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Bridging Gaps in Wearable Technology for Exercise and Health Professionals: A Brief Review

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ABSTRACT

The proliferation of wearable devices, especially over the past decade, has been remarkable. Wearable technology is used not only by competitive and recreational athletes but is also becoming an integral part of healthcare and public health settings. However, despite the technological advancements and improved algorithms offering rich opportunities, wearables also face several obstacles. This review aims to highlight these obstacles, including the prerequisites for harnessing wearables to improve performance and health, the need for data accuracy and reproducibility, user engagement and adherence, ethical considerations in data harvesting, and potential future research directions. Researchers, healthcare professionals, coaches, and users should be cognizant of these challenges to unlock the full potential of wearables for public health research, disease surveillance, outbreak prediction, and other important applications. By addressing these challenges, the impact of wearable technology can be significantly enhanced, leading to more precise and personalized health interventions, improved athletic performance, and more robust public health strategies. This paper underscores the transformative potential of wearables and their role in advancing the future of exercise prescription, sports medicine and health.

Introduction

Since the inception of the “Quantified Self” movement approximately 15 years ago [1], the proliferation of consumer wearable devices has been remarkable. Today, consumer wearables have become a staple in many people’s lives. In the United States and Europe, consumer wearable ownership is between 40–53 %, respectively [2]. In the realm of exercise and health, the adoption of these devices is even more pronounced, particularly among younger athletes [3].

Consumer wearable devices are increasingly used in competitive sports to quantify performance and monitor training load [4–6]. For example, in team sports such as soccer, field hockey, basketball, and American Football, GPS units and heart rate monitors are commonly used to measure player activity profiles, physiological demands, and recovery [6, 7]. Similarly, both elite and recreational runners have reported finding these devices useful in improving performance, tracking training loads, and providing real-time feedback on speed and cadence [8].

Also, in healthcare and public health settings, consumer wearable technologies are playing an increasing role in transforming approaches to disease prevention, management, and research. Traditionally, public health surveillance has relied on self-reported measures such as interviews and questionnaires [9]. Despite their widespread application, these methods are susceptible to various biases [10, 11]. The emergence of smartphones as tools for health surveillance marked an important transition in the field, enabling researchers to investigate patterns of human movement [12], mood [13], the spread of disease [14], and socioeconomic status [15]. For example, "Our Future Health" in the UK aims to be the largest research program to understand how diseases can be prevented by using a variety of data sources, including consumer wearable devices, to track health data in real-time, thereby enabling early intervention and personalized healthcare strategies [16]. Similarly, research conducted by the Robert Koch Institute utilizes consumer wearables to gather large-scale epidemiological data, enhancing the understanding of public health trends and contributing to the development of targeted health policies [17]. The Scripps Research Translational Institute's DETECT study leverages consumer wearables to monitor physiological signals that may indicate viral illnesses, such as COVID-19, demonstrating how these devices can support early detection and response to outbreaks [18].

These initiatives underscore the versatility of wearable devices in not only advancing personal health and fitness but also in contributing to critical research efforts that aim to improve public health outcomes on a global scale. Through the integration of consumer wearable technology in diverse settings, from sports to comprehensive health studies and exercise prescription, we are witnessing a paradigm shift towards more data-driven and personalized health and fitness solutions. This review aims to summarize the main challenges and opportunities presented by consumer wearable technology in exercise, health, and sports contexts. The discussion extends across five key areas, including the requirements for harnessing wearables to improve performance and health, the need for data accuracy and reproducibility, user engagement and adherence, ethical considerations in data harvesting, and future research directions.

