



Pioneering women of the International Society of Biomechanics[☆]

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ABSTRACT

The presence of successful female role models in biomechanics can encourage girls, women, and other under-represented groups in STEM fields to pursue and remain within the discipline. It is, therefore, vital that women and their contributions to the field are publicly visible and recognized across all areas of professional biomechanical societies, such as the International Society of Biomechanics (ISB). Enhancing the visibility of female role models in biomechanics can act to mitigate current bias and stereotyping in the discipline by broadening what it looks like to be a biomechanist. Unfortunately, women are not publicly visible in many aspects of ISB activities, and finding details of women's contributions to ISB, particularly during ISB's formative years, is challenging. This review article aims to raise the visibility of female biomechanists, particularly women in ISB leadership positions who have helped shape the Society over the past 50 years. We summarize the unique backgrounds and contributions of some of these pioneering women who blazed pathways for other female biomechanists. We also recognize the women who were charter members of ISB, women who served on ISB Executive Councils and the portfolios they have held, women who have received the highest awards of the Society, and women awarded a Fellowship of ISB. Practical strategies to enhance women's participation in biomechanics also are presented so that women can thrive and progress in ISB leadership positions and awards and, in turn, serve as positive role models to encourage girls and women to pursue and remain within this unique discipline.

1. Introduction

The International Society of Biomechanics (ISB) was founded in 1973 during the 4th International Seminar on Biomechanics, hosted by the Pennsylvania State University, USA. The 259 participants who attended this seminar were deemed charter members of the Society (Challis, 2006). Of these charter members, only 18.9 % were women (Table 1). A 2004 survey completed by 246 ISB members, three decades after ISB was founded, revealed that the percentage of members who identified as female was relatively unchanged at 21 % (Rodgers, 2004a). The low percentage of women within the ISB is not surprising given that today there is a disproportionate underrepresentation of women in science, technology, engineering, and mathematics (STEM)-skilled workforces globally. For example, although in 2022 close to 50 % of the workforce in Australia were women, they comprised only 16 % of Australia's STEM-skilled workforce (Arabia, 2022). Engineering, the discipline from which many biomechanists emerge, remains the STEM

field with the lowest proportion of women (Leigh et al., 2020). Similarly, in the USA, in 2019, women were vastly underrepresented in engineering occupations, comprising only 15 % (Fry et al., 2021).

1.1. Why Include Women in Biomechanics?

There are numerous compelling reasons why we must equitably include women in science-related fields such as biomechanics (Bert, 2018; Kirk et al., 2023). For example, women bring different perspectives to biomechanics research than men and are more likely to explore crucial female-centric research topics, such as breast health or pelvic floor biomechanics. Unfortunately, male reviewers have previously deemed such female-centric research "likely not relevant to the [biomechanical] audience" (Steele, 2022). We must work together to conquer deep-rooted gender stereotypes, and biases ingrained in our institutions. By mitigating these persistent stereotypes and biases and celebrating the impact of successful female role models in biomechanics,

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Table 1
Female* charter members of the International Society of Biomechanics.

First Name	Last Name	Country
Marlene	Adrian	United States
Julia	Aegerter	United States
Marion J.L.	Alexander	Canada
Anne E.	Atwater	United States
Angela	Ballreich	Germany
Katherine	Barthels	United States
Florence	Brush	United States
Annie	Clement	United States
Ruth	Conrad	United States
Helga	Deutsch	United States
Patricia D.	Downie	Australia
Barbara A.	Fecht	United States
Marilyn M.	Flint	United States
Micheline	Gagnon	Canada
Gladys E.	Garret	United States
Gale	Gehlsen	United States
Barbara	Gowitzke	Canada
Geraldine A.	Greenlee	United States
Ditza	Gross	Canada
Leslie D.	Gross	United States
Ruth W.	Harris	United States
Betty H.	Haven	United States
Marilyn M.	Hinson	United States
Genevieve H.	Hunebelle	Belgium
Anne E.	Irwin	United States
Francoise K.	Jouffroy	France
Ellen	Kreighbaum	United States
Angela	Kuhlow	Germany
Dorothy A.	Legget	Canada
Kathryn	Luttgens	United States
Mary E.	McKee	United States
Doris	Miller	Canada
Marjorie G.	Owen	United States
M. Joan	Popp	United States
Bonnie L.	Pronk	Canada
Jean Landa	Pytel	United States
Elizabeth M.	Roberts	United States
Diane	Ross	United States
Heidrun	Schewe	Germany
Therese	Simard	Canada
Joan M.	Stevenson	Canada
Susan M.	Tendy	United States
Ella M.	Trussell	United States
Joan C.	Waterland	United States
Joan	Weston	United States
Carol J.	Widule	United States
Judith	Wilson	United States
Gloria	Young	United States
Carole J.	Zebas	United States

* Of the 259 charter members, the gender of two individuals could not be established. We have therefore excluded the names of these individuals from this table. Although some charter members were not active on the ISB Council and are therefore not profiled in this article, they indirectly impacted the Society in other ways. For example, charter member Elizabeth (Betty) Roberts was the primary PhD supervisor for Ron Zernicke, who later served as an impactful ISB President (1993–1995).

we can encourage girls and women to pursue and remain within science-related fields (Van Schooten et al., 2021). This is often colloquially summarized as “...you can’t be what you can’t see” (Australian Academy of Science, 2019). It is, therefore, vital that women, especially women in high-status and leadership positions (Olsson & Martiny, 2018), are publicly visible across all areas of the ISB to create strong female role models and broaden what it looks like to be a biomechanist (Ebrahimi et al., 2023; Kirk et al., 2023).

Unfortunately, women are not visible in many aspects of ISB activities, and finding details of women’s contributions to the ISB is challenging. Interestingly, in the ISB newsletter archives, references to women were extremely scant during the Society’s formative years. Most ISB leadership positions were filled by men, profiles of biomechanics laboratories globally rarely referred to female researchers, and

advertisements for biomechanics equipment often depicted women as ‘models’ rather than scientists. It was not until 26 years after the ISB was founded that, in 1999, a woman was elected by the ISB membership to the key leadership position of President-Elect.

