Sports Engineering (2024) 27:32
https://doi.org/10.1007/s12283-024-00472-6

PERSPECTIVE

Towards inclusive sports engineering research: considerations of research methods

Aimée C. Mears[1] · Elisabeth M. P. Williams[2] · Pui Wah Kong[3] · Paul Wood[4] · Kristina Brubacher[6] · Tom Allen[5]

Accepted: 14 August 2024

Abstract

Understanding and addressing the needs of diverse demographics is critical for creating sports products or technologies that can enhance the enjoyment, safety, or performance for more inclusive populations. This perspective article has identified opportunities for innovative sports engineering research by considering factors such as sex, socioeconomic background, culture, religion, age, ethnicity, or neurodiversity when developing research studies. The importance of considering diverse study populations, appropriate data collection methods, and ethical considerations to avoid biases is addressed and supported by research.

Keywords Inclusive · Sports · Research · Engineering · Physical activity · Methods

1 Introduction

Sports and physical activity should be accessible and inclusive for all individuals to help promote and facilitate overall healthier populations. Sports engineering research has made gains in fostering inclusivity for some demographics, such as advancements in prosthetics [1], sportswear for wheelchair users [2] and wheelchair designs [3] tailored for parasport participants. However, there is a scope to further inclusivity across other demographics as highlighted in a recent IMechE: Institute of Mechanical Engineers report [4]. Considering diverse demographic factors such as, sex, socioeconomic background, culture, religion, age, ethnicity, and neurodiversity, which have often been underrepresented in sports engineering research, presents an opportunity for generating innovative and novel research to be applied in sport/physical activity and beyond.

Sports engineering research should seek to develop products and technologies that address the diverse needs of varying populations when it comes to enhancing the enjoyment, safety or performance in sport and physical activity. Guidance produced on how to achieve diversity, inclusion and equity in clinical research shares many parallels to the challenges and considerations for sports engineering [5]. As such, there is an opportunity to readdress and consider research and data collection methods to promote inclusivity, eliminate any potential biases and further the applicability of the results to a wider demographic.

This perspective article will cover aspects relating to conducting research with inclusive populations for sports

✉ Aimée C. Mears
A.C.Mears@lboro.ac.uk

Elisabeth M. P. Williams
E.M.P.Williams@Swansea.ac.uk

Pui Wah Kong
puiwah.kong@nie.edu.sg

Paul Wood
paulw@ping.com

Kristina Brubacher
kristina.brubacher@manchester.ac.uk

Tom Allen
T.Allen@mmu.ac.uk

[1] Sports Technology Institute, Wolfson School of Mechanical, Electrical and Manufacturing Engineering, Loughborough University, Loughborough, UK

[2] Applied Sport, Technology, Exercise and Medicine (A-STEM), Faculty of Science and Engineering, Swansea University, Wales, UK

[3] National Institute of Education, Nanyang Technological University, Singapore 637616, Singapore

[4] PING Inc., Phoenix, AZ 85029, USA

[5] Manchester Metropolitan University, Manchester, UK

[6] Department of Materials, University of Manchester, Manchester, UK

Published online: 26 September 2024

engineering applications. The article aims to raise awareness for engineers and researchers to potential biases and wider ethical considerations in sampling, data collection methods and measurement instrument choices when considering submitting to the Sports Engineering journal or other journals. Published research will be used to highlight some of these aspects, emphasizing the importance of interpreting study findings within the context of the specific population studied.