Requirements for the Effective Use of Wearables for Improving Performance and Health

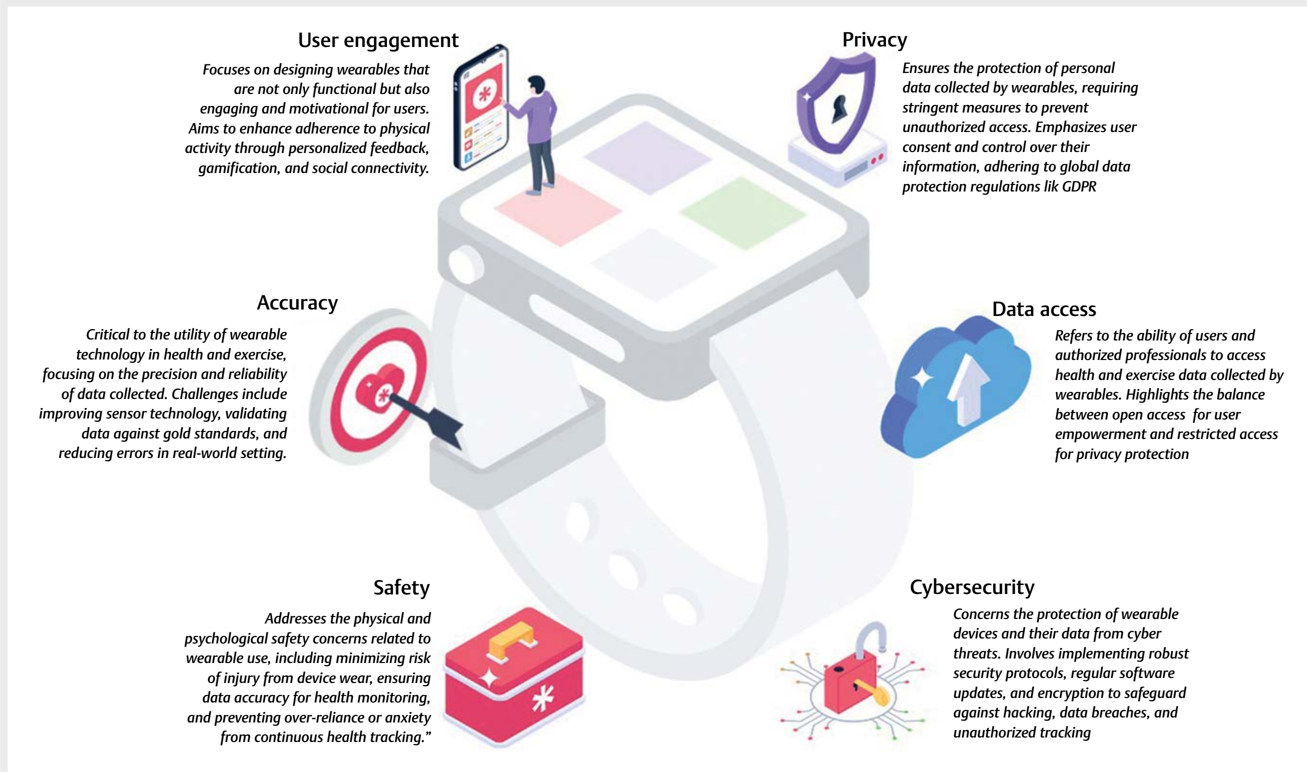
Recent advancements in wearable technology, driven by innovations in material science, microchip technology, and the integration of a wider array of sensors, have significantly enhanced the potential capabilities of these devices. Developments in flexible electronics, e-textiles, and ultra-low-power microcontrollers have enabled wearables to become more comfortable, powerful, and capable of sophisticated real-time data analysis [19]. Presently, wearable devices not only can track step counts through accelerometers or inertial measurement units (IMUs) but can also capture a range of physiological signals, including heart rate, blood oxygen saturation, and blood pressure; they can even detect atrial fibrillation [20], falls [21], and car crashes [22].