1.2. Aim of the Article

This review article aims to highlight and raise the visibility of those female biomechanists who have held high-status ISB leadership positions and who have won the most prestigious ISB award. This article is not intended as a history of biomechanics, which is well described elsewhere (e.g., Atwater, 1980; Nigg, 2007; Norman, 1992). Instead, we aim to provide a glimpse into the unique backgrounds and contributions of some of the pioneering women who impacted how the ISB developed as a professional society, particularly those women who blazed pathways for other female biomechanists. In addition to acknowledging each woman’s contribution during the ISB’s development, these descriptions provide biographies of role models, which educators can use to increase interest among students and trainees studying biomechanics (Shin et al., 2016).

2. Women in ISB leadership roles

An Executive Council governs the ISB, together with The General Assembly of Members (<https://isbweb.org/about-us/constitution>). In the ISB’s 50-year history, women have held only ~ 17 % of Executive Council positions, with most Councils until 1989 consisting only of white men (Fig. 1). More specifically, since 1973, women have only held:

- 3 of the 24 positions (12.5 %) as President,
- 1 of the 13 positions (7.7 %) as Secretary General,
- 2 of the 11 positions (18.2 %) as Newsletter Editor, and
- 0 of the five positions (0 %) as Treasurer.

The one domain women have dominated is the Student Representative position. Although Motoshi Kaya was appointed as the first Student Representative, student members have since elected women to the position on every ISB Council, despite numerous male candidates (see Section 2.6).

Despite only holding 12.5 % of the ISB presidential positions, these women have played pivotal roles in shaping the ISB into the professional society we know today. Below we profile the first few pioneering women to hold positions on Council. Table 2 lists the women who have served on the ISB Executive Council and the portfolio each woman held. Although word limits do not allow us to detail every woman’s contribution, the tremendous impact of the women listed in Table 2 in shaping the ISB is gratefully acknowledged.

2.1. Doris Ida Miller (1939-)



Doris Miller was a member of the first ISB Executive Council and the first woman to serve on Council. In 1973 the ad hoc Organizing Committee proposed the first ISB Council, which the ISB charter members then confirmed (<https://isbweb.org/about-us/constitution>). Miller was opted to this Council in 1975. She was then elected for a second 2-
















			
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Fig. 1. The 1989–1991 ISB Executive Council (International Society of Biomechanics Newsletter, 1989, 36, p. 12). Micheline Gagnon was the first woman to serve on the ISB Executive Council since Doris Miller’s term on Council was completed a decade earlier, in 1979. Note: An image of Eadweard Muybridge has been used for Peter Cavanagh, the first Muybridge Medal recipient.

year term. As a member of the first two Executive Councils (1975–1979), Miller helped shape the foundations upon which the ISB was built. Her phenomenal contribution to biomechanics and, notably, the ISB was recognized when the ISB awarded her an Honorary Membership in

2009. Honorary membership is restricted to individuals who have made outstanding contributions to the ISB and the field of biomechanics. Miller is only one of two women awarded this honour to date. So, who is Doris Miller?.

Table 2

Women who have served on Executive Councils of ISB from 1973 to 2023 and the portfolios they have held. In addition to elected Council members, the President can recommend individuals to serve as Treasurer, Secretary-General, Publications Officer (Newsletter Editor), and any other key roles if the portfolio is not assigned to a Council member (such as Archives Officer). Then, with the approval of the Council, these individuals are deemed to be appointed officers to The Executive Council (<https://isbweb.org/about-us/operating-codes>).

Years	Presidents	Council Member† (Country – Council Portfolio ^{††})
1973–1977 ^{†††}	—	Doris Miller (Canada) (1975–1977)
1977–1979	—	Doris Miller (Canada)
1979–1981	—	—
1981–1983	—	—
1983–1985	—	—
1985–1987	—	—
1987–1989	—	—
1989–1991	—	Micheline Gagnon (Canada – Affiliated Societies)
1991–1993	—	Micheline Gagnon (Canada – Affiliated Societies) Sandra Olney (Canada – Education)
1993–1995	—	Micheline Gagnon (Canada – Affiliated Societies) Sandra Olney (Canada – Education)
1995–1997	—	Sandra Olney (Canada – Education)
1997–1999	—	Mary Rodgers (USA – Student Grants) Gisela Sjøgaard (Denmark – Student Grants Committee)
1999–2001	Sandra Olney (President-Elect)	Mary Rodgers (USA – Student Grants) Julie Steele (Australia – Codes & Constitution)
2001–2003	Sandra Olney (President) Mary Rodgers (President-Elect)	Jill McNitt-Gray (USA – Affiliated Societies & Developing Countries Officer) Julie Steele (Australia – Secretary-General)
2003–2005	Mary Rodgers (President) Sandra Olney (Past-President)	Jill McNitt-Gray (USA – Affiliated Societies & Developing Countries Officer) Karen Søgaard (Denmark – Newsletter Editor) Julie Steele (Australia – Secretary-General)
2005–2007	Mary Rodgers (Past-President)	Jill McNitt-Gray (USA – Affiliated Societies & Developing Countries Officer) Karen Søgaard (Denmark – Publication Officer) Cheryl Metcalf (UK – Student Representative) Appointed: Julie Steele (Australia – Secretary-General) Appointed: Elizabeth Hardin (USA – Sponsorship Officer)
2007–2009	Julie Steele (President-Elect)	Véronique Feipel (Belgium – Affiliated Societies) Krystyna Gielo-Perczak (USA – Tutorials) Karen Søgaard (Denmark – Newsletter Editor) Ediuska Laurens (USA – Student Representative) Genevieve Dumas (Canada – Technical Groups)
2009–2011	Julie Steele (President)	Véronique Feipel (Belgium – ISB2011 Chair and Organizer) Krystyna Gielo-Perczak (USA – Tutorials) Allison Gruber (USA – Student Representative)
2011–2013	Julie Steele (Past-President)	Genevieve Dumas (Canada – Technical Groups) Véronique Feipel (Belgium – Sponsorship) Antonia Zaferiou (USA – Student Representative)
2013–2015	—	Catherine Disselhort-Klug (Germany – Awards) Genevieve Dumas (Canada – Technical Groups) Kelsey Collins (Canada – Student Representative) Appointed: Andrea Hemmerich (Canada – EDC Project Officer)
2015–2017	—	Catherine Disselhort-Klug (Germany – Awards) Tajja Finni (Finland – Education) Kirsty McDonald (Australia – Student Representative)
2017–2019	—	Elizabeth Clarke (Australia – Technical Groups) Catherine Disselhort-Klug (Germany – Awards) Rajani Mullerpatan (India – Affiliated Societies) Tajja Finni (Finland – Education) Melissa Boswell (USA – Student Representative)
2019–2021	—	Jaqueline Alderson (Australia – Education) Katherine Boyer (USA – Student Awards) Elizabeth Clarke (Australia – Technical Groups) Janet Dufek (USA – Sponsorship) Jennifer Shin (Korea – Affiliated Societies)