2 Study populations and sampling

A large proportion of sports engineering research requires knowledge of users whether it is direct measurements of users (e.g., biomechanics, perceptions) or establishing real-world boundary conditions for the design or testing of new equipment/technology via computer simulations or built prototypes. Authors should, therefore, be critical of the study populations they include, or have previously included in studies, and how these could influence the interpretation of results or be a limitation of the study. A lack of female specific research has already been acknowledged in the field of sport and exercise science, with a 2021 study highlighting only 34% of participants were females, across 5261 included studies, and less than 10% of the studies focussed only on females [6]. This disparity could be even more pronounced in certain sports. For instance, a systematic review of golf biomechanics found that this disparity was higher (89% of participants were male, 11% female) [7]. From January 2021 to February 2024, the Sports Engineering journal has published 48 studies involving human participants, with 32% including females (7% female only), 58% males and 10% provided no further information. Many of these studies analyzed male and female data collectively, however, drawing conclusions on a combined cohort could be problematic, application specific and not readily applied to both sexes [8]. For example, Swaren and Fahlstedt [8] examined the impact attenuation performance of ice hockey helmets for both male and female teams after a hockey season. They observed that the rules for female ice hockey teams do not permit deliberate checking, which could result in different patterns and locations of helmet damage compared to the male game. This context enabled the authors to interpret their findings in a more meaningful way. For female focussed research, there is also a scope to further segment the population and consider how the stage in a woman's lifespan (e.g., menopause or pregnancy) could influence aspects of sports engineering research outcomes such as aspects relating to thermoregulation [9] or female-specific products such as sports bras [10].

The interaction and adoption of products/technologies by users is often of interest for sports engineering researchers. To generalize results for different ages, races, or ethnicities could be problematic when experiences, culture, and religion can influence study objectives and outcomes. When considering age, sporting equipment, apparel, and footwear for children and adolescents should not be mere replicas of adult counterparts. Instead, they should be carefully designed and scaled to suit children's specific anthropometrics and developmental stages, as evidence indicates that these factors impact their performance [11, 12].

The approval of religious head coverings in football, provided they meet medical standards, highlights the importance of considering religious needs in sports engineering research to ensure proper development, testing, and validation of future products [13]. By utilizing purposeful diverse sampling methods, Nield et al.'s [14] study on the perception of three-dimensional surface imaging technology, a technology readily used for sports engineering applications such as compression garment development, revealed that participants from various genders, socioeconomic backgrounds, ethnicities, and ages had differing emotional responses to the technology. These differing responses might present measuring challenges if the technology is adopted on a larger scale.

Non-probability sampling methods (defined as a sampling method where not all the population have a known or equal chance of being selected for the study) are common in sports engineering research based on convenience sampling but should acknowledge the challenges of recruiting underrepresented populations. Typical statistical methods are often based on either the power or precision of previous studies which are subsequently reliant on participant numbers to determine the most suitable sample size [15]. While determining appropriate sample sizes for underrepresented population has received less attention, alternative sampling methods like Bayesian adaptive sampling or big data sampling, as used in clinical research, could be considered [16]. Alternatively, as Nakashima and Chida [17] acknowledge, only having a single unilateral armed swimmer as a participant reduces the generalizability of the results but it is still important to consider as a case study example for the innovative possibilities of sports engineering in solving solutions for diverse populations [18, 19]. For smaller population cohorts, authors could also consider alternative study design methods such as single subject study designs [20].

3 Data collection methods and measurement instruments

Many articles published in the Sports Engineering journal involve the development of new technologies, products, or measurement tools for users. The development and design processes often require interaction with participants to uncover their needs. However, care should be taken about the approaches used when involving participants with

cognitive impairments, such as autism, who could have difficulty processing information and whose needs may not currently be met in some sporting contexts [21]. Interviews or questionnaires may be challenging for people with cognitive impairments and may require additional support to take part in studies [22] and should rely on person-centred language to ensure it is non-stigmatising to the participant [23, 24]. Following best practice guidelines / resources from established organisations for the groups they may be working with (e.g., disabled people) would be a suitable approach.

Differences in socio-cultural environments could also change ways in which users interact or perceive technologies, for example the use of wheelchairs [25]. Other subtle cultural differences could also be important to consider in product prototype development, for example, the colour of sports apparel, as in some cultures white clothing is associated with newness (e.g., marriage) but death in others (e.g., Japanese or Chinese culture) and would require adaptation across cultures. Additional measures such as translating participant recruitment materials, participant instructions, and research outputs into a participant's first language would be beneficial, however, it is crucial to ensure content validity and maintain conceptual consistency across cultures, as demonstrated in guidance for healthcare self-reported measures [26].

