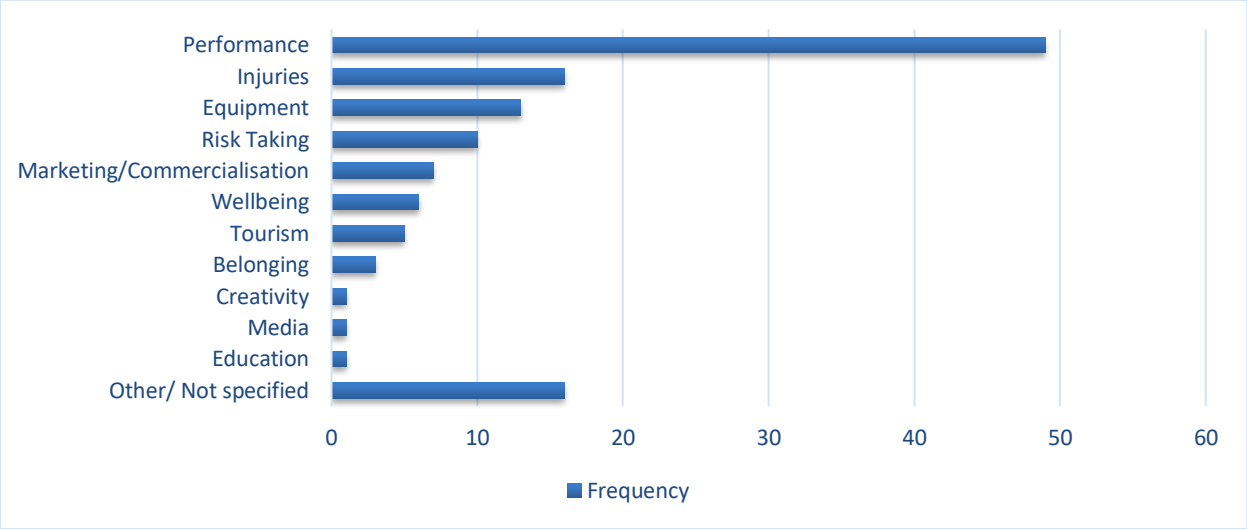

Figure 5. Frequency of focus of inquiry.

The majority of studies about BMX took place at race/test tracks (27), followed by laboratories (16), hospitals (11), specific events (6), and skate/sports parks (3) and [BMX] jumps (3). Other settings included simulations (2), and training sessions (2), with Other/Not specified (16). It is important to note that many settings were not specified in the articles. It should be noted that some studies were conducted in more than one type of setting.

DISCUSSION

To the authors' knowledge, this is the first attempt to identify and synthesise all published academic, peer-reviewed articles on BMX to date. The findings of this scoping review suggest that there has been a limited number of studies conducted over the past 25 years, with momentum increasing from 2008 onwards. The scoping review revealed to us 87peer reviewed academic studies that have been published and met the criteria we established. For a full list of the 87 included articles, please refer to Supplementary Document 1.

Prior to 2005, BMX was barely studied but gained momentum around 2008. This timing reflects the overall increasing public interest in BMX with BMX racing events being included in the 2008 Beijing Olympics

(Wheaton & Thorpe, 2018). Figure 7 shows the type of BMX studied by year of publication. Later, freestyle was added to the 2021 Tokyo Olympics. Early research about BMX essentially focussed on injury within the BMX riding community, while Reinhart, (2002), was the first peer-reviewed research on BMX and grassroots trails (Rinehart & Grenfell, 2002).

