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Increasing women's participation in biomechanics through National Biomechanics Day events

Maddison M. Kirk [a,*], Joshua P.M. Mattock [a], James R. Forsyth [a], Celeste E. Coltman [b], Julie R. Steele [a]

[a] Biomechanics Research Laboratory, School of Medical, Indigenous & Health Sciences, Faculty of Science, Medicine & Health, University of Wollongong, Australia
[b] University of Canberra Research Institute for Sport and Exercise, Faculty of Health, University of Canberra, Australia

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ABSTRACT

Science, technology, engineering and mathematics (STEM) occupations represent one of the broadest gender gaps in any professional field, with women and girls grossly underrepresented in STEM education and careers, particularly engineering and biomechanics. Factors such as bias, stereotyping, and a lack of female role models can significantly influence women's and girls' decisions to enter and remain in the field of biomechanics. A critical first step in increasing the number of female biomechanists is to create early opportunities for girls to explore biomechanics. To address this, international initiatives, such as National Biomechanics Day (NBD), have been developed to expand the awareness, influence, and impact of biomechanics by engaging young people in school biomechanics programs. The Biomechanics Initiative, the official sponsor of NBD, offers grant programs aimed at empowering women to host an NBD event designed to promote biomechanics to girls and women in an immersive, interactive, and engaging manner. In 2021, Biomechanics Research Laboratory (BRL) Ph.D. student Maddison Kirk was a recipient of the grant program. In this paper we describe the BRL NBD event, which involved 20 female athletes from diverse backgrounds, demonstrating to them how biomechanics can be used to assess their physical fitness and performance. Female biomechanists and research assistants running the NBD event acted as female role models to participants, increasing the visibility of women in biomechanics and, in turn, helping to address current bias and stereotyping in STEM. By diversifying biomechanics and ensuring STEM fields are representative of the society in which we live, we can advance the field of biomechanics both nationally and internationally.

1. Gender disparity in biomechanics

Rapid technological change is driving new workforce needs. As many industries become reliant on emerging technologies, the demand for science, technology, engineering, and mathematics (STEM) skills is becoming increasingly widespread (Office of the Chief Scientist, 2022). Unfortunately, STEM occupations represent one of the broadest gender gaps of any professional field (Emelianova & Milhomen, 2019; Frazway et al., 2009; Kersley et al., 2019), with females grossly underrepresented in STEM education and careers. Statistics illustrate the disparity between males and females studying and working in STEM, particularly engineering. Specifically, in Australia, only 16 % of individuals who graduate with an engineering degree are women, and men are four times more likely to graduate with a Masters and Ph.D. in engineering than females (Bendemra, 2012; OECD., 2019; Romanis, 2022). The low representation of women in engineering has flow-on effects regarding the number of women represented in the field of biomechanics.

Biomechanics is a sub-discipline of biomedical engineering that fundamentally merges the various components of STEM (DeVita, 2018). It combines engineering, physics, and computational mathematics with biology to understand human and animal movement. Recent data from the International Society of Biomechanics in Sports (ISBS) confirms that gender disparity still exists in biomechanics. For example, in 2021, twice as many males attained professional membership of ISBS compared to females (68 % vs 32 %) (Breen & Janssen, 2022). Furthermore, only one woman (5 %) has ever received the Muybridge Medal, the most prestigious award of the International Society of Biomechanics (ISB) (https://isbweb.org/activities/awards-and-honours/muybridge-award). This

* Corresponding author at: Biomechanics Research Laboratory, School of Medical, Indigenous & Health Sciences, University of Wollongong, New South Wales, Wollongong 2500, Australia.
E-mail address: mkirk@uow.edu.au (M.M. Kirk).

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gender disparity must be addressed to diversify biomechanics because female biomechanists bring different ideas and perspectives to roles and research that can enrich and expand the field (Steele, 2022).

The causes of poor attraction and retention of girls and women in biomechanics begin from an early age and can be explained using the analogy of a "leaking pipeline". Specifically, statistics gathered from Ontario, Canada revealed that there is an equal ratio of boys and girls studying essential STEM subjects in the early years of education. However, throughout the pipeline, there are places where girls and women "leak out" of STEM fields, particularly when selecting senior high school subjects. In the later years of high school, 50 % fewer female students decide to study maths and physics subjects compared to their male counterparts (OECD, 2019). Subsequently, women are underprepared and underqualified to enroll in science, engineering, and mathematics degrees at a tertiary level necessary for graduate study in biomechanics. This leads to fewer females undertaking STEM-based degrees at a tertiary level and choosing to pursue a graduate degree in biomechanics. Consequently, fewer females are attracted to and retained in biomechanics faculty, industry, and management positions post-Ph.D. Ultimately, this results in a disproportionate number of men and women in STEM workplaces and senior-level leadership positions (Australian Government, 2019).