Table 2 (continued)

Years	Presidents	Council Member† (Country – Council Portfolio ^{††})
2021–2023	Elizabeth Clarke (President-Elect)	Megan Smidebush (USA – Student Representative) Appointed: Melissa Boswell (USA – Social Media) Jaqueline Alderson (Australia – Education) Katherine Boyer (USA – Student Awards) Janet Dufek (USA – Sponsorship) Elena Gutierrez-Farewik (Sweden – Informatics) Hannah Rice (Norway – Education) Jennifer Shin (Korea – Affiliated Societies) Anja-Verena Behling (Australia – Student Representative) Appointed: Helen Bayne (South Africa – African Representative)

† The Executive Council initially (1973–1981) included a President and Vice President, a Secretary-General, a Treasurer, and up to 10 additional Council members representing various disciplines in biomechanics. In 1981 the position of Vice-President was replaced with a President-Elect and a Past-President to ensure leadership continuity. In 2005, an elected Student Representative joined the Council. Members of the Executive Council are elected from among full members of ISB, except the Student Representative, who is elected from among the Society’s student members.

†† Specific responsibilities for each member of the Executive Council were introduced in 1985 when Council members were assigned to a particular sub-committee(s) during his/her term of office (Wood, 1986). These sub-committee responsibilities transitioned into Council member portfolios, which are now described in the ISB Operating Codes.

††† The first Executive Council served a 4-year term. In 1977 the terms for Council members became two years (i.e., biennial elections). Council members can only be re-elected twice, a 6-year total term, apart from the Student Representative, who will have a single term of 2 years (<https://isbweb.org/about-us/constitution>).

Miller completed a Bachelor of Physical & Health Education at the University of Toronto, Canada (1961), and a Master of Arts at the University of Oregon, USA (1964). In 1967 Miller traveled to Penn State, USA, to undertake a PhD supervised by Richard Nelson (2nd ISB President, 1977–1982). Having coached competitive diving at the University of Saskatchewan, Canada, during the previous two years, Miller was attracted to this new doctoral program to pursue her love of diving performance and because the laboratory supposedly featured an automated film analysis system. Arriving at Penn State, Miller found the “automated” motion analysis device not yet connected to a computer (Miller, 2021). Despite these challenges, Miller completed her doctoral dissertation, titled: *A computer simulation of the airborne phase of diving*, in 1970. She was the first PhD graduate from the Biomechanics Laboratory at Penn State (Miller, 2021). In her thesis, Miller used a revolutionary three-dimensional multisegmented dynamic model to investigate the flight characteristics of diving performance, with accompanying computer graphics (Fig. 2). This research required Miller to patiently create over 3000 punch cards to enter data into the University mainframe computer (O’Brien, 2021). This tedious approach to developing the model took almost a week to obtain results for each computer program modification. Biomechanics research during this era required incredible perseverance, patience, and persistence.

Although Miller’s research spanned a variety of sports, including amputee running, she was most passionate about competitive diving biomechanics. Miller has been labeled the world leader in diving biomechanics research, consistently demonstrating originality and depth in her research (McNitt-Gray, 2015). Her ability to combine both practical skills as a coach with her aptitude for systematic biomechanical research is evident in her appointment (2003–2009) to the Performance Enhancement Team for USA Diving, and as a biomechanist for the Olympic Medal Program (O’Brien, 2021). In addition, Miller collected biomechanical data during international diving competitions, including the Fifth World Aquatics Championships in Madrid (1986), and the Olympic Games in Atlanta (1996). At these two events, a force platform

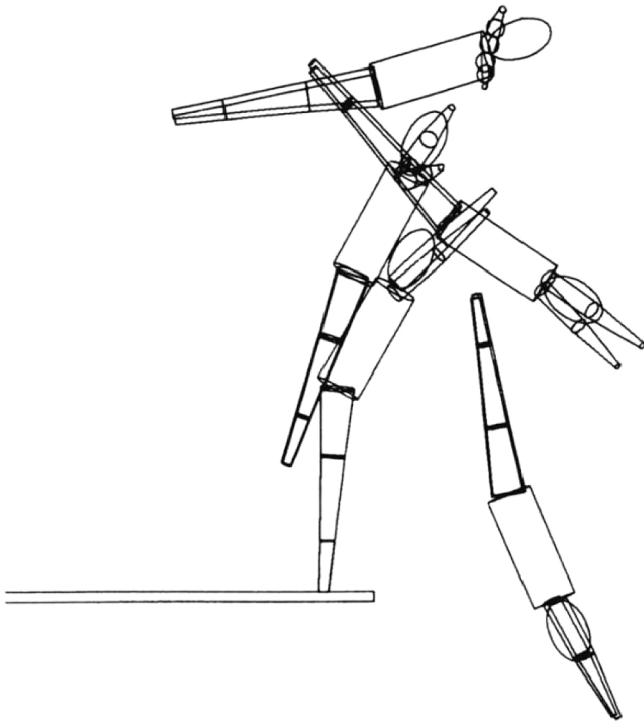


Fig. 2. Revolutionary computer graphics of a three-dimensional multi-segmented dynamic model developed by Doris Miller in her PhD to investigate the flight characteristics of diving performance (Miller, 1970). This iconic figure was featured on the cover of Miller and Nelson (1973) and Nelson and Morehouse (1974).

was embedded in the 10-m diving tower to capture kinetic data during competitive dives. The extreme “behind the scenes” challenges associated with installing sophisticated equipment to collect biomechanical data at an international championship, including turning a 10-m diving platform into an active construction zone the night before the competition, are eloquently described by Miller (2021). McNitt-Gray (2015) commented: “Few have conquered the many obstacles encountered during competition including those requiring video recording from rooftops in near tropical storm conditions or from flooded underwater window locations”.