Conducting lab-based studies offers the benefit of controlling extraneous factors. However, it is important to consider accessibility and inclusivity when selecting research methods. Physical barriers, such as mobility difficulties or childcare/caring responsibilities, can prevent certain populations from participating in lab-based studies. To address this, incorporating non-lab-based approaches can remove these barriers and ensure the inclusion of diverse populations. For example, with alternative data collection approaches such as pop-up or temporary research sites, adopting citizen science research approaches (defined as a process whereby scientists and general population collaborate to capture data [27]) or field-based data collection methods. Field based data collection, utilising wearable technologies, has gained popularity in Sports Engineering in recent years, allowing data collection in real-world settings [28]. By embracing these tools, researchers can access data from individuals who may face challenges attending a physical lab. Additionally, engaging with potential participants prior to study design can help identify barriers and tailor research methods, accordingly, ultimately improving participant retention and enhancing the overall quality of the study. When engaging with participants before the study, it would be important to address only critical study design aspects and avoid providing feedback or influencing their responses to ensure unbiased participation in future studies.

The use of artificial intelligence, computer vision, and machine learning is also becoming more popular in sports engineering research, but caution has been raised about possible biases in their implementation [29]. When using machine vision and artificial intelligence methods researchers should be cognisant of possible variations that may arise due to the measurement technology itself and adjustments to processing algorithms might be required. For instance, when three-dimensional body scanning technologies utilising computer vision algorithms were compared to gold standard technologies (e.g., dual energy X-ray absorptiometry), differences in body composition were discovered when groups were segmented by ethnicity. These differences required adjustments to the measurement algorithms [30]. Similarly, the pose estimation of individuals with missing limbs and atypical movement patterns can be challenging and may also require more complex algorithms [31].

4 Ethical considerations

Considering the type and terminology used to identify study populations is often a key requirement in ethics applications for gaining approval to conduct studies with human participants. The terminology used to define populations should therefore be carefully considered such as identifying participants' gender or sex, race or ethnicity and how it is reported. The International Organisation for Standardisation (ISO) and the United Nations Human Rights, Office of the High Commissioner both provide a comprehensive database of terms and definitions which authors submitting to Sports Engineering should consider accessing when determining appropriate and consistent terminology [32, 33]. Similarly, defining the eligibility criteria is a key requirement for ethics applications which plays an important role in ensuring the safety and protection of participants in studies. However, exclusion criteria of participants (predominantly regarding those with disability) require sufficient justification so as not to be identified as a source of discrimination as has been highlighted as a problem in clinical research [34]. There is a tendency in research to only include "healthy" populations in sports studies and exclude people who are or may be pregnant, have had previous surgery or had recent injuries. Whilst this can protect the participants in some instances, (i.e., experimenting something new which is deemed risky/harmful such as new sport equipment), by excluding these participants it also means that the findings cannot be applied to these people who could also benefit from the products.

5 Conclusion

The Sports Engineering journal is committed to increasing and promoting research for inclusive populations, to help ensure the development of innovative sports products and

Fig. 1 Key considerations for promoting inclusivity in sports engineering and technology research

technologies. This commitment is evidenced with the latest call for papers to the topical collection "Inclusive Sports Engineering and Technology Research". This perspective article intended to highlight ways to approach inclusive research in sports engineering. For future authors submitting manuscripts to the journal, a list of considerations based on this article include, but are not limited to Fig. 1:

- Where possible, and appropriate, actively seek to include participants from varied backgrounds, including different sexes, genders, ages, ethnicities, and abilities and provide justification for their inclusion.
- Carry out preliminary investigations to identify potential barriers to participation, such as accessibility issues, language differences, and technological proficiency and implement support strategies or alternative data collection methods.
- Develop research questions and methodologies that account for the diverse needs and perspectives of all potential participants.
- Establish ongoing feedback from participants and stakeholders to continually refine and improve research practices.

By carefully considering these various aspects we can promote inclusive research. This ensures that future sports products, technologies, and services prioritise safety, performance, and enjoyment for all participants in sport or physical activity.

Declarations

Conflicts of interest Aimée Mears is Associate Editor of the Sports Engineering journal. Tom Allen is Editor-in-Chief of the Sports Engineering journal. Elisabeth Williams, Pui Wah Kong and Kristina Brubacher are all Editorial Board members of the Sports Engineering journal and guest editors of a topical collection.

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