

Editorial: Advances in Wearable Devices for Sports

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In sports, coaches and support staff spend considerable time analyzing athletes' technique. It is well known that athletes who can perform movements associated with their sport of choice using a better technique are more likely to present better performances. Video-based analysis has traditionally been the most used procedure to assess athletes' technique [1,2]. This consists of recording sports skills and the subsequent computation of meaningful parameters describing the movement from raw data [3]. However, this data acquisition and handling is a time-consuming process. Consequently, coaches and support staff are looking for less time-consuming procedures that lead to real-time outputs and that they themselves can also use and handle. The use of wearables allows the acquisition of kinematic [4], kinetic [5], or physiological variables [6] that are of paramount importance for coaches and athletes. For instance, Lim et al. [7] aimed to predict the lower limb kinetics and kinematics during walking with a single inertial measurement unit (IMU) placed on the lower back. In the specific case of the aquatic environment, cable handling makes data collection more difficult. Thus, wearable usage is a solid alternative in aquatic sports. Besides kinematic data, swimming researchers can also measure kinetic parameters, such as propulsive force, that are key determinants for performance enhancement [5,8]. Regarding physiological parameters, these can also be measured or estimated with the data collected with wearables. A study by Dasa et al. [9] aimed to assess the accuracy of commonly used global positioning systems/accelerometer-based tracking devices to estimate energy expenditure during high-intensity intermittent exercise in soccer. The authors noted an underestimation of the energy expenditure since these gears do not account for anaerobic energy production during high-intensity exercise [9]. Nonetheless, and despite the deviations observed in energy expenditure that should be considered by practitioners and researchers, it was argued that the devices tested can still provide useful information, but with the limitations addressed.

Based on the considerations above, this Special Issue entitled "Advances in Wearable Devices for Sports" aimed to publish multidisciplinary research (original articles, reviews, etc.) focused on the development, validation, or practical application of new wearables to monitor variables related to sports or advances observed in wearables already used by the sports community. Five papers (two reviews and three articles) were included in this Special Issue after receiving peer review. One review paper (contributor 1) aimed to explore the measurement and monitoring of athletic performance, injury prevention, rehabilitation, and overall performance optimization using body wearable sensors in a broader context. The authors provided a comprehensive bibliographic analysis covering the advantages and disadvantages of sensor technology and data utilization within the realm of sports, with a specific focus on the applications of wearables in sports. It was noted that there is an increase in the number of publications related to wearable technology in sports. The authors argued that this evidence is indicative of the increasing prevalence and adoption of such technologies in the sports context. It was also noted that Eastern countries had a greater contribution to this increase in comparison to their Western counterparts. Others (contributor 2) aimed to synthesize based on a systematic review of wearable technology used to assess and monitor physical performance, specifically in

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volleyball players. It was noted that assessing and monitoring vertical jump height with wearables is a general procedure in volleyball. Being a specific marker of athletic performance in volleyball (jump as high as possible, block, react quickly, attack the ball, and combine these actions with a high technical level), its accurate measurement in training and competition and the ability to track changes over time are critical for coaches and researchers. As with any other piece of equipment, wearable usage has advantages and disadvantages. The authors noted that the moderate-to-high correlations found could be caused by the homogeneity of the sample tested, and the greater degree of underestimation could be caused by several factors, such as the type of surface, the jump, or the specifications of the device itself. The authors also argued that the literature lacks evidence about the use of wearables in a volleyball context, indicating that more knowledge is needed to better understand jump characteristics during training and competitions across different age groups, player levels, and sex.

Regarding the articles, one research group (contributor 3) aimed to evaluate the external training load of elite-level goalkeepers in the days before the match day and their playing status in subsequent matches. The specific physical performance quantification of variables related to goalkeeping was performed with a global positioning system and accelerometer technology. The authors argued that this study is one of the first to evaluate the external training load of elite-level goalkeepers during a competitive micro-cycle quantifying goalkeeping-specific physical performance. The main findings indicated that it was possible to understand when goalkeepers experienced the greatest external training load, and specifically, when starters and nonstarters' external training loads were similar. The authors argued that such outputs can be of meaningful importance in goalkeeping-specific training and prescription processes. Specifically, they found out when (i) situational drills involving a high number of dives, jumps, and explosive reactions can be implemented and (ii) such drills should be reduced to allow goalkeepers to achieve optimal performance on the match day. Moreover, it was field testing; thus, only with wearables would it be possible to perform such measurements in a real training/competition context.

Others (contributor 4) aimed to investigate whether the exclusion or inclusion of body segments affects the acceleration, velocity, rotation angle, and timeline of execution of a reverse punch, as well as examine the correlation between such quantities. The authors argued that joint kinematics are traditionally restricted to laboratory research, and the equipment used is usually robust, expensive, and demands trained experts who know how to operate it. Consequently, athletes face limitations that are not common in competition and training. Therefore, acquiring data with wearables marks a major advance in such types of movements or sports. Overall, it was noted that there were significant differences in the temporal and kinematic variables of the reverse punch that arise from the modality of execution. The authors also highlighted that some sports issues can be solved with engineering applied to sports sciences. Moreover, real-time data synchronization combining multimodal sensors and camera fusion is not a common approach because of numerous constraining factors in data acquisition. Therefore, wearables can be a less expensive and time-consuming approach to acquiring these data. Finally, the study by Lopes et al. (contributor 5) aimed to understand the variation of a set of kinematic and kinetic variables between two swimming sections and their relationship to swimming velocity. The kinetic data were acquired using a wearable system that measures the propulsive force generated by the upper limbs, where the hand is the fitting proxy. The authors noted that the propulsive force did not significantly change over time and also had a non-significant side effect (difference between right and left arm pulls). The authors highlighted that (i) using wearables in a swimming context enabled the measurement of the propulsive force; (ii) it allowed them to visualize the hand's trajectory during the arm pull; and (iii) it was possible to execute this with an easy setup (without cabling, less time-consuming, and less expensive) and with practical applications for coaches and swimmers that they can also use without expert supervision.

As a summary, wearable technology is becoming an affordable and accurate alternative for real-time acquisition of physiological, kinematic, and kinetic data in several sports where conventional camera-based tracking systems face different challenges. Sports communities (researchers, coaches, athletes, and all support staff) are continuously searching for paths to improve performance and reduce injury risk for the athletes. Over the last few decades, motion analysis based on video recording and computer digitization has been extensively used to analyze and measure athletes' technique to improve performance [10]. However, based on technological developments, video-motion analysis is becoming outdated. The time-consuming nature of data handling and processing and the inability to track key metrics such as bio signals, physiological parameters, and biochemicals all provide real-time data that are pertinent to the health and performance of the athlete [11]. This Special Issue acknowledges that the trend is shifting. Sports communities are showing a trend towards using wearables to provide accurate and reliable information in a real-time and training/competition context that is harder to achieve in laboratory settings. Moreover, it was indicated that sports clubs or teams are promoting a closer relationship with sports scientists, who are responsible for disseminating the data acquired from the sensors into metrics that can be clearly interpreted by coaches and athletes in a performance enhancement and injury prevention context [11]. Despite the fact that the use of wearables in sports is in an early stage, where most sensors are used to measure movement-based parameters such as distance, velocity, and acceleration, there is still a major need to understand the athlete's biophysical profile.

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