Miller used her extensive biomechanical database of dives to create practical software in which coaches could compare any diver’s performance to biomechanical data of internationally ranked competitors (O’Brien, 2021). This innovative software bridged the gap between coaching and sport biomechanics research, enhancing the information interchange between researchers and coaches. Besides her numerous research papers, Miller provided USA Diving with reports on competition performances, and participated in coach education. She received the International Swimming Hall of Fame 2000 Paragon Award for Competitive Diving. “Her commitment to pursuing a better biomechanical interpretation of competitive diving is second to none, and her years of service to the sport have advanced its growth, safety, and technique” (<https://www.ishof.org/awards/paragon-awards/>).

During her expansive career, Miller held faculty positions at the University of Toronto, Canada (1961–1963), the University of Saskatchewan, Canada (1964–1967, 1970–1973), the University of Washington, USA (1973–1984), and the University of Western Ontario, Canada (1984–2000), where she is currently a Professor Emerita.

Miller’s career and contributions to biomechanics have been exceptional. In addition to shaping the ISB, Miller co-authored one of the early classic biomechanics textbooks (Miller & Nelson, 1973). She was a founding member of the Canadian Society for Biomechanics (CSB/SCB), serving as a Member at Large on the first Executive Board of the Society

(1973–1974). In 2006, Miller became a CSB/SCB Fellow of the Society and was awarded a CSB/SCB Career Award, the highest honour conferred by the Society. A founding member of the American Society of Biomechanics (ASB) in 1977, she was the first female President-Elect of the ASB (1982–1983), serving as its 6th President (1983–1984). In 2009, Miller was the first woman to be awarded the ASB Jim Hay Memorial Award, which “recognizes originality, quality, and depth of biomechanics research that address fundamental research questions relevant to the extraordinary demands imposed in sport and exercise” (<https://asbweb.org/award-winners-spotlight/>). Of the 19 recipients of the Jim Hay Award since 2004, only one other woman, Jill McNitt-Gray (Table 2), has received this prestigious award. In 1993 Miller was awarded the Geoffrey Dyson Lecturer award, the most prestigious award of the International Society of Biomechanics in Sports (ISBS). Since it was first awarded in 1987, only six females (17.1 %) have received this annual honour. The ISBS also recognized Miller as a Fellow in 2002 for her outstanding sustained contributions to sports biomechanics (<https://isbs.org/awards?start=4>). Miller has undoubtedly had an enormous impact on biomechanics globally and pioneered a pathway for women.

2.2. Micheline Gagnon (1943-)



Micheline Gagnon was the next woman elected by the ISB membership to the Executive Council. She was elected in 1989, 16 years after the ISB was founded and 10 years after Miller had completed her Council term.

After completing a Bachelor’s degree in Physical Education at the University of Montreal, Canada, like Doris Miller, Gagnon traveled to Penn State to join Richard Nelson’s Biomechanics Laboratory. There Gagnon obtained a Master’s degree in 1969, and a PhD in 1976. Her doctoral dissertation was titled: *Biomechanical comparison of the standing and kneeling sprint starts*. At Penn State, Gagnon spent many hours with Miller, manually digitizing 16-mm high-speed films. Miller would digitize the segmental endpoints of study participants, calling out the coordinates so that Gagnon could write each number onto a data sheet. These data were painstakingly punched onto computer cards, checked, and then submitted to the University computer centre with a data analysis program (Miller, 2021).

Before undertaking her PhD, Gagnon commenced a faculty position in the Department of Physical Education at the University of Montreal, Canada (1969). There she built an innovative biomechanics research laboratory designed to investigate occupational health and safety issues, such as optimizing material handling procedures. Gagnon received substantial financial support from the Occupational Health and Safety Research Institute in Quebec for over 20 years. She also received continual financial support from the Natural Sciences and Engineering Research Council of Canada. Gagnon emphasized the imperative need to observe unconstrained novice and expert workers in the field rather than analyze tasks that did not reflect “real world” scenarios. “In the current literature in biomechanics, there are too many theoretical analyses, not sufficiently based on the study of the workers themselves” (Pichette, 2003 [translated from French]). Comparing novice and expert workers performing similar tasks allowed Gagnon to pinpoint safer strategies regarding body postures, manual materials handling, and foot placements. Gagnon worked tirelessly at the University of Montreal to ensure practical research outcomes that would benefit those in the field. Her

rigorous research was used to redesign guidelines for safe lifting (Dumas, 2015).

Gagnon blazed a leadership trail for female biomechanists worldwide, being one of the first women to hold high-status positions in biomechanics societies globally. She was initially elected as an Executive Member of the CSB/SCB as Secretary-Treasurer (1977–1978), and again in 1979–1980. Gagnon re-joined the CSB Executive as the Conference Chair of the first North American Congress on Biomechanics (NACOB I, 1985–1986), a joint venture of the CSB/SCB and the ASB, before serving as the first female President and the Past Conference Chair (1987–1988). In recognition of her leadership and her entire body of research, she was awarded a CSB/SCB Fellowship, and a Career Award in 2000. Gagnon was the first female recipient of both these prestigious awards. She was elected for three consecutive 2-year terms on the ISB Council (1989–1995), serving as the ISB Affiliated Societies Officer for much of that time. In this role, Gagnon communicated directly with the Presidents of Affiliated Societies to discuss practical ways the ISB could enhance biomechanics in their countries. She traveled under the auspices of the ISB to countries such as Poland and Czechoslovakia to meet personally with Society Presidents and biomechanics students, and to deliver lectures. She also encouraged new societies to become affiliated with the ISB. In 1991, Gagnon joined forces with newly elected Council member Sandra Olney, the ISB Education Officer, to develop a coherent plan to support and foster biomechanics in Economically Developing Countries (EDC). They formed a committee to solicit suggestions from each ISB Affiliated Society on what the societies truly needed and how best the ISB could contribute to biomechanics in each country (Zernicke, 1993). Over the next four years, the committee, under the dynamic leadership of Gagnon and Olney, instigated several initiatives including the ISB/ASB Student Award to help EDC students present research at an ISB congress. These women also developed a distinguished lecture tour whereby a prominent biomechanist would visit several countries with ISB-Affiliated Societies to enhance communication and support biomechanical research (Zernicke, 1994). In 1995, then ISB President, Peter Cavanagh, acknowledged, “One of our most important initiatives in the past two years has been the collaborative program with countries who are ‘economically developing’” (Cavanagh, 1995).

