Journal of Back and Musculoskeletal Rehabilitation 36 (2023) 779–782
DOI 10.3233/BMR-235002
IOS Press

Editorial

Assessing disability and function in patients with musculoskeletal disorders utilizing wearable medical technology: Opportunities and challenges

Ram Haddas
University of Rochester Medical Center, 601 Elmwood Ave, Box 665, Rochester, NY 14642, USA
E-mail: Ram_Haddas@URMC.Rochester.edu
ORCID: https://orcid.org/0000-0002-1273-5499

Traditionally, disability and function assessment for musculoskeletal disorders patients involve patient-reported outcome measures (PROMs), physical assessment, radiographic, electromyographic (EMG) analysis, motion laboratory referral, and depression indices [1]. The PROMs were developed to better evaluate and assess a patient's self-perceived physical function, disability level, pain, and overall self-awareness of their health. These tools have been highly successful in allowing patients to provide insight into their disease and functional disability. There are, however, limitations to these tools, such as inherent subjectivity, personal bias, and the fact that they are time-dependent [2,3]. In a clinical environment, physical assessments are commonly used to evaluate patients' function and strength, including strength testing, basic function, and range of motion. These exams can be fairly limited in the clinical setting and intraobserver reliability issues. In the office, objective measures such as range of motion and radiographic metrics are readily available, but these do not offer insight into how the patient is affected in their daily lives [4]. For more sophisticated disability and function analysis, clinicians may order a gait/function analysis at a local human motion analysis lab for their patients. In this lab, clinicians could expect a detailed report on patients' kinematics (walking speed, step length and time, range of motion, and range of sway), neuromuscular activity (muscle onset, magnitude, and coordination), kinetic (ground reaction force and pressure), and physiological factor (heart rate, VO_2 capacity, and max) [5,6]. An in-depth analysis is possible, however it can be costly and have geographical limitations, and insurance coverage may not always be available [3]. Over the past decade, there has been use of disability and functional outcome measurements (DFOMs), objective quantitative measurements of physical function, in orthopedics care, and are beginning to be included as part of the standard of care [3,6]. DFOMs, along with other PROMs, can provide better and more objective insight regarding patient care and may help to define optimal patient-specific treatment plans [3,6,7]. With new technological advancements, as well as a renewed emphasis on self-awareness of personal health in the post-COVID-19 pandemic era, there has been an increased demand for feasible and easy-to-use tools to better quantify a patient's health. Telehealth has also become increasingly important, and wearables have proven to be a useful adjunct for providing effective remote clinical care [8]. Healthcare providers have begun to explore the use of wearable devices to more accurately access physical function [2,9]. The advancement of wearable technology and growing demand from consumers to control their health has influenced the medical industry to further develop more wearable devices including smartwatches, phone applications, and wearable monitors [1,2,4,9].

Traditionally, common wearable devices measure levels of activity, heart rate, and sleep time. Health met-

ISSN 1053-8127/$35.00

ric data can be collected continuously by wearable devices throughout the day, week, and month. This can provide a longitudinal representation of the general health and mobility of the wearer, as opposed to the time-dependent and subjective PROMs and in-office physical assessment [2]. Smartphones with substantial computing capabilities and built-in sensors, such as accelerometers and gyroscopes, have increased worldwide in recent years [10]. Smartphone accelerometer data was used to measure individual patient activity patterns based on their smartphone movements [11]. Mobile health, a component of eHealth, is a rapidly growing method of providing health care that could have a significant impact on healthcare research, healthcare delivery, and health outcomes [12]. It is becoming increasingly common for orthopedic clinicians to use wearable devices to optimize patient care and efficiency. Knee and hip clinicians are the main utilizers of wearables in orthopedics following lower extremity arthroplasty to measure spatiotemporal gait parameters [13]. The majority of studies used accelerometers and inertial measurement units (IMU) to measure spatiotemporal gait parameters [14,15] and some joint kinematic parameters [16]. Shoulder and elbow clinicians are using wearables sensors to evaluate shoulder movement following total shoulder arthroplasty [17]. They conclude that accelerometers, although not replacing other clinical measures, have been shown to provide a unique insight into functional recovery following total shoulder arthroplasty outside of the clinic and are useful as an additional metric when evaluating postoperative recovery [17]. Similarly, wearable technology presents the opportunity to objectively measure physical activity in children recovering from surgery, a vulnerable population that does not communicate as well as older patients [18]. Studies in pediatric patients have demonstrated the feasibility of using accelerometers to measure physical activity after surgery [18,19]. Neurologists have been using IMUs to investigate pre- and post-concussion performance, 24 to 48 hours post-injury, and at the point of returning to full contact training [20].