2. What is causing the gender disparity in biomechanics?

The causes of this gender inequality in STEM, particularly engineering and, subsequently, biomechanics, are broad and complex. Women and girls face multiple barriers to STEM participation. As a result, females must overcome more challenges than their male counterparts (Hughes, 2018; Estrada et al., 2016) to succeed in STEM and biomechanics. Factors such as bias and stereotyping, lack of confidence and encouragement, and particularly a lack of female role models greatly influence girls' and women's decisions to enter and remain in STEM education and careers (Dee & Gershenson, 2017).

Experiences of bias, stereotyping, and cultural and sociological issues begin early in life and significantly impact females' development of confidence (Ceci et al., 2009; Dee & Gershenson, 2017) and their interest in biomechanics. The perception that some STEM fields are more appropriate for males, particularly by influencers such as parents, educators, and career counselors, is one of the most significant barriers to females participating in STEM (Dee & Gershenson, 2017). A lack of diverse female role models further decreases girls' and women's likelihood of persisting in STEM education and careers. A recent survey by the International Women in Biomechanics (IWB) group supported the need for female role models in biomechanics. One hundred and forty-six female members of the IWB were asked, "*What are your biggest concerns about being a woman or non-binary person in biomechanics?*". The two biggest concerns were: (i) the lack of female role models, mentoring, and support in career progression, and (ii) not being taken seriously and missing out on opportunities due to biases (Ebrahimi et al., 2023).

3. How do we address the gender disparity in biomechanics?

Gender disparity issues in biomechanics are broad-ranging and intersectoral. Thus, a multifaceted approach involving all levels within the field is needed to support, guide, and advocate for gender equity in biomechanics. A critical first step in increasing the number of female biomechanists is to create early opportunities in the pipeline for girls to explore biomechanics. Critically, this must be before subject selection in the final years of high school to reduce the flow-on effects. Despite numerous potential applications of biomechanics, it is not an obvious career path for many students, particularly females (DeVita, 2018). Therefore, biomechanics must be made more accessible to the public so that women and girls can be excited, educated, and involved in the discipline. By showcasing how biomechanics applies to everyday life and activities of daily living, its relevance can be illuminated to change the way girls think about themselves being biomechanists. A strong and supportive education that encourages girls' interests in STEM builds the foundation, skills, and self-confidence for girls to aspire to a career in a STEM field (Australian Government, 2019). Empowering girls and supporting their teachers and parents is critical in creating a supportive environment that encourages females to join and remain in the field throughout their education and careers. Therefore, we must create diverse, strong role models to ensure women in biomechanics are visible and help address the bias and stereotyping in STEM. Increased visibility of biomechanics careers will ensure that females are aware of the many different pathways a biomechanics career can take. Several international initiatives have been developed to expand the awareness, influence, and impact of biomechanics by engaging young people in school biomechanics programs and research projects. One of these initiatives is National Biomechanics Day (NBD).

4. National Biomechanics Day as a strategy to increase participation in biomechanics

National Biomechanics Day seeks to increase awareness of biomechanics among young people, leading to more people choosing to study and pursue careers in biomechanics. This goal is achieved through worldwide synchronized and coordinated celebrations of biomechanics with school students. Since its inception in 2016, 434 NBD events have been conducted, involving over 32,000 school students across 31 nations. Of the 32,000 participants involved in these events, 50 % were female (DeVita, 2018). National Biomechanics Day has also explicitly targeted events for female students, offering grant programs to support initiatives for girls. For example, since 2021, The Biomechanics Initiative, the official sponsor of NBD, has awarded 12 "Outreach for Women in Biomechanics" grants (valued at USD 1,000 each) to female and non-binary Masters and Ph.D. students within the field of biomechanics. The grant program aims to empower women to host an NBD event designed to promote biomechanics to girls and women in an immersive, interactive, and engaging manner. In 2021, one such grant was awarded to Ph.D. student Maddison Kirk from the Biomechanics Research Laboratory (BRL) at the University of Wollongong, New South Wales (NSW), Australia. This initiative is described below.