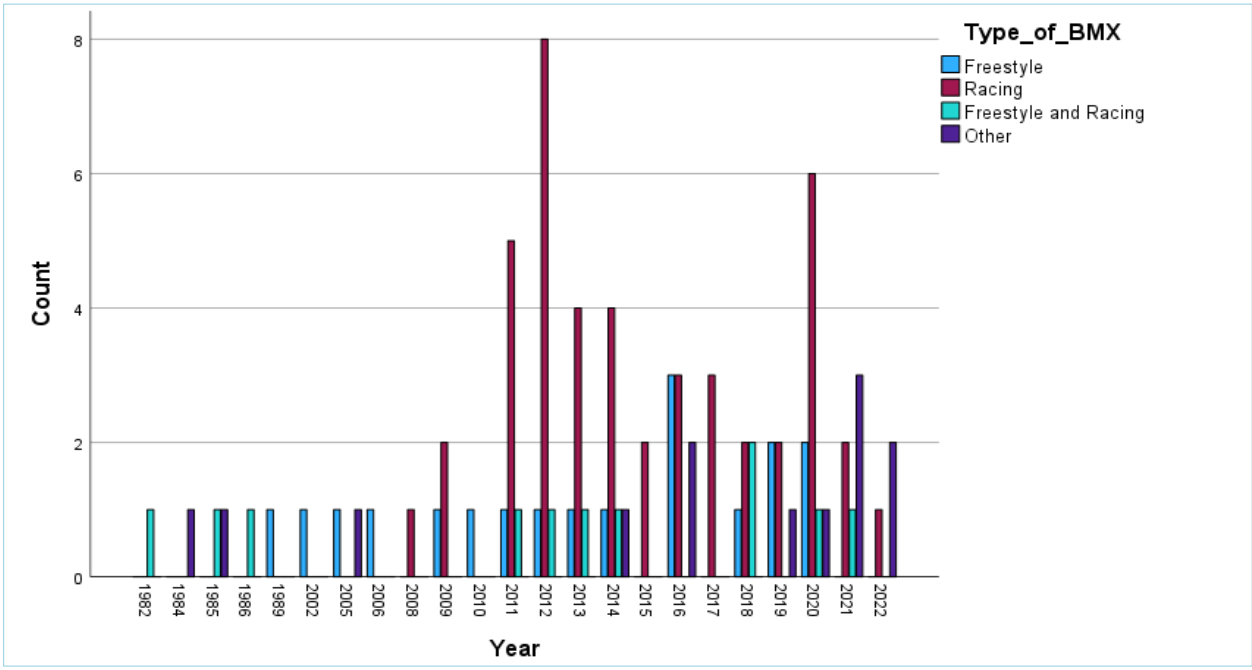

Figure 6: Type of BMX studied by year of publication.

The trends in the data extracted from the articles reveal there is a notable gender disparity in BMX research participation, with males being more represented compared to females and other genders. Wheaton & Thorpe (2018) argue against the suggestion that action sports have provided a more progressive gender equity space than more traditional sex-segregated sport. Instead, they believe this trend is possibly plateauing out as action sports become more institutionalised via Olympic inclusion. Additionally, we argue that this is possibly due to an increase in levels of competition. The exclusion of genders from sport places these groups at greater risk of social exclusion (Fernandez Gavira et al., 2017). As such, there is increasing debate and a growing body of literature around transgender people in competitive sport, particularly concerning any athletic advantages that testosterone levels may or may not give transgender women (Safer, 2022; Harper et al., 2021; Goldbach et al., 2022; Cooper, 2023). This has typically resulted in some transgender people feeling marginalised and having negative experiences when engaging in competitive sport (Jones et al., 2017).

We contend that gender equity in BMX research is important due to the emphasis placed on sport providing positive social outputs (Benitez Silva, 2018) and physical activities that foster a sense of belonging and health for people of all genders (Meredith et al., 2023). The lack of research on females and other genders in BMX highlights potential areas for further investigation into gender inclusivity and equity in BMX. Furthermore, the results underscore the intersectionality of gender identity and BMX participation, highlighting the need for inclusive approaches to promote diversity and equity within the BMX community. Understanding and addressing barriers to participation for underrepresented genders is crucial for fostering an inclusive and welcoming environment within the sport of BMX.

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The importance placed on sport and international success may determine the amount of investment (e.g., financially, socially, and through physical infrastructure) a country makes in developing their athletes. For example, De Bosscher et al., (2016) discovered a link between a country's elite sport policy systems and success in international competitions involving social, cultural, and political factors. This includes outlay in financial resources, athletic and post-career support, training facilities, and coach development (De Bosscher et al., 2009). This investment leads to what Grix and Carmichael (2012) term a "*virtuous cycle*" where international success is rewarded with an increase in participation, which results in a larger pool of people from which to choose the champions of the future (Grix & Carmichael, 2012). Such findings are relevant to the sport of BMX.

Considering the locations of research conducted, the majority of BMX studies have emerged from the United Kingdom (19) and the United States (16), indicating a strong research presence in these countries. This trend likely reflects the historical development of BMX as a sport in these regions and the availability of research infrastructure and funding to support scholarly inquiry. Spain (12), Australia (11), and France (10), have also made substantial contributions to BMX research, suggesting active research communities and institutional support for studying the sport. Interestingly, Rylands & Roberts (2019) found that Europe had produced the highest amount of research on Racing in their scoping review on performance in BMX racing (Rylands & Roberts, 2019). Lastly, New Zealand (7) has contributed a moderate number of studies to the BMX research literature. While these numbers are lower compared to the leading countries, they indicate an engagement with BMX research within their respective academic communities.