Several benefits and challenges are anticipated from a wearable-based quantitative tool to assist with preoperative planning for patient-specific alignment objectives such as assisting in choosing the right surgical procedure for the right patient, recognition of red flags, leading to avoidance of surgery where it is not going to help, recovery monitoring, early detection of perioperative complications, prognostic information, and prediction of treatment outcomes [1]. General information, such as heart rate, activity level, sleep pattern, and nutrition information, can help clincians decide whether or not to perform surgery to serve as a baseline for each patient. Such insights may lead to changes in assessments of disability, treatment strategies, or modifications of rehabilitation regimens.

Benefits: Clinically, these devices could help physicians develop a deeper connection with their patients. To a patient, these devices could be a way to stay connected to their physician and make them feel more involved in their care. In a rural environment, patients sometimes travel hours to see their physician and only feel "connected" with their physician for a few minutes during a visit. The longitudinal aspect of the devices should not be understated as it can serve to improve the physician-patient relationship by allowing monitoring of data remotely and serve as a constant reminder to the patient to follow the treatment plan and they will figuratively have their physician right there with them as the treatment plan progresses. Moreover, by using remote monitoring, orthopedic surgeons and clinicians can get a more complete picture of the disease during preoperative planning as well as detect disease progression during perioperative care [21]. Similar strategies have been used with halter monitors for cardiologists in order to detect disease processes with intermittent etiologies that are difficult to identify.

Challenges: One significant barrier to widely adopting medical devices is the security concerns that come with utilizing these devices. Most of the available wearable devices are not capable of user authentication and often lack appropriate security provisions, making the task of protecting the confidentiality of patient information challenging. In the medical field, there is an emphasis on data protection and confidentiality. Wearable technology poses potential problems for guarding patient data and anonymity in medicine. Furthermore, commercial wearable devices are being developed and marketed far faster than the capacity for independent reliability assessments, device validation, and rigorous regulatory oversight. Historically, medical-grade sensors have been regulated by FDA, with most wearables classified as class 1 or 2 noninvasive medical devices. The FDA issued a digital health innovation action plan in 2017 to address the regulation of software as a medical device and most recently launched the Digital Health Center of Excellence as a resource for digital health policy [22]. To date, only a small percentage of wearable devices have obtained FDA clearance. Another limitation of this technology is its energy consumption and battery life. Having a short battery life would require multiple batteries or multiple charging sessions which may add another constraint on patients' compliance or clear data collection. Additionally, data storage, processing, and sharing could be a challenge. The proliferation of wearable devices may facilitate remote monitoring and real-time care, much like the advent of big data a few decades ago with the advances in genomics. However, there is a lag in the development of protocols to share, process, review, and create a meaningful actionable plan in response to these data. Moreover, consumer health wearables are available at a wide price range but remain a luxury item primarily used by higher-income individuals. As wearables become more integrated into healthcare delivery, they may become a source of health disparity. Additionally, health systems in rural or safety-net areas may be unable to afford the clinical infrastructure required to integrate telehealth and virtual data into practice. The adoption of reimbursement policies by health insurance, Medicare, and Medicaid would likely be necessary to bridge this gap.

