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Editorial

Research on Biomechanics, Motor Control and Learning of Human Movements

Gongbing Shan

Biomechanics Lab, Faculty of Arts & Science, University of Lethbridge, Lethbridge, AB T1K 3M4, Canada; g.shan@uleth.ca; Tel.: +1-403-329-2683

1. Introduction

The discipline of biomechanics, devoted to understanding human movement, has ancient roots reaching back over 2300 years to the ancient Greek civilization [1–3]. However, its rapid development began between the mid-1960s and the 1970s [4–6]. During this period, researchers established biomechanics as the study of the structure and function of biological systems through mechanical principles [7]. From this pivotal era onward, biomechanics research into human movement has concentrated on two primary objectives: enhancing human performance and mitigating the injury risk associated with physical activities [8–12].

Embedded within the broader domain of human movement science, biomechanics intersects significantly with two closely related fields: motor control [11,13,14] and motor learning [15,16]. Motor control addresses the organization of major human systems—particularly the brain, muscles, and limbs, and sometimes external objects—in the execution of physical tasks to enable the precision required for motor skills, while motor learning concerns the acquisition of these skills over time, with a relatively permanent capacity for efficient performance established through repeated practice or training [17–19]. Together with biomechanics, these three areas converge to examine not only the structural mechanics of movement but also the neurological, muscular, and experiential factors that contribute to skilled motion.

The convergence of biomechanics, motor control, and motor learning represents a rapidly advancing frontier in human movement science [20–23]. This interdisciplinary intersection seeks to illuminate the fundamental mechanisms of human motion by exploring the biomechanical properties, control strategies, and adaptive learning processes that underpin the acquisition and refinement of skills. Through the integration of emerging methodologies and analytical tools, researchers are increasingly able to decode complex movement patterns and previously understudied motor skills—often intricate or acrobatic [24–26]—that were previously inaccessible but are essential for both athletic and functional performance. Furthermore, this approach reveals movement control patterns [26–29] that enhance performance by allowing us to improve training methods and develop injury prevention strategies for safer training [30,31]. Understanding these elements promotes evidence-based learning and contributes to safer, more efficient physical training environments.

This Special Issue presents recent advancements in cross-disciplinary research into biomechanics, motor control, and motor learning, highlighting the depth and diversity of contemporary work in this interdisciplinary field. The twelve articles included showcase a range of innovations, from novel analytical methodologies and artificial intelligence (AI) applications to biomechanics-based learning and training strategies, along with new perspectives on the application of biomechanical feedback. By focusing on biomechanically decoding motor control processes and enhancing motor learning and training methods, this collection sheds light on practical applications aimed at improving physical performance and reducing injury risk. The topics of this Special Issue span biomechanical analyses of complex skill acquisition to innovative AI approaches that support the use of personalized,

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Citation: Shan, G. Research on Biomechanics, Motor Control and Learning of Human Movements. *Appl. Sci.* **2024**, *14*, 10678. https://doi.org/10.3390/app142210678

Received: 12 November 2024
Accepted: 18 November 2024
Published: 19 November 2024

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data-driven feedback in practice. Additionally, this Issue underscores the value of biomechanics beyond sports, providing insights into occupational contexts and rehabilitation practices, where movement efficiency and injury resilience are essential. In summary, this collection offers a comprehensive exploration of human movement science, demonstrating how a multidisciplinary approach can drive significant advancements in human performance, safety, and well-being.

2. An Overview of the Published Articles

The articles in this Special Issue provide several new insights and perspectives.

2.1. Novel Analytical Approaches and AI Integration

The integration of machine learning (ML) with biomechanics offers promising advancements in the rapid and accurate diagnosis of human motor skills and in providing reliable feedback to improve skill learning and training [32–34]. In this collection, several studies illustrate how AI and novel techniques enhance movement analysis. Research by Cossich and colleagues, for example, applies artificial neural networks (ANNs) to predict the rate of torque development from accelerometer signals, providing a portable and cost-effective tool for both sports and rehabilitation [35]. Another study examines the impact of sensor orientation on accelerometer-derived angles, proposing an error reduction algorithm that improves measurement accuracy. Together, these studies demonstrate how AI-based tools are revolutionizing data processing and performance assessments.