However, this wealth of information also presents a significant challenge: translating diverse wearable-derived data into actionable insights for exercise and health professionals. Effectively analyzing wearable-derived data necessitates expertise in data science, human physiology, and health behaviors. However, the scarcity of researchers with the required training diversity in these areas complicates collaboration and communication between disciplines. Furthermore, the rapid evolution of wearable technology introduces concerns regarding data privacy, the validity of results, and the impact of academic partnerships on business models. These challenges underscore the need for a multidisciplinary approach to harness the full potential of wearable devices in improving health and performance outcomes, balancing technological innovation with ethical considerations and data accuracy. ▶ **Fig. 1** illustrates key areas that require attention when utilizing consumer wearable technology in exercise and health settings.

The challenge extends to using this data to make positive impacts in exercise and health and to influence individual decision making. In a practical framework that was established by a collaboration between practitioners and researchers, key questions for the use of wearable devices were raised in order to facilitate the decision making for end users [23]. These questions included information related to the value of the collected data; the necessary trust in the accuracy of the collected data; whether the obtained data can be integrated and effectively analyzed (or processed); and whether the technology can actually be implemented in daily practice. In this context, there is an urgent need to develop sensing technology that is robust, easy-to-wear, and able to measure biosignals with increased detection sensitivity and improved signal-to-noise ratios, specifically at the interface between soft sensing components and rigid electronics, such as textile-based/fiber-shaped-, multifunctional- and self-powered sensors [24–27].

Data accuracy and reproducibility

Data quality remains among the most essential requirements for the sustainable implementation of consumer wearable technology in exercise and health settings. In this context, signal quality has also been proposed as a key challenge in the recent 2023 wearable photoplethysmography roadmap [28]. One of the primary challenges highlighted in a recent umbrella review that evaluated the validity of wearable devices is the rapid and ongoing evolution of the consumer wearable technology landscape [29]. The inherent delay in academic research and publication processes results in a situation where the research captured within the review acts as a historical snapshot, capturing the accuracy and validity of devices that were on the market approximately two years prior to the review's execution. This temporal gap is underscored by the chronology of the studies cited – only one of the identified reviews was published in 2023, with the majority being from 2022. The authors noted the ephemeral presence of devices in the market; every device analyzed had either been phased out or replaced by a newer model by the time of the review – and fewer than 5 % of the devices had been validated for the range of outcomes they measure [29]. Although newer models may maintain a semblance of hardware continuity, the introduction of updated firmware and algorithms likely alters device performance and the accuracy of the data being produced. This scenario underscores a tension between the slow,



▶ **Fig. 1** Navigating the complex landscape of wearable technology – key considerations.

deliberate pace of academic research and the fast-moving, ever-changing nature of the commercial technology sector. To overcome this, likely a closer collaboration between the industry and the exercise and health science community is required. First attempts are currently underway as part of the funding scheme of the European Commission [30, 31].

The abundance of factors that affect the signal quality of optical and strain sensors incorporated in consumer wearable devices have been summarized in two recent publications by the INTERLIVE-network [32, 33], an initiative to which the primary author has significantly contributed. The INTERLIVE-network's efforts are aimed at advancing our understanding of the parameters that influence sensor accuracy, particularly in real-world conditions. This work emphasizes the importance of interdisciplinary collaboration to address the complexities of wearable technology and to improve data validity.

In laboratory settings, sensors may provide a very high validity and reproducibility, however in the real world (i. e. in scenarios representing the intended use of the wearable device), their accuracy is often low or at least unknown. For example, it has previously been shown that optical sensors may provide accurate readings in resting conditions but their accuracy reduces in exercise settings that are characterized by high-intensity body movements [34, 35]. This may largely be attributed to factors related to the human-wearable interface, namely the contact pressure, skin temperature and motion artefacts [32]. While research on the effects of ambient or skin temperature on the signal quality of optical sensors is still in early stages [36], contact pressure between the wearable device and the skin seems to have a profound effect on the readings of the obtained pulse wave [37]. In a similar manner, motion artefacts have been shown to influence optical signal readouts, and may be caused by a number of factors, including displacement of the sensor over the skin, changes in skin deformation, blood flow dynamics and/or ambient temperature [38]. Importantly, the individual contribution of each factor may be very dynamic and prone to changes throughout an exercise bout (i. e. depending on the exercise intensity and/or duration) or prolonged physical activity, requiring a thorough validation of these devices and possible adjustments during periods of continuous data recording.