One of the unique advantages of wearable devices is that the measurements are truly patient-specific since the data collection takes place in a patient's own home or work environment while they are performing their daily activities. The use of wearable devices can differ based on their application and the goals of the user. Some users may utilize the data gathered from a wearable device to improve their quality of life and others may choose to monitor their function in the workplace for performance evaluation and injury prevention. Using wearables to measure workers' activity objectively and provide patient-specific information in real time can improve our understanding of risk factors for low back pain. Therefore, the study by Gomes et al. on the prevalence and factors associated with low back pain in warehouse workers has been selected as the Editor's Choice article and has thus made been freely available [23].

In conclusion, wearable technology has the potential to revolutionize healthcare through its ability to collect data continuously and in any environment. As wearable technology becomes more prevalent in orthopedics, it may facilitate patient-physician communication, potentially reducing healthcare costs and physician burnout. Wearable technology is an emerging technology sector that can provide valuable health information to patients and clinicians. A combination of DFOMs using a wearable device with PROMs and radiographic measurements may provide a more comprehensive evaluation of a musculoskeletal disorders patient's health and assist the physician in better treatment decision-making, a customized definition of return to work, and mitigate risk exposure. Having ubiquitous diagnostic capabilities will not only allow us to monitor our patients better but also help us learn about postoperative recovery and the impact of our interventions. By advancing this technology, orthopedic caregivers may be able to assess preoperative functional capacity, monitor postoperative progress, and measure outcomes more objectively in the future.

Conflict of interest

None to report.

References

[1] Haddas R, Lawlor M, Moghadam E, Fields A, Wood A. Spine patient care with wearable medical technology: state-of-the-art, opportunities, and challenges: a systematic review. Spine J. 2023.

[2] Mobbs RJ, Fonseka RD, Natarajan P. Wearable sensor technology in spine care. J Spine Surg. 2022; 8(1): 84-6.

[3] Haddas R, Wood A, Mar D, Derman P, Lieberman I. Reporting and tracking objective functional outcome measures: implementation of a summary report for gait and balance measures. Spine J. 2021; 21(7): 1193-204.

[4] Lee TJ, Galetta MS, Nicholson KJ, et al. Wearable Technology in Spine Surgery. Clin Spine Surg. 2020; 33(6): 218-21.

[5] Haddas R, Ju KL, Belanger T, Lieberman IH. The use of gait analysis in the assessment of patients afflicted with spinal disorders. Eur Spine J. 2018; 27(8): 1712-23.

[6] Haddas R, Sambhariya V, Kosztowski T, Block A, Lieberman I. Cone of economy classification: evolution, concept of stability, severity level, and correlation to patient-reported outcome scores. Eur Spine J. 2021; 30(8): 2271-82.

[7] Maldaner N, Stienen MN. Subjective and Objective Measures of Symptoms, Function, and Outcome in Patients With Degenerative Spine Disease. Arthritis Care Res (Hoboken). 2020; 72(Suppl 10): 183-99.

[8] Beavers DL, Chung EH. Wearables in Sports Cardiology. Clin Sports Med. 2022; 41(3): 405-23.

[9] Aroganam G, Manivannan N, Harrison D. Review on Wearable Technology Sensors Used in Consumer Sport Applications. Sensors (Basel). 2019; 19(9).

[10] Shin DC. Smartphone-based visual feedback trunk control training for gait ability in stroke patients: A single-blind randomized controlled trial. Technol Health Care. 2020; 28(1): 45-55.

[11] Panda N, Solsky I, Huang EJ, et al. Using Smartphones to Capture Novel Recovery Metrics After Cancer Surgery. JAMA Surg. 2020; 155(2): 123-9.

[12] Hamilton SJ, Mills B, Birch EM, Thompson SC. Smartphones in the secondary prevention of cardiovascular disease: a systematic review. BMC Cardiovasc Disord. 2018; 18(1): 25.