2.2. New Insights into Understudied Sports: Key Factors Related to Performance and Skill Acquisition

This Special Issue also explores less-examined areas within human movement science, with several studies concentrating on biomechanics and skill enhancement in specific sports. Soccer, recognized worldwide as the most popular sport, has identified 43 soccer scoring techniques (SSTs) [36]. However, biomechanical research on these SSTs significantly lags behind practice, with only about one-sixth of identified SSTs having been studied biomechanically [37]. Shan and colleagues have contributed to this limited body of knowledge by investigating an additional SST, the diving header [38]. Their pioneering work quantifies both the ball speed enhancement (BSE) and effective offensive range (EOR), identifying key biomechanical factors that optimize performance.

Similarly, another study delves into the biomechanics of ski jumping, emphasizing the importance of monitoring multiple movement stages using force platforms, inertial sensors, and wind tunnels. Additionally, a scoping review on Paralympic table tennis proficiency in individuals with disabilities provides a comprehensive summary of the assessment protocols currently used while suggesting future directions, including AI-driven skill evaluations. Collectively, these studies underscore the value of biomechanics in gaining essential insights into skill acquisition, performance enhancement, and injury prevention within sports.

2.3. Emerging Research in Occupational Biomechanics: Biomechanics and Mobility in Police Activities

Recent research has begun to address the specific biomechanical demands of police work; however, this area remains relatively underexplored. A recent systematic scoping review in 2024 [39] identified only 11 biomechanical studies focused on police activities, with 9 of them conducted after 2016. This indicates a pressing need for further research to provide scientific insights that could improve police performance and reduce training-related injuries. This emerging field seeks to inform occupational practices through evidence-based approaches.

Two notable studies in this Special Issue contribute to this area. The first, by Kasović et al., examines the effects of load carriage on police officers' gait mechanics, showing how external loads alter movement patterns [40]. The findings suggest ergonomic adjustments to support high-risk occupations. The second study investigates the impact of equipment

loads on static posture in police recruits, demonstrating that carrying additional weight affects postural stability and the center of pressure path. These findings have implications for training and injury prevention, emphasizing the need for load-related adaptations that could enhance movement efficiency and reduce injury risks in police work.

This growing body of research highlights the importance of using customized biomechanical evaluations to meet the demands of physically intensive professions.

2.4. Technological and Methodological Explorations: Exoskeletons, Biomechanical Motor Control Assessments, and Rehabilitation

Exoskeletons offer a promising approach to augmenting and restoring the physical capabilities of humans, especially within medical and industrial sectors [41–43]. Biomechanical interventions tailored to motor learning and rehabilitation play a vital role in improving motor skills, aiding recovery, and minimizing injury risks. In this context, evidence-based approaches are essential to refine the design, application, and integration of exoskeletons into training and therapeutic environments. One significant study in this Special Issue, conducted by Favennec [44], investigates the familiarization process of a soft back-support exoskeleton, providing valuable guidelines for its optimal application in practice. By examining user interactions with the exoskeleton, this study offers insights into adapting these devices for safer and more effective therapeutic use, highlighting the importance of assessing physical human–exoskeleton interactions to establish best practices that ensure both user safety and comfort. This research forms a foundation for advancing human performance enhancement and supports the development of exoskeletons as reliable rehabilitation tools.

This Issue also emphasizes advancements in 3D kinematic and kinetic assessments. One study explores the influence of slope and walking speed on spatiotemporal gait parameters and ground reaction forces during hiking, offering insights into postural control strategies. Another study examines lower-limb muscle co-activation during team lifting tasks, providing valuable knowledge about how coordination strategies adapt across different risk levels and team dynamics.

In the area of rehabilitation, a third article compares the use of different instability devices for postural sway measurements, providing insights into designing effective balance training programs. A fourth study on asymmetric lumbar stabilization exercises adds to our understanding of bilateral muscle activation strategies, further informing injury prevention and rehabilitation practices. Together, these articles demonstrate how biomechanical assessments and training devices can significantly enhance motor learning and rehabilitation outcomes.

3. Conclusions and Future Directions

The articles in this Special Issue collectively illustrate the evolving landscape of human movement science, with a focus on integrating biomechanics, motor control, and motor learning. These studies not only push the boundaries of methodological innovation but also provide practical applications across diverse domains, including sports, rehabilitation, occupational health, and disability research.

Looking forward, several avenues warrant further exploration. Emphasizing real-time feedback systems, AI-enhanced tools, and ecological research methods will help bridge the gap between laboratory findings and real-world applications. With ongoing advancements in technology and research methodologies, the field of human movement science is poised to make substantial contributions to both academic knowledge and practical applications.

We extend our gratitude to the authors and reviewers whose contributions make this collection a valuable resource for future research in biomechanics, motor control, and motor learning.

Funding: This research received no external funding.

Conflicts of Interest: The author declares no conflicts of interest.

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