

Special Issue “Biomechanics and Human Motion Analysis”

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1. Introduction

In March 2021, we invited submissions to the MDPI Special Issue “Biomechanics and Human Motion Analysis”, in the form of original research papers, methodological advances, mini reviews or perspective articles. The topic was solicited through the scientific experience of these three Guest Editors, with each of them having made considerable contributions to the areas of Human Motion Analysis (HMA) and Biomechanics. The latter discipline generally refers to the application of mechanical terms, concepts and knowledge to biological systems, traditionally the human body and its major organs and systems. This is performed with many different instruments and tools, including in silico modelling, and in vitro and in vivo experimental measurements. These instruments and techniques are also traditionally used for the purposes of HMA. Strengthening the connections between these two research specialities will enable greater insights into human motion [1,2].

Due to its ability to gather, analyse and interpret, and hence somehow capture, the complexity of the overall dynamics of human motion [3,4], HMA and its tools have attracted the interest of many clinicians in recent decades [5–10], and also the attention of many scientists from a wide range of other disciplines [4], as well as application domains as diverse as elite sport, art, law, the military and entertainment. The measurements used in HMA are usually non-invasive and can now be very accurate and repeatable, very comprehensive, and with limited encumbrance for the subject being analysed. The apparatus of a fully instrumented motion analysis laboratory [3,6], for example, can include a stereophotogrammetric system to track in reflective markers which would have previously been stuck on the skin in 3D space by using a set of digital cameras, force plates on the ground to measure the ground-reaction force, EMG surface electrodes to capture myoelectric signals from the muscles and instrumented platforms in the floor or in insoles to map the plantar pressure distribution. In addition, as a result of recent technological advancements, in modern laboratories the major kinematics and kinetics variables of a large number of joints and in all anatomical areas of the human body can be calculated in 3D, and this is possible even in real-time during the execution of those locomotion exercises that are typical of daily living. Due to these attractive features, HMA techniques have been largely exploited worldwide to assess medical conditions, e.g., the effects of neurological or orthopaedic pathologies and those of trauma and amputations, and to assess the efficacy of pharmacological, orthotic and surgical treatments. This area of application is clearly the largest and best known, in the way that the phrase HMA is usually only associated with the more traditional concept of “clinical gait analysis”, where established procedures are used to assess patients before and after interventions. These routine procedures, however, still frequently use minimal marker-sets, primitive experimental protocols and complex graphical reports [8,11]. In the last two decades HMA has been expanded to include videofluoroscopy [12], in which algorithms for 2D-to-3D spatial matching take planar medical images of human joint motion in three anatomical planes, and wearable inertial sensing technology, which integrates



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various sensors into so-called Inertial Measurement Units [13,14]. In this latter context, this technology, which is also the standard technology embedded into common smart phones, is used to track elementary human motion. In the present Special Issue, all of these technologies have been explored to develop a full and valuable picture of their advantages and drawbacks.

Biomechanics has also developed considerably in recent decades, revealing new knowledge relevant to human joint function, medical imaging analysis, experimental methodologies and musculoskeletal modelling, together with relevant tools for computer simulations and graphical representations of biomechanical variables [1,2,15,16]. New instrumentation has even been developed and validated. Unfortunately, not all of these steps forward in Biomechanics have been exploited to enhance HMA. In this context, it is worth noting the efforts of the International Society of Biomechanics (<https://isbweb.org>, accessed on 14 February 2024) to provide guidelines and possible standard definitions for all research activities related to HMA by publishing the so-called ‘ISB Recommendation Papers’ since 2002. The ISB also has an official Technical Group which explicitly addresses the ‘3D Analysis of Human Movement’.

The present Special Issue aimed to support the transmission of recent biomechanical knowledge into HMA, as well as promoting the use of traditional and more modern HMA techniques to address complex biomechanical problems found within the dynamics of the human body. Manuscripts were rejected if either Biomechanics or HMA were only a very small part of the study.

2. An Overview of the Published Articles

Twenty papers have been collected for this Special Issue, all reporting original research work apart from two interesting Review papers (contributions 1 and 2). The latter papers address two intriguing and complex anatomical areas, i.e., the patello-femoral and shoulder joints, respectively, by searching for and summarising the most relevant approaches and instruments used for modern analyses of their functions. The other eighteen papers address many different anatomical areas, including the upper limb, the spine and the lower limbs, with a few investigating full body movements, even those during difficult tasks such as lunging (contribution 3) or military crawling (contribution 4). Level walking is the motor task which is analysed the most, but stepping (contribution 5), sitting (contribution 3 and 6), obstacle crossing (contribution 7), up-right balancing (contributions 8 and 9), basketball shooting (contribution 10) and weight-lifting (contribution 11) were also examined, in addition to a number of elementary exercises; thus, these contributions span from daily living motor tasks to sport and even military human body movements. These analyses were performed by using many different instruments and techniques, including, of course, stereophotogrammetry and other standard instruments used in HMA (ground-reaction force platforms, EMG); however, inertial sensors (contribution 6), videofluoroscopy (contribution 3), smart-phones (contributions 11 and 12) and state-of-the-art technologies for medical imaging (standard MRI, CT and X-ray, but also the modern Cone-Beam CT—contribution 13) were also used within these studies. These technologies were used in isolation and in combination. Interestingly, more than half of these research papers used musculo-skeletal modelling to carry out their investigations, including complex calculations for the estimation of the centre-of-mass and the centre-of-pressure (contributions 5, 8 and 9). The vast majority of these papers examined voluntary healthy subjects, but patients suffering from joint disease (and treated with total joint replacements), knee varus deformity (contribution 13), ACL deficiency (contribution 14) and cerebral palsy (contribution 15) were also explored. A number of the papers addressed the exploitation of established techniques in new clinical and biomechanical contexts; others aimed to validate novel instruments and tools. In addition, elementary physical exercises are addressed with original techniques (contributions 16 and 17) and Many of the authors used musculo-skeletal modelling to develop or to support their investigation (contributions 5, 7, 8, 13–15 and 18–20).

These papers were received from Europe, Asia, South and North America, with a number combining the expertise of researchers from different countries and even different continents. Finally, we are particularly pleased with the breadth of authors, topics, techniques and findings that can be found within this Special Issue.

3. Conclusions and Future Perspectives

With the publication of the present Special Issue, we hope to contribute to better links being formed between Biomechanics and Human Motion Analysis; as such, we have selected original work aimed towards including advanced biomechanical analysis and instruments in motion analysis, or special motion analysis studies involving innovative biomechanical research. The twenty papers published here have shown the huge spectrum of research topics that are available, and have also shown their ability to integrate various competences and sub-disciplines into their work. It has been further demonstrated that recent advancements in biomechanical knowledge can enhance HMA for the collection, analysis and interpretation of in vivo measurements. In addition, modern HMA techniques can provide reliable measurements for a number of biomechanical variables (kinematics, kinetics, EMG), allowing the complex biomechanical problems within human body dynamics to be addressed successfully. As a concluding remark, it can be seen that Biomechanics and Human Motion Analysis shall progress hand in hand, as most of the present papers have demonstrated the synergy between the two, i.e., the value of their mutual support. In the future, we expect that Biomechanics and Motion Analysis will further sustain each other.

Conflicts of Interest: The authors declare no conflict of interest.

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