2.3. Sandra Jean Olney (1942-)



In 1999, 26 years after the ISB was established, Sandra Olney was elected as the first female ISB President-Elect. Olney accepted the role as President, despite just completing six months of chemotherapy for breast cancer. Before serving as President (2001–2003) and Past-President (2003–2005), Olney spent six years (1991–1997) on the ISB Executive Council as the Education Officer. In the first four years of her term on Council, Olney worked closely with Micheline Gagnon to develop a proactive plan to support biomechanics in EDC (see Section 2.2). As Education Officer, Olney coordinated the distribution of journals, books, and equipment provided by ISB members to colleagues in EDC (Cavanagh, 1997a). She was also a member of a “Long Range Planning Committee” established by then President-Elect, Peter Cavanagh. The committee brief was to consider issues important to the future of the ISB (Cavanagh, 1994). Olney was joined on this committee by a second woman, Krystyna Gielo-Periczak. During her term as

President, Olney continued to oversee the implementation of the numerous new ISB activities initiated before her presidency. In her 2003 President’s report, Olney included statistics on gender differences in what males and females seek when selecting work preferences, one of the first references to gender imbalances in any ISB documentation (Olney, 2003). Olney’s outstanding professional organizational and leadership skills, her detailed philosophical President’s reports in the ISB Newsletters, and her intense warmth and passion for biomechanics earned her deep respect from her colleagues in biomechanics.

Olney completed a Bachelor of Science (Physical & Occupational Therapy) at McGill University, Canada (1964), before practising clinically in Australia and Canada. She then worked as a Research Physical Therapist at Queen’s University, Canada, mentored by bioengineer Philip Lowe. During that time, Olney completed a Master of Education at Queen’s University (1974). Employed on the faculty in the School of Rehabilitation Therapy in 1974, Olney took leave to commence a PhD at the University of Waterloo, Canada, supervised by David Winter, after whom the ISB named the “David Winter Young Investigator Award”. Olney’s doctoral dissertation, completed in 1982, was titled: *Predictions of knee and ankle moments of force in walking from EMG and kinematic data*. In this research, Olney developed and validated a biologically based deterministic model to predict muscle moments from electromyographic and kinematic data (Olney & Winter, 1985).

Since 1974 Olney held numerous positions in the School of Rehabilitation Therapy at Queen’s University, including as a Professor, Director of the School, Associate Dean (Faculty of Health Sciences), and currently as Professor Emeritus. At Queen’s University, Olney established and fostered a novel gait laboratory and the School’s first biomechanics research group. She also collaborated in developing an interdisciplinary, interprofessional ‘Clinical Mechanics Group’, renamed the Human Mobility Research Centre, and now the Centre for Health Innovation - a respected national centre for human mobility research. In addition, Olney has contributed substantially to research in rehabilitation biomechanics globally, exploiting her expertise in analyzing and treating gait in cerebral palsy, cerebrovascular accidents, joint replacements, and mobility technology. In 2004 Olney’s substantial work translating research into practical strategies to improve health outcomes in developing nations resulted in her receiving an Honorary Doctorate (Doctor Honoris Causa) from Riga Stradiņš University, Latvia. Olney’s impact on women in biomechanics is profound. She was the President-Elect of the ISB during Mary Rogers’ second term on Council and Julie Steele’s first term (1999–2001). Both these women went on to serve as Presidents of the ISB.

2.4. Mary McIntyre Rodgers (1954-)



Mary Rodgers was the second of only three women to serve as ISB President (2003–2005) in the Society’s first 50 years. Like Olney, Rodgers came to biomechanics from a clinical background. She initially completed a Bachelor of Science in Physical Therapy (1976), and a Master of Science in Biomechanics (Medical Allied Health, 1981) from the University of North Carolina, Chapel Hill, USA. Then, like Miller and Gagnon, Rodgers traveled to Penn State, where she completed her PhD in Biomechanics (1985), supervised by Peter Cavanagh. Her thesis was titled: *Plantar pressure distribution measurement during bare foot walking: Normal values and predictive equations*. After graduating Rodgers joined

the faculty at West Virginia University, USA, 1986, with joint appointments in Physical Therapy, and Orthopaedics. In 1988 Rodgers accepted a research faculty position at Wright State University in Dayton, Ohio, USA. Finally, in 1994, Rodgers moved to the University of Maryland School of Medicine, Maryland, USA, where she served as the Chair of the Department of Physical Therapy and Rehabilitation.

Rodgers was first elected to the ISB Executive Council in 1997, where she was responsible for implementing an ambitious new student grant program initiated by ISB Past-President, Peter Cavanagh (Cavanagh, 1997b). Rodgers developed and introduced detailed descriptions of the requirements for three new grants for which ISB student members could apply, and chaired the review committee (Rodgers, 1997). The three awards were: The Matching Dissertation Grant Program, The International Travel Grant Program, and The Congress Travel Grant Program – all of which still exist 25 years later. ISB President, Kit Vaughan noted how effectively Rodgers implemented the student grant program (Vaughan, 1999). Four years later, Rodgers noted: “When we award these grants...we are providing intelligent men and women with the needed funds, and thus, the opportunity to excel and succeed. By doing this, we are fostering up-and-coming biomechanists, while at the same time ensuring that the future of the biomechanics field will be a great one.” (Rodgers, 2003). Another initiative implemented during Rodgers’ Presidential term was the appointment of Motoshi Kaya to the ISB Council as the first Student Representative (see Section 2.6). In 2005, Rodgers announced that the ISB would be transitioning many of the Society’s activities, including the ISB elections, membership surveys, and the newsletter, to an electronic format (Steele, 2006).