5. The BRL hosts National Biomechanics Day

To maximize female participation, the BRL invited two Premier League netball teams to participate in an NBD event held in February 2021 in NSW, Australia, which we describe below. Netball is one of the most popular team sports played by women in Commonwealth countries (International Netball Federation, 2022), with over half a million female athletes in Australia (Australian Sports Commission, 2019). Netball is a fast-paced game in which two teams of seven players compete for possession of the ball (International Netball Federation, 2022). At the end of the match, the team with the most goals scored is the winner. The sport requires players to perform repeated bursts of rapid acceleration to "break free" from a defender in combination with sudden changes of direction and frequent jumping to receive a pass or intercept (Steele, 1990). However, despite Premier League being the pinnacle of netball competition in NSW, these athletes had limited or no previous access to any systematic assessment of their physical performance using biomechanical tools. This lack of scientific support for female sports is, unfortunately, unsurprising. Therefore, we saw this event as an ideal way to immerse female athletes in activities with a strong biomechanics flare, which was highly relevant to this eager cohort.

Twenty female athletes aged between 15 and 25 years from different backgrounds (see Fig. 1) and their coaches (n = 5) accepted our invitation to participate in our NBD event. Maddison Kirk, mentored by Emeritus Professor Julie Steele and helped by several female research assistants (Emma Houghton, Emily Kirk, Natalie Sligar and Paige Penrose), acted as female role models for the participants. Creating diverse,

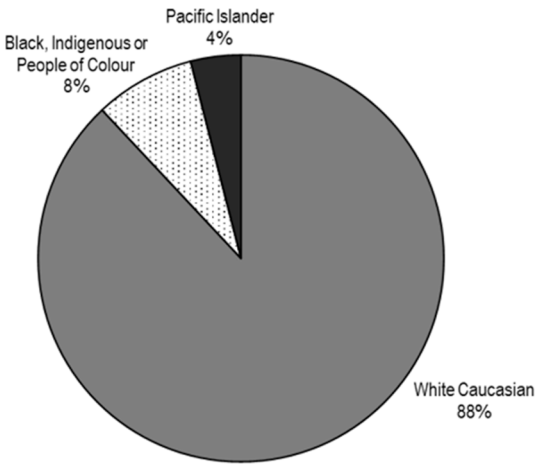

Fig. 1. Backgrounds of the participants from the NBD event ($n = 20$).

strong role models is vital to ensure that women in biomechanics are visible and, in turn, help to address current bias and stereotyping. The director of the BRL, Dr Joshua Mattock, and other male BRL team members, Dr James Forsyth and Jarred Cooper, were strong allies throughout the event, helping to run the activities. To facilitate access to the participants, we traveled to the team's training venue to host the event at a time that suited the players and their coaches.

During the event, we assessed each player's physical performance using a variety of tasks involving biomechanical instrumentation. This included activities such as evaluating the players' lower limb strength using the isometric mid-thigh pull test on a portable force platform, assessing their vertical jump and landing technique via countermovement and drop jumps onto portable force platforms (50 cm × 60 cm each, Type 9260AA6, Kistler Instruments Australia Pty ltd, Australia), and quantifying speed and change of direction ability through timed 20 m sprints and 5–0-5 tests (SmartSpeed Pro, Fusion Sport Pty ltd, Australia; see Fig. 2 A, B & C). Some players also had their foot shape quantified using a three-dimensional foot scanner (Tiger full foot 3D scanner, RS scan International NV, Paal, Belgium), and we measured the forces they generated while performing a variety of netball-specific movements (e.g., running, jumping, and cutting) using pressure insoles (Novel loadsol-t, Munich, Germany) see Fig. 3). Throughout the event, the athletes were taught to visually interpret their data from graphs produced on iPads and computers (see Fig. 4). Following the event, each participant's data were analyzed, and individual athlete performance reports were produced and distributed to the participants and their coaches (see Appendix). We also discussed the results with each athlete, so they were aware of their strengths and any areas that required further development. These data were then used to inform individualized strength and conditioning and injury-prevention programs for each participant. With the player's permission, the BRL shared photos and videos (see video https://youtu.be/JDfwOeMZSos) from the NBD event on various social media platforms, including Twitter (@BRLUOW), Facebook (Biomechanics Research Laboratory), and Instagram (@BiomechanicsResearchLab). These photos and videos further increased the positive exposure of female athletes participating in biomechanics activities to a broader audience and showcased women running these activities.