To overcome this, incorporating measures that assess whether a signal is actually caused by the intended physiological or chemical changes may facilitate the implementation of feedback mechanisms to the end user. For example, strain sensors could be utilized to assess the contact pressure or high-sensitivity motion sensors may be used for the detection of motion artefacts (e. g. the shifting of the sensor over the skin), thereby distinguishing between artefacts and actual movement. The data from these sensors could be fed back to the user, for example, prompting them to adjust their device to improve accuracy. Additionally, this data could be incorporated at the backend during export or processing, allowing for the labeling of data quality and suggesting whether the data might be of lower or higher quality. This could be especially important when wearables provide clinical readouts, such as the detection of atrial or even ventricular fibrillation [39, 40]. However, to the best of our knowledge, very few manufacturers currently implement high-sensitivity motion sensors for data quality assurance in a commercially available device [41].

Data transparency

Ensuring data accuracy in wearable devices also necessitates transparency regarding data quality to allow for individual decision making and to bolster the confidence of consumer wearable technology in exercise and health settings. Often, the data displayed by these devices are estimates, resulting from low signal quality or decreased sampling frequency to save battery life. This is particularly common in lower-cost wearables, which adjust sampling rates based on the user's activity. For instance, the sampling rate may decrease during steady-state activities and increase for activities with higher intensity or dynamic movements. This approach is logical for slowly-changing variables, such as heart rate, but may not suit dynamic or pulsatile measures like blood pressure. Regardless of the data source, it is crucial to provide feedback on the quality of the data retrieved and to determine whether adjustments (such as to sensor placement) are needed to enhance signal quality. We do acknowledge that there are multiple ways to make end users aware of the confidence of the obtained values (e. g. through coloring or displaying values as ± to highlight that this is an estimate rather than an actual measure). In fact, Fitbit provides confidence values on a scale of 0–2 (with 0 being the lowest and 2 being the highest confidence) for each HR value obtained, but this information is only accessible once the data is exported retrospectively. Moreover, the calculation is based on algorithms that remain unknown to the user. Unfortunately, scientific work on the efficacy of such measures remains in its infancy and should be encouraged to further support efforts aimed at enhancing data quality.

The transparency issue is evident in the scarcity of white papers from manufacturers that explain the calculations underpinning their algorithms and the conditions required for these algorithms to yield accurate results. For example, many manufacturers strive to develop algorithms capable of estimating maximal oxygen consumption (VO_2max) using linear associations between heart rate, workload, and VO_2, thereby offering real-time feedback on an individual's fitness and health status. A recent meta-analysis uncovered significant random errors in VO_2max estimations across various studies, with limits of agreement ranging from ± 15.24 ml · kg^{-1} · min^{-1} to ± 9.83 ml · kg^{-1} · min^{-1} in resting and exercise settings, respectively [42]. Since the systematic bias was very low in either condition (i. e. resting vs. exercise), these findings may support the use of consumer wearable devices to estimate VO_2max at a population level. However, since the random error was high, these findings also underscore the difficulties of using these devices for tailored and personalized exercise prescription. Yet again this is exaggerated by the lack of reporting the algorithm, making it impossible to identify potential sources of errors in the provided VO_2 estimations. This lack of transparency is a significant barrier to the trust and reliability of wearable devices. Users and healthcare professionals are left without a clear understanding of how data is processed and interpreted, leading to potential misapplications of health and fitness metrics. This gap highlights the need for manufacturers to disclose their methodologies and for independent research to validate these devices comprehensively. By addressing these transparency issues, the industry can enhance the credibility and effectiveness of wearables in delivering accurate health insights, thereby fostering greater user confidence and adherence [43].