Rodgers’s term as President was characterized by her strong administrative ability and a desire to formalize the processes and organization of the ISB, which had traditionally been somewhat more “relaxed” (Rodgers, 2001). Rodgers proudly promoted the achievements of other Council members in her regular Newsletter President’s Reports. She also promoted mentorship and raised the notion of gender inequity in biomechanics, noting in her President’s report that while at Penn State she was the only female in the biomechanics program (Rodgers, 2004b).

After graduating from Penn State, Rodgers’s research focused on the biomechanics of injury prevention during wheelchair propulsion, and technology development for rehabilitation, healthy independent living, and mobility. She served as Director of the Pilot & Exploratory Studies Core for the University of Maryland Claude D. Pepper Older Americans Independence Center, funded by the National Institute of Aging, National Institutes of Health. This core provided start-up support for research proposals that explored mechanisms underlying the disability phenotype in older persons, and the functional and clinical responses to exercise.

Rodgers is currently a Professor Emerita in the School of Medicine at the University of Maryland. Rodgers is a Fellow of the American Physical Therapy Association (2009) and the American Society of Biomechanics (2012). In recognition of her outstanding contribution to the ISB, Rodgers was awarded an inaugural ISB Fellowship in 2015, an award scheme instigated by the third female ISB President, Julie Steele.

2.5. Julie Robyn Steele (1960-)



Julie Steele initially completed a Diploma in Teaching (Physical & Health Education) at Kuring-gai College of Advanced Education (1980), Australia, before completing a Bachelor of Physical Education at the University of Western Australia, in 1982. Here, Bruce Elliott supervised Steele’s biomechanics Honours research and inspired her passion for biomechanics. In 1983 Steele accepted a faculty position at the University of Wollongong (UOW), Australia, where she remained until her retirement in 2020. Steele completed her PhD at UOW (1997), with her thesis titled: *Knee function of chronic ACLD patients during static knee laxity assessment and dynamic deceleration*. Over a 40-year career, her research expanded to include lower limb injuries caused by high-impact landings; innovative wearable technologies for health applications; effects of obesity, ageing and occupational loading on lower limb structure and function; and breast health biomechanics.

A member of the ISB since 1985, Steele served on the ISB Executive Council for 14 years (1999–2013). As the only female Secretary-General of the ISB (2001–2007), Steele initially focussed on revising the wording of the ISB Constitution to remove ambiguity and ensure this critical document was current. Steele was also responsible for keeping detailed records of the Society’s activities, including the minutes of all General Assembly and Executive Council meetings and “...keeping everyone focused on their action items” (Rodgers, 2003).

During her term as the ISB President (2009–2011), Steele focussed on ensuring its initiatives were sustainable. To enhance sustainability Steele substantially revised the ISB Operating Codes to ensure that the transition from Council to Council every two years was smooth and efficient (Steele, 2009). In addition, to facilitate the sustainability of the ISB EDC initiatives, Steele employed Andrea Hemmerich, who earned a PhD from the University of Cape Town, South Africa, supervised by Kit Vaughan, ISB President (1999–2000). Hemmerich reviewed past and current initiatives to ascertain the needs of each program, and how the ISB could integrate these programs with other ISB schemes, such as the student travel awards (Steele, 2009). Hemmerich’s tireless work, including spending substantial time with some of the EDC recipients in Africa, and productive outcomes in this role were recognized when she was appointed to the ISB Council as the first EDC Project Officer in 2013. As Past-President, Steele proposed and developed the ISB Fellowship program “... to recognize distinguished achievement in biomechanics and to encourage continuing service and leadership to the society” (Challis, 2013). ISB President, John Challis, then appointed Steele as the first Censor of the Fellows to draft, in conjunction with the President, recommended candidates for the first round of ISB Fellows (Cresswell, 2015) (Table 3).

Besides her ISB Council roles, Steele passionately presented a keynote address at ISB2005 titled: “Developing textile biofeedback technology: From brassieres to noisy knees”. Despite initial apprehension from the Congress Organizers, the strongly female-centric focus on breast health biomechanics in this address was well received by the audience (Anon, 2006). She, with Walter Herzog and Krystyna Giolo-Perczak (Table 2), also participated in the first formal ISB student mentoring session, organized by Student Representative Eduiska Laurens, held at the Aquila Private Game Reserve in South Africa during ISB2009.

Like her female predecessors, Steele served on the Boards of other professional biomechanics societies. In 1996 Steele was elected to the inaugural board, and later President (1998–2000) and Past-President (2001–2003), of the Australian & New Zealand Society of Biomechanics, where she assisted in developing the Society’s infrastructure and constitution. She was also on the Board of Directors of the ISBS for 10 years (1993–2003), serving as their Newsletter Editor (1996–2001) and Vice President of Publications (1996–2000). Like Miller, Steele is one of only six females to have received the Geoffrey Dyson Award (in 2021) from the ISBS. In 2019 Steele was awarded a Member of the Order of Australia (AM) for significant service to: science in the field of biomechanics, higher education, and professional associations. Steele was also awarded an ISB Fellowship in 2017 in recognition of her

Table 3

Women who have been awarded a Fellowship of the International Society of Biomechanics (FISB)*. Since ISB appointed the first Fellowships in 2015, 35 % of ISB Fellows are women.

Year	Name	Affiliation	Service to ISB
2015	Véronique Feipel	Université Libre de Bruxelles, Belgium	ISB Executive Council: 2007–2009 (Affiliated Societies) 2009–2011 (ISB2011 Chair) 2011–2013 (Sponsorship)
	Jill McNitt-Gray	University of Southern California, USA	ISB Executive Council: 2001–2007 (Affiliated Societies & Developing Countries Officer) See “Fellows Update: Jill McNitt-Gray” (ISB Now, 2016, March) See Section 2.4
	Mary Rodgers	University of Maryland, USA	See Section 2.4
2017	Julie Steele	University of Wollongong, Australia	See Section 2.5
2019	Karen Søgaard	University of Southern Denmark, Denmark	ISB Executive Council: 2003–2009 (Newsletter Editor)
2021	Catherine Disselhorst-Klug	RWTH Aachen University, Germany	ISB Executive Council: 2013–2019 (Awards)
	Taija Finni	University of Jyväskylä, Finland	ISB Executive Council: 2015–2019 (Education)

* The ISB Council agreed to establish a Fellowship of the International Society of Biomechanics in 2013, awarding the inaugural Fellowships in 2015. Fellowships are awarded to recognize distinguished professional achievement in biomechanics, including a high standard of service to the Society. Fellows are encouraged to provide continued professional service and leadership to the Society, particularly to foster the activities of Early Career Researchers within the Society (<https://isbweb.org/activities/awards-and-honours/isb-fellows>).

sustained contributions to the Society.