Our NBD event successfully demonstrated to the female athletes how biomechanics could be used to assess their physical performance. Furthermore, many participants expressed a desire to pursue tertiary education aligned with their passion for netball, such as a degree in Exercise Science. Participants were very engaged in the activities and asked the BRL members questions regarding the subjects and degrees they had undertaken to pursue careers in biomechanics. One participant stated: *"Participating in these fitness tests today has been really exciting to see all of the different things that go into biomechanics, and especially seeing females like Maddy and Julie in the field is really exciting, especially because I'm finishing high school and wanting to go into something [degree] similar"* (Biomechanics Research Laboratory, 2021; https://youtu.be/JDfwOeMZSos).

Although the event confirmed that many of the female participants had little to no prior knowledge or experience in biomechanics, we did not systematically collect data about the participants' perceptions about biomechanics. We, therefore, recommend that hosts of future NBD events gather data before, during, and after an event to be able to quantify and evaluate the impact of the activities on the participants' perceptions about biomechanics. Furthermore, we recommended collecting similar pre- and post-event information from any young female mentors involved in an NBD event to be able to evaluate the impact of the event on the mentors' perceptions of biomechanics and their retention in the field. During our event, the BRL team operated the biomechanical equipment to collect data while the participants performed the planned activities. In future events we would design additional activities to allow the participants themselves to gain "hands on" experience using appropriate biomechanical equipment to further empower and engage the girls in these unique STEM initiatives.

6. Other STEM initiatives to increase women in biomechanics

The NBD initiative described above has been designed to raise awareness of biomechanics among young people and to increase the number of girls entering the pipeline to pursue education and careers in biomechanics. There have been an increasing number of other initiatives worldwide to increase schoolgirls' exposure to biomechanics, as well as to retain women in biomechanics and stop women from "leaking out" of biomechanics at critical phases of their careers (e.g., in their early career post Ph.D.). These initiatives include innovative programs such as the "Biomechanics Research and Innovation Challenge" (BRInC; see website https://www.canberra.edu.au/about-uc/faculties/health/brinc). The BRInC program is a 100-day research and innovation challenge involving 100 Australian high school girls from different cultural and socioeconomic backgrounds and regional areas who work with 25 early-career female biomechanists (Cherry, 2022). The girls conduct a biomechanics project, supported by female mentors, and attend a series of immersive workshops to build critical STEM skills. Simultaneously, early career biomechanists access training and support to develop their expertise as STEM mentors and future leaders and network with other early and mid-career female researchers in the field.

To try and retain women in biomechanics, in 2015, the International Society of Biomechanics (ISB) initiated an Inaugural "Women in Biomechanics Lunch," which was designed as "A networking and conversation forum to celebrate contributions from the women of ISB over lunch." Based on the overwhelmingly positive response to this luncheon, ISB has since hosted "Advancing Women in Biomechanics" events and workshops at ISB Congresses to address gender bias and stereotyping in biomechanics and to encourage men as allies. Affiliate societies to ISB, such as the Australian and New Zealand Society of Biomechanics, now host similar events, for example, the Women's breakfast at their biannual Australasian Biomechanics Conference. In 2021, the ISB also introduced the "Jacquelin Perry Emerging Female Scientist Award", designed to acknowledge female researchers who have performed superior biomechanics research early in their career, with a monetary award of $5,000 USD to be used for research purposes. The IWB group was formed in 2019 to support early and mid-career female biomechanists (see website https://intlwomxninbiomech.wixsite.com/website). With over 500 members from ~ 150 universities across 20 countries, the IWB aims to foster an environment where women in biomechanics can gain support, advice, and mentorship throughout their careers (International Women in Biomechanics, 2022). The IWB achieves its goal by hosting regular events and meetings and holding a platform where members can network, seek support for professional