User engagement and adherence

The integration of wearable technology in the realm of exercise and health has brought about a paradigm shift in how users monitor and understand their training, performance, and overall health. However, user engagement is highly heterogenous. Studies have shown that many users discontinue use after just a few weeks or months [44, 45], with only approximately 40 % maintaining regular use for 24 months [46]. The reasons for this lack of long-term adherence among the majority of wearable users are varied and not yet fully understood [47].

To effectively promote long-term engagement and healthier lifestyles, wearables must be designed to enhance motivation and adherence [48]. Personalized feedback and goal setting can help users achieve realistic health goals by providing tailored recommendations and progress tracking [49]. Incorporating gamification elements like challenges and rewards can increase motivation and make physical activity more enjoyable [50]. Social features that connect users with support networks and communities can foster accountability and encouragement [51, 52]. Behavioral nudges and reminders tailored to individual schedules can prompt users to engage in healthy behaviors [53]. Integrating wearables with healthcare systems can enhance adherence by involving providers in monitoring and encouraging patient behaviors. User-centered design, involving patients in the development process, can help to ensure that wearables are user-friendly and meet the needs of the target population [48].

Despite issues with long-term adherence, over-reliance on wearables presents a significant challenge: the paradox of wearable dependency. The core of this problem is not just the use or adherence to these devices, but the extent to which users become dependent on them for measuring their training success, defining their athletic identity, or assessing their health status.

To extract the maximum benefits from wearables, they need to be worn consistently, so that they can provide a comprehensive picture of sleep, stress, physical activity, energy expenditure, aerobic capacity, and other markers of health. However, this high level of attachment has several downsides. Younger generations in particular have been shown to exhibit a strong attachment to self-quantification, often using wearable devices as the yardstick for their success [3, 54]. This over-reliance can diminish the intrinsic joy and motivation derived from the activity itself, undermining primary goals such as fitness, strength, or skill improvement. This over-reliance seems to be especially pronounced in athletic settings where for many athletes, especially in endurance sports, wearables and fitness trackers have become more than tools – they are integral to their identity and daily routines. Research has shown that endurance athletes in particular feel "naked" without their wearables, underscoring the deep-seated reliance on these devices [55]. This dependence, while beneficial in tracking and improving performance, raises concerns about the psychological impact and the potential for reduced enjoyment in sports. Digitizing every aspect of health and training can paradoxically lead to deteriorations in the very outcomes these technologies aim to improve. A case in point is the development of orthosomnia, a condition where athletes obsess about achieving optimal sleep, driven by data from sleep trackers. Ironically, this obsession can lead to poorer sleep quality and recovery, defeating the purpose of using the technology [56].

The challenge therefore lies in balancing the benefits of wearable technology with the need to preserve individual autonomy and enjoyment in physical activity and health monitoring. It is crucial to educate users on the appropriate use of these devices, ensuring that they complement rather than dictate training and lifestyle choices. Exercise and health professionals have a pivotal role in guiding users to interpret and use data in a way that enhances, rather than overshadows, their natural instincts and enjoyment.

Ethical and Legal Considerations in Wearable Technology

The integration of wearable technologies in everyday life and healthcare systems marks a significant shift towards more personalized and preventative health strategies. These devices offer unprecedented opportunities for large-scale health research and public health surveillance [57]. However, this evolution necessitates a considered discourse concerning the ethical implications of data collection, user consent, privacy, and long-term utilization [57–59].