Steele is currently an Emeritus Professor at the University of Wollongong and a member of the World Council of Biomechanics (since 2014). She continues to participate extensively in community-based seminars to raise the profile of women in research and to encourage young women to pursue careers in research and science.

2.6. Cheryl Diane Metcalf (1979-)



In 2005, Cheryl Metcalf became the first elected Student Representative to the ISB Executive Council. Although Motoshi Kaya was the first ISB Student Representative, he was appointed to promote student involvement in ISB Council activities and transition the position into an elected one. Since 2005, student members have elected women to the Student Representative position to every ISB Council.

At the time of her election to Council, Metcalf was a PhD student (Electronics & Computer Science) at the University of Southampton, United Kingdom (UK). Metcalf's PhD thesis, completed in 2008, was titled: *Investigating the relationship between wrist movement and hand function: a clinically focused kinematic study*. Before her PhD, Metcalf earned a Bachelor of Arts (Honours) in Computer Studies (2002) from

the University of Sunderland, UK, and a Master of Science (Evolutionary & Adaptive Systems) (2003) from the University of Sussex, UK. Her family, friends, and colleagues encouraged her to stand for the position of Student Representative. During her 2-year term as Student Representative, Metcalf worked to create a more accessible interface between the ISB and its student members ([Søgaard, 2005](#)). Apart from encouraging student members to forward ideas for future initiatives, Metcalf worked to develop a framework to allow student members easier access to the wealth of knowledge and experience of ISB members. As part of this framework, Metcalf arranged for the ISB pre-congress tutorials to be recorded and available to student members via the ISB website ([Metcalf, 2006](#)).

Like Metcalf, each female Student Representative ([Table 2](#)) has been dynamic in formulating and implementing unique initiatives to benefit ISB student members. These initiatives have ranged from promoting biomechanics and the ISB in EDC, increasing web-based resources and mentorship opportunities for students, maximizing student networking opportunities for research collaborations with other laboratories, organizing student social events, and promoting all things biomechanical via social media. These initiatives are largely responsible for the ever-growing ISB student membership. Still a member of the ISB, Metcalf is currently a Professor and Head of the School of Healthcare Enterprise and Innovation, Faculty of Medicine, with a joint position in the School of Health Sciences, Faculty of Environmental & Life Sciences, at the University of Southampton.

3. Women represented in ISB awards

To create strong female role models and help address current bias and stereotyping in biomechanics, women must be equally represented in the proportion of a professional society's awards ([Ebrahimi et al., 2023](#)).

3.1. The Muybridge Medal

The most prestigious ISB award is the Muybridge Medal, bestowed for career achievements in biomechanics. Although the Medal has been awarded to 18 worthy recipients since 1987, only one woman, Mimi Koehl, has received the award, which was presented at ISB2009, South Africa. There, Koehl presented an engaging talk titled: *The effects of ambient wind or water flow on locomotion*, in which she brought her subject to life and enthused the audience, particularly the students, with her passion for biology ([Vaughan, 2009](#)). A Professor of Biology at the University of California, Berkeley, USA, Koehl is an expert in evolutionary and ecological biomechanics and investigates the physics of how living organisms interact with their environment so effectively. [Parks \(2005\)](#) details Koehl's compelling and inspirational story.

This stark underrepresentation of women award winners is likely multifactorial – including unconscious and other biases in the Awards Committee and a lack of women nominated for the awards ([Lincoln et al., 2012](#); [Australian Academy of Science, 2019](#)). Interestingly, the language used to promote the new ISB Promising Scientist Grant in 1988 was exceptionally biased, with the eligibility requirements (Art. 3) stating that “...both the candidates and his academic advisor must be ISB members” ([Anon, 1988](#)).

3.2. Jacquelin Perry Emerging Female Scientist Award

In 2020, the ISB introduced the biennial Jacquelin Perry Emerging Female Scientist Award to acknowledge female researchers who have “performed superior research early in their career” ([Derrick, 2020](#)). Before this award, the ISB named its other awards after men: the Muybridge Award, the Wartenweiler Memorial Lecture, the David Winter Young Investigator, and the Carlo de Luca Emerging Scientist Award.

Perry (1918–2013) initially studied physical education at the University of California, Los Angeles, USA (1940), before retraining as a

physical therapist with the US Army and serving in army hospitals during World War II. During this time, Perry helped polio, rheumatoid arthritis, and trauma patients regain their ability to walk. After the war, Perry studied medicine, becoming, in 1950, the first woman to graduate with a medical degree from the University of California, San Francisco, USA (Elliott and Headley, 2012). In 1958 Perry was one of the first ten women to be certified as an orthopaedic surgeon by the American Board of Orthopaedic Surgery (Watts, 2013). Although Perry joined the Rancho Los Amigos National Rehabilitation Center (RLANRC) in California as a surgeon in 1955, she abandoned surgery in the late 1960s after suffering a brain arterial blockage, which caused severe vertigo when she turned her head. Instead, Perry focussed on analyzing the biomechanics of normal and pathological gait, establishing the internationally acclaimed Pathokinesiology Laboratory at RLANRC in 1968. She also created the observational system clinicians use worldwide to examine and manage gait deficits (Delzell, 2013). Her interest in gait was sparked after being exposed to polio patients early in her career. After vaccines effectively ended polio in the Western World during the mid-1950s, Perry directed her attention to improving movement capabilities of patients with spinal cord injury, cerebral palsy, stroke, amputation, peripheral nerve injury, limb fracture, and arthritis – to name a few (Craik, 2010). Perry (1992) wrote the classic textbook *Gait Analysis: Normal and Pathological Function*, which became the international gold standard for gait analysis. Despite living with Parkinson’s disease for 20 years, Perry continued working, being in the laboratory the week before she passed away (Watts, 2013).