The growing interest in BMX studies is evident since the inclusion of the sport in the Olympics. Correspondingly, this is marked by the increase in literature from 2008. With this, there has also been an increase in interest in other dimensions of BMX. With eight studies dedicated to investigating belonging and another eight focusing on wellbeing, and some research has been undertaken to understand the social and psychological aspects of BMX. Research has established the positive effects that various levels of participation in sport has on identity formation, social skills, and positive youth development (Bruner et al., 2017), as well as sense of belonging and subjective wellbeing in adults (Inoue et al., 2020) and general resilience (Soria et al., 2022). This marks a significant shift towards recognising the importance of factors like community cohesion and identity formation within the BMX community. Conversely, hostility towards participants of active sports, of which BMX is one, has been found to develop entrenched feelings of alienation. This generates a "*disengagement threshold*" whereupon individuals give up striving for acceptance and became disconnected (Brown, 2016). This often leads to creation of sub-cultures and a rejection of mainstream sports and society.

Concurrently, the emergence of seven studies centred on marketing and commercialisation highlights an awareness of BMX's position within the broader sports industry and the economic influences shaping its trajectory. The initial formation of businesses "*by riders, for riders*" saw enterprises created by grassroots riders in the production of bikes, equipment, and related merchandise. These companies traditionally re-invested back into the community by organising events including exhibitions and contests to build their base of rider customers (Edwards & Corte, 2009). According to Edwards and Corte (2010), the mass commercialisation of freestyle BMX took three forms: paraphernalia, movement, and mass market (Edwards & Corte, 2010), which some riders argue altered the once carefree and highly supportive ethos of early BMX in response to the raised economic stakes (Edwards & Corte, 2009). This train of thought claims that a strong overlay of mass-market commercialisation has decentralised grassroots informal social networks of local lifestyle-sport scenes (Edwards & Corte, 2010). Counter-marketing concerns are now focused on maintaining

the image of spontaneity, unsupervised, "*risky, free, individualistic, and non-conformist character that separates them from mainstream activities*" (Giannoulakis & Pursglove, 2016, p. 128).

There has been a consistent focus on performance since 2008, indicating a sustained interest in understanding and enhancing BMX athletes' performance levels (Ryland & Roberts, 2019). Inclusion into the Olympics has impacted the research agenda relating to BMX, perhaps at the expense of the grassroots level cultures. The predominant focus on performance, with 49 studies, indicates a significant interest in understanding the factors influencing BMX athletes' performance levels. This trend suggests a strong emphasis on factors such as training methods, skill development, and competition strategies and is similar in other extreme sports with a particular burgeoning of literature around mountain biking performance (Chidley et al., 2015; Inoue et al., 2021). Following performance, the focus on injuries (16 studies) highlights a substantial interest in injury prevention and management. This trend underscores a recognition of the physical risks associated with the sport and efforts to mitigate them through research and intervention. Reflecting a focus on safety and technology in BMX, 14 studies concentrated solely on equipment, including bikes and helmets. This trend suggests ongoing efforts to enhance equipment design and promote safety standards within the sport. Finally, research on risk-taking (11 studies) indicates an interest in understanding the psychological and behavioural aspects associated with extreme sports, including risk perception, decision-making, and risk management strategies (Martinkova & Parry, 2017; Willmott & Collins, 2015).

Interestingly, Boudreau et al. (2020) argued that adventure recreation has the potential to provide opportunities to experience flow. They found "*flow experiences can be influenced through immersion in nature and a desire to control and reduce risk*" (Bourdreau et al., 2020, p. 1). Mitigating these risks has also become a focus in BMX research (Black et al., 2021).

While the number of studies on wellbeing and injuries fluctuates from year to year, there appears to be periodic spikes in interest, suggesting moments of heightened research activity around these topics. Studies focusing on marketing and commercialisation are present over recent years, reflecting a recognition of BMX's economic significance and the influence of marketing strategies on the sport's development. More broadly, there is growing body of literature sports entrepreneurs (Dobson & McLuskie, 2020) within the fitness sector, albeit BMX has not been a focus in these areas recently. Topics such as media have received relatively less attention compared to performance, equipment, wellbeing, and injuries. However, there are occasional spikes in research activity for these areas, indicating intermittent interest or emerging trends within the BMX research landscape. With the inclusion of BMX in the Olympics, this trend may change.