The increasing use of consumer wearables in exercise and health settings has highlighted significant data security and privacy challenges. These devices collect extensive data, often beyond the explicit knowledge of users [60]. This data can be used for a variety of purposes, which are not always aligned with the user's intentions [60, 61]. A notable example of the risks involved was a recent security breach that exposed over 61 million fitness tracker records, compromising the privacy of user data [62]. Such incidents underscore the complexities of managing wearable device data, which involves navigating intricate technological protocols and maintaining continuous user consent, often leading to incomplete datasets that compromise research integrity and findings [63]. Moreover, the opaque processing of data by third parties [64, 65], coupled with the strategic location of data servers in jurisdictions with less stringent data protection laws [66], exacerbates these security risks, suggesting a need for greater regulatory oversight beyond what is currently afforded by Institutional Review Boards (IRBs) [67]. Different regulatory environments further complicate these issues; for example, the General Data Protection Regulation (GDPR) in the EU imposes stringent requirements on data privacy and user consent, while the Health Insurance Portability and Accountability Act (HIPAA) in the US focuses more on protecting health information within healthcare settings. These variations impact the development and global use of wearable technologies, as companies must navigate a complex landscape of compliance requirements. Often, companies may skirt the regulatory grey areas of different legislation to maximize their operational flexibility and data utilization [68].

At the same time, users need to have significant expertise to properly understand "appropriate use" and how it differs across regions, placing an unrealistic burden on individuals to stay informed about the legal nuances that affect their data privacy and security. The surrender of data begins when the user agrees to the terms of service and end user license agreement. The complexity and length of these documents are such that a vast majority of users – up to 97 % – agree to the policies without fully understanding them, simply skimming through documents that would require considerable time to read thoroughly [60, 69, 70]. Moreover, these terms are often only presented to users after purchasing the device and during the setup process, leaving them with little choice but to agree or return the device. This lack of transparency and accessibility in the terms of service agreements undermines informed consent and highlights the need for clearer, more concise information upfront. Then, as users begin to use their devices and capture health data, these data are often sent to the manufacturer's servers in a separate location. This situation allows data to become more accessible legally once stored on overseas servers, thereby increasing data security risks and allowing private companies to extract the maximum value from their users' data [68].

This issue is compounded by the phenomenon of choice legacy, where users become increasingly tethered to a device manufacturer's software and service ecosystem to continue extracting value from the data they generate. The current revenue model locks users – and their data – into a specific device manufacturer, making migration between different app ecosystems challenging. For instance, to maximize the utility of a Garmin, Fitbit, Oura, or Whoop device, users must use the corresponding app. These apps often require a paid subscription; at the time of writing, the yearly costs are €79.99 for Fitbit Premium, €69.99 for Oura membership, and €264.44 for Whoop membership, in addition to the initial purchase price of the device. If users decide to switch devices or stop using a wearable altogether, they may lose access to their historical data. Although companies like Apple and Google offer aggregator apps (Google Fit, Google Health Connect, and Apple Health) that can fetch data from individual apps with user permission, they often do not access the full granular data (such as HRV values, sleep quality, or readiness metrics like "body battery"), which many users find beneficial [71]. Furthermore, using these aggregators ties the user to the aggregator app and its core operating system, whether iOS or Android, propagating the problem.

These issues have significant implications for the ethics of data ownership, the right to be forgotten, user privacy, and legislative control. There is a pressing need for more transparent data policies and greater regulatory oversight to protect user rights and ensure that the value derived from wearable device data benefits both users and the broader health community. Currently, the power dynamics often leave users at a disadvantage, constrained by their limited influence over the data security practices of large tech companies. As the use of wearable technologies expands, it is essential to adapt how we manage and utilize the data they produce.

Here, we propose a series of recommendations for the ethical capture and utilization of wearable device data in sports and healthcare settings: Users should 1) read privacy policies carefully, use strong, unique passwords, and enable two-factor authentication on their accounts; 2) regularly audit app permissions, limit data sharing, and keep software updated; 3) opt out of data collection, if possible, disable data sharing where feasible, and turn off Bluetooth when the device is not in use; 4) use encrypted connections, be cautious with third-party apps, and back up data securely; 5) understand regional privacy laws and delete unnecessary data to minimize digital footprints. Some companies also allow users to delete data within the app or by email request.