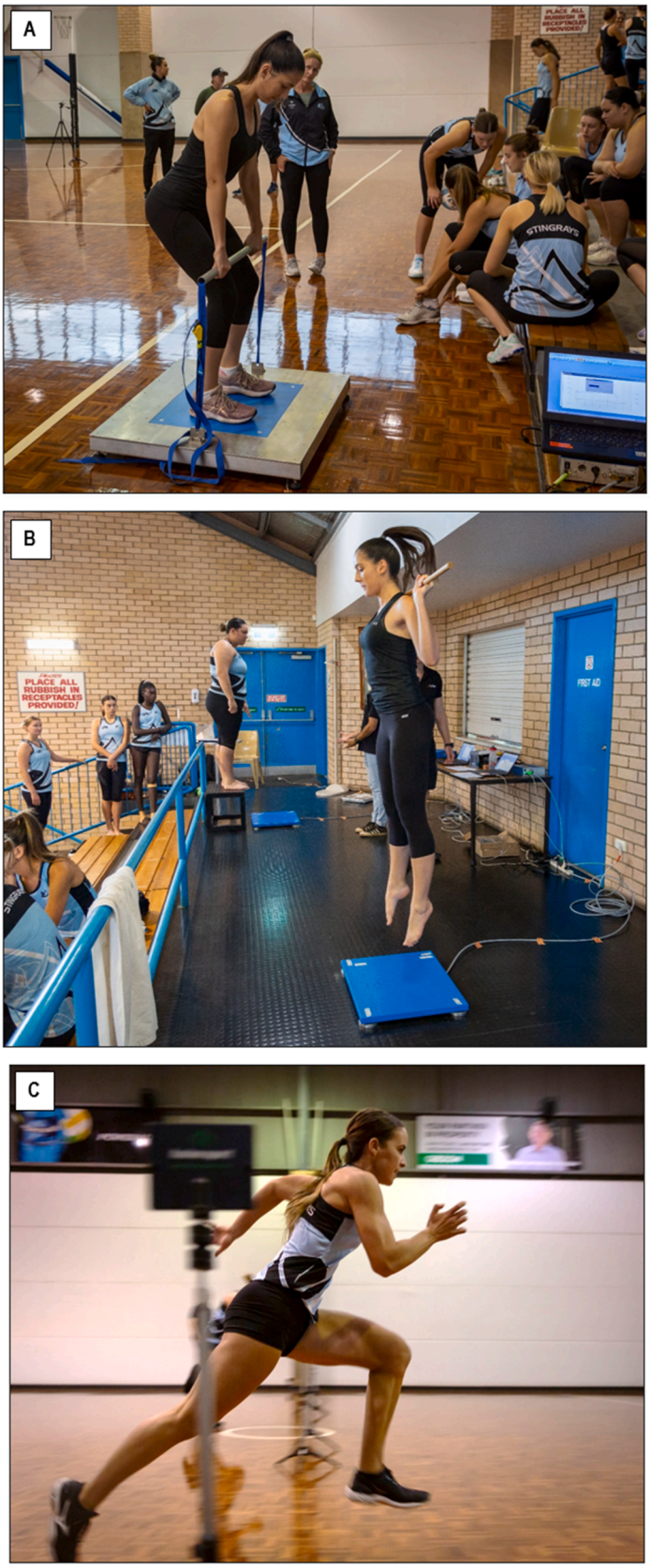

Fig. 2. A) Netball athlete performing an isometric mid-thigh pull test on a Kistler force plate to assess lower limb strength. B) Netball athlete completing a countermovement jump on a Kistler force plate to assess vertical jump. C) Netball athlete completing a timed sprint trial using timing gates.

Fig. 3. Netball athletes perform netball-specific movements (e.g., running and catching a netball) to determine the forces generated using Novel Loadsols and the Loadsol application on an iPad.

Fig. 4. National Biomechanics Day host, Maddison Kirk, explains to the participants how to interpret biomechanical data during the NBD event.

issues, and celebrate each other's successes (International Women in Biomechanics, 2022). These initiatives, in addition to the NBD events, have increased participation and inspired more young girls to consider pursuing education and a career in biomechanics, as well as creating a supportive network of women in biomechanics so that they are retained within the field (Cherry, 2022).

7. Conclusion

Despite it being 2022, women and girls are still underrepresented in STEM education and careers, including biomechanics. Factors such as bias, stereotyping, and a lack of female role models can significantly influence women's and girls' decisions to enter and remain in the field of biomechanics. Initiatives such as NBD aim to increase the awareness of biomechanics among young people and, via specific programs, aim to ultimately lead to more women and girls choosing to study and commence careers in biomechanics. Grant programs offered by The Biomechanics Initiative and NBD have been successful in reaching underserved populations and helping to address the bias and stereotyping that currently exist in STEM. By diversifying biomechanics and ensuring STEM fields are representative of the society in which we live, we can make more impactful and inclusive advancements to the field of biomechanics on a global scale.

8. Role of the Funding Source

The Biomechanics Initiative and the International Society of Biomechanics funded the NBD Outreach for Women in Biomechanics grant that supported our NBD event.

CRediT authorship contribution statement

Maddison M. Kirk: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Joshua P.M. Mattock:** Writing – review & editing, Supervision, Methodology, Investigation. **James R. Forsyth:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Celeste E. Coltman:** Writing – review & editing, Supervision, Conceptualization. **Julie R. Steele:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization.

Declaration of Competing Interest

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

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbiomech.2023.111433.

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