As reflected by its higher representation in the data, BMX research indicates a predominant focus on racing. This suggests that the majority of research has been directed towards competitive aspects of the sport, such as performance, training, and competition dynamics. The emphasis on performance implies a focus on the professionalisation of BMX, where participants may compete at a high level and have sponsorships or endorsements (Ellmer & Rynne, 2019). The results of this scoping review show limited exploration of grassroots and recreational participation in BMX riding outside of injury. We suggest that further research could include activities such as BMX street riding, park riding, or backyard ramp sessions, and trail riding which may not align with the structured formats of professional BMX competitions. The research emphasis on performance and competition possibly reflects the interests of researchers and funding priorities aimed at success at the Olympics.

The majority of BMX studies (48) have employed quantitative data collection and analysis methods. This reflects a strong preference for data-driven approaches, statistical analysis, and numerical measurements

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within BMX research. Following quantitative methodology, mixed methods have been employed in a significant number of BMX studies (23), indicating a recognition of the value of combining qualitative and quantitative approaches to provide a more comprehensive and deeper understanding of BMX phenomena. Qualitative methods have been employed in a smaller but still substantial number of BMX studies (16). This indicates a need for more qualitative approaches to exploring the nuanced psychosocial aspects of BMX culture, identity formation, and social interactions. Based on the findings of systematic review of research on BMX Racing, Rylands and Roberts (2019) recommend "*ecological research designs which places an emphasis on the interactions of the rider in their natural environment where actions are viewed as interconnected rather than separate*" (Rylands & Roberts, 2019, p. 8). While they are referring to research on performance, the results of the current review also shows this need for more multidimensional studies investigating BMX.

This scoping review found that the predominant focus of research has been on aspects related to quantitative studies of performance within the BMX riding community. However, what has also emerged is that there has been relatively limited attention given to broader themes such as rider wellbeing, creativity, and participation at a grassroots level. Echoing Rylands & Roberts (2019) call to include psychological factors such as coping skills, confidence, determination, we suggest there is a gap in the existing research literature, highlighting the need for further exploration of these neglected areas to provide a more comprehensive understanding of the BMX culture and its impact on riders' overall experiences and outcomes.

Limitations

The following limitations of this scoping review need to be acknowledged. Only articles written in English were included. Thus, it is possible that important articles on BMX have been published in languages other than English. Only peer reviewed journal articles were in scope and so the findings contained within book chapters, opinion pieces or grey literature have not formed part of our findings.

CONCLUSION

In conclusion, this scoping review has provided a comprehensive overview of the existing literature on BMX, revealing key trends, gaps, and potential areas for future research. The review has highlighted a predominant focus on performance and competition, reflecting the sport's evolution and increasing institutionalisation with its inclusion in the Olympic games. However, it has also underscored the need for more research on underrepresented areas such as gender equity, social and psychological aspects, and the cultural and economic significance of BMX, particularly in relation to socio-cultural aspects of this new Olympic sport.

The review has further revealed a strong research presence in countries such as the United Kingdom and the United States, with emerging contributions from Spain, Australia, France, and New Zealand. The majority of studies have employed quantitative methodologies, indicating a preference for data-driven approaches. However, there is a growing recognition of the value of mixed methods and qualitative approaches for exploring the nuanced aspects of BMX culture and social interactions.

Moving forward, it is crucial to address the identified gaps and diversify research approaches to foster a more inclusive, equitable, and comprehensive understanding of BMX. This includes incorporating more research on female riders, informal BMX riding styles such as trails and freestyle, and social and behavioural aspects of BMX riding from Humanities based disciplines. There is also a need for more qualitative research to gain a deeper understanding of the lived experiences of BMX riders, this also applies to high level athletes.

Addressing these gaps will not only contribute to the academic discourse but also inform policy and practice, ultimately enhancing the sport's positive social outputs and the wellbeing of its diverse community of riders.

AUTHOR CONTRIBUTIONS

Camilleri, D., lead researcher – screening texts, drafting, writing. Williams, R., screening texts, drafting, writing. Sallis, R. J. T., screening texts, drafting, writing. Hyde, C. L., screening texts. Quach, J. L., screening texts.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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