In 2009, Perry was awarded an Honorary Membership of the ISB for her pioneering and extensive contribution to gait analysis. Although she had little, if any, direct involvement in the ISB, Perry inspired many to pursue research in gait and biomechanics. The ISB named the award after Perry because her ground-breaking research in gait came at a time when gender inequities established barriers for female researchers (Derrick, 2020). The first recipient of the Jacquelin Perry Emerging Female Scientist Award was Taylor Dick from The University of Queensland, Australia. Dick’s presentation was titled: *Series elasticity facilitates safe plantar flexor muscle–tendon shock absorption during perturbed human hopping* (Dick et al., 2021).

4. The future of women in the ISB

In recent years the ISB has instigated initiatives to address the underrepresentation of women in biomechanics. For example, the inaugural Women in Biomechanics Lunch was held at the ISB2015 Congress in Glasgow, UK. This event was designed as a “networking and conversation forum to celebrate contributions from the women of ISB” (Collins, 2014). This event’s enormous attendance and success sparked the ISB Advancing Women in Biomechanics program, which has since held themed events at ISB congresses to address issues such as Fighting Gender Bias (ISB-ASB2019) and Becoming an Ally (ISB2021). The ISB, together with The Biomechanics Initiative, also jointly funded the 2021 National Biomechanics Day Outreach for Women in Biomechanics (Kirk et al., 2023).

Given that these ISB initiatives have been relatively recent, it is difficult to ascertain their impact on women’s participation in the Society. However, of the 737 ISB members who declared their gender when renewing their 2022 membership, 39 % were women. These data represent twice the percentage of women who were charter members of the ISB 50 years ago. Interestingly, from 1973 to 1999 women held only 6.1 % of positions on the Executive Council. However, from 1999 to 2003 this increased to 27 % of Executive Council positions (Fig. 3). Also encouraging is that a fourth dynamic woman, Elizabeth Clarke, from The University of Sydney, Australia, will become ISB President in 2023. This increase in women in ISB leadership is encouraging, yet we still have more to do to reach gender equity in the Society’s activities.

Although the ISB introduced the Jacquelin Perry award to recognize women’s scientific achievements, women-only awards can artificially inflate the number of female award recipients and possibly marginalize women’s research (Lincoln et al., 2012). Therefore, the ISB must adopt strategies to counteract implicit bias when selecting all awards and leadership positions. These strategies can, for example, include more women in nomination pools and ensure women are on selection committees, especially as chairs. Furthermore, the ISB must make selection committees aware of such biases and regularly review the language associated with and the outcome of awards and elections (Lincoln et al., 2012). There are also actionable changes, eloquently described by

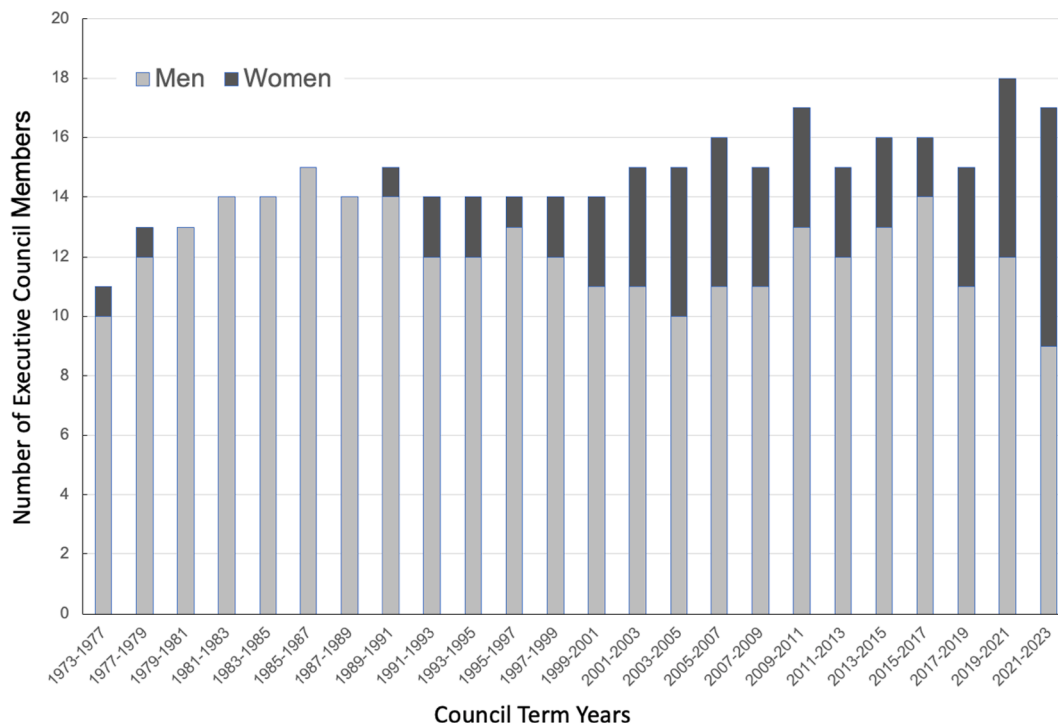


Fig. 3. The number of women and men on the Executive Council of ISB from 1973 to 2023.

Ebrahimi et al. (2023), that the ISB, as a professional, scientific society can implement to bolster the careers and continue the growth of women and other underrepresented individuals at all levels of biomechanics. Furthermore, individual actions such as advocating for women for awards and leadership positions, publicly celebrating and amplifying the achievements of women, and speaking up when there are few or no women represented can also make a positive change (Chow, 2021; Ebrahimi et al., 2023).

Although we acknowledge that gender is non-binary, most professional societies have only recorded membership statistics on men and women. Therefore, it is imperative that professional societies, including the ISB, broaden the demographic information collected on members so they can objectively address inequalities in diversity, equity, and inclusion for all underrepresented groups. Then, by implementing proactive strategies, the ISB can become a professional society that regularly promotes inspiring biographies of women and other underrepresented individuals as these individuals thrive and progress in the Society's leadership positions and receive the highest ISB awards.

CRedit authorship contribution statement

Julie R Steele: Conceptualization, Data curation, Writing - original draft, review & editing. **John H. Challis:** Data curation, Writing - reviewing and editing.

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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