Future Areas of Research

The future of wearable technology in exercise and health is poised for further innovation, particularly through the integration of AI and machine learning. These advancements promise to revolutionize how we approach predictive analytics in these fields. Here, we provide few examples of areas bearing an enormous potential for the further utilization of wearable technology.

Real time data streaming

In the context of sports performance, new developments are underway to comprehensively assess physiological, biochemical, and biomechanical variables in real competition situations, which is considered one of the Holy Grails of modern sports science. Traditionally, due to a lack of available technology and regulations outlined by sports federations, these assessments have been conducted mainly through simulations in laboratory settings or during training. Advances in material science and the integration of AI and machine learning algorithms could enable wearables to provide immediate, actionable insights during competitions, enhancing both performance and safety. Real-time tracking in sporting environments has so far been possible only in pilot projects, such as one carried out at the Tokyo Olympics 2020 in 2021 [72]. However, such developments may ignite discussions about fairness, as not all athletes may have equal access to these technologies. Once established, these ecosystems could also be utilized in health-related settings, such as remote exercise therapy for patients suffering from chronic diseases. Current attempts are underway, opening a new era for the use of wearable technology at the interface between exercise and health [73].

Intelligent training guidance

Ultimately, the abundance of physiological and biomechanical data gathered by wearable technology may be used for intelligent (automated) exercise prescription. Indeed, nearly every commercially available smart device incorporates some form of training load estimation or recovery prediction. However, assessing training load and recovery is an enormously complex phenomenon involving literally all bodily systems and understanding recovery dynamics has been a matter of debate for many decades. In 2018, a consensus statement on recovery and performance outlined that single physiological or psychological parameters will only represent very isolated aspects of recovery [74], making it also challenging to define protocols for the validation of recovery predictions.

In conjunction with this, most algorithms currently incorporated in wearable devices are mainly based on surrogates of cardiovascular function (i. e. heart rate, heart rate variability, or excess post-exercise oxygen consumption [EPOC]). For example, EPOC represents the increased rates of oxygen intake following strenuous activities and is based on the restoration of resting states, including factors such as replenishment of fuel stores, restoring hormone balance, and cellular repair [75]. However, wearable sensors typically estimate EPOC solely from the calculated (or directly assessed) heart rate (or in some cases heart rate variability) and thus the estimates provided are not based on actual physiological or chemical alterations. Due to the complexity of recovery dynamics, it becomes obvious that multivariate approaches are needed to provide automated guidance on exercise and recovery, including, for example, additional biomarkers obtained from saliva or sweat in a non-invasive and continuous manner. Developing sensors that can continuously track changes in biomarkers, for example, lactate, electrolytes, or even hormonal concentrations will open new avenues for a better understanding of the physiological processes during exercise and recovery. AI algorithms could analyze these diverse data streams to provide more accurate predictions of recovery and readiness.

Safety aspects of exercise training

Wearable technology may also be used to improve the safety of competitive sports. For example, it has recently been debated whether headers should be banned from soccer in order to reduce the risks of concussion and subsequent brain injuries [76]. In fact, only recent advances in wearable technology (e. g. strain sensors such as accelerometers) have helped to quantify the frequency and intensity of headers in amateur and professional soccer [77]. As a consequence of this, the English Football Association has very recently introduced new guidance on the use of headers during training and matches, reducing the regular exposure of head impacts [78]. However, while guidelines on the diagnosis, treatment and return-to-sport decisions after concussion currently do not include sensor-derived data, it is plausible that further advancements in sensor size and accuracy may also enable wearable technology to aid important medical decisions.

In line with this, attempts have been made to assess core temperature during competitions. Tracking of the core temperature was implemented during the 2016 Road Cycling World Championships as well as the 2019 World Athletic Championships in Doha, Qatar [79, 80]. In fact, these systems would also have merits for global health monitoring, e. g. in countries with high temperatures. However, despite issues related to the accuracy of such systems, implementing this also requires further guidance on possible ethical dilemmas. This concerns especially decisions that are to be made when critical core temperatures indicative of exertional heat illness are observed. A summary on the possible issues related to this can be found elsewhere [81]. In this context, attempts have been made to allow sensors to assess skin temperature and induce cooling when a certain temperature has been exceeded. The primary aim of such devices is to improve the perceived thermal comfort of individuals, e. g. in the presence of hot flashes. However, the scientific evidence for the efficacy of the device remains contradictory. While initial data showed beneficial effects on the perceived temperature [82] or sleep in women experiencing sleeping problems due to hot flashes [83], others did find improved distal skin temperature with no beneficial effects on temperature perception in adults not separated by sex [84]. So far, the use of these devices in exercise related settings seems unexplored but it is obvious that there is potential especially when performing in hot environments.

Discussion and Conclusion

The landscape of wearable technology in exercise, health, and sports settings is rich with opportunities but also fraught with challenges. A confluence of factors – the rapid advancements of wearable technologies, the accumulation of large datasets offering novel insights into health and performance, and the nascent role of new commercially available AI technologies – mean that we stand on the brink of a technological revolution that promises to redefine our approach to personal health, fitness, and athletic performance. However, realizing this potential requires us to navigate the complex interplay between technological innovation, data accuracy, user engagement, privacy, and ethics.

To harness the full power of wearable technology, a concerted effort among various disciplines is essential. Engineers working with healthcare professionals and patients to design devices that meet user needs; data scientists developing algorithms to accurately interpret complex data from wearables; and ethicists who ensure the ethical use of data, safeguarding user privacy and consent. We posit that this multidisciplinary approach will be essential to address the complexities of designing, implementing, and utilizing wearable devices – and such an approach will need to take into account a number of key priorities.

First, this interdisciplinary community needs to develop agile validation frameworks that adhere to accepted methodologies to keep up with the commercial ecosystem. When validation studies are conducted according to best practice protocols, they should no longer be subjected to the traditional journal-peer-review system. Alternative, fast-track platforms are required that allow for a rapid peer-review process that is primarily based on the protocol used, with the results being published with no delay – so that key stakeholders have access to the most relevant validation research for the latest crop of wearable devices.

Second, the fragmented digital health landscape limits the utility of collected data. A multidisciplinary approach can address this by standardizing data formats and terminologies across various systems. Engineers can contribute by designing interoperable technologies that comply with standards such as Health Level Seven International (HL7) and Fast Healthcare Interoperability Resources (FHIR) [85]. These standards facilitate seamless data exchange between different health IT systems. Data scientists can develop algorithms that not only integrate data from multiple sources but also ensure it is comparable and actionable. This includes using standardized terminologies such as SNOMED CT and LOINC to harmonize data [86]. Healthcare professionals can collaborate to ensure these systems support clinical workflows and meet the needs of end users. Together, these efforts enable comprehensive data integration and analysis, enhancing the overall impact of wearable technology.

Third, incorporating end users as partners in the development process is vital. While different fields of expertise are needed, true value is attained by focusing on end user needs. Engaging patients in user-centered design ensures that wearables meet real-world needs and are user-friendly. This partnership leads to solutions that are technically advanced, widely accepted, and effective in improving health outcomes.

Together, we must strive for advancements that not only push the boundaries of what is technically possible and affordable but also prioritize data accuracy and integrity, ethical standards, and user well-being. A multidisciplinary approach will be essential to ensure that wearable technology serves as a force for good, empowering individuals to achieve their health and performance goals while safeguarding their privacy and autonomy, and at the same time providing new insights into human physiology to further advance exercise and health sciences.

Conflict of Interest

The authors declare that they have no conflict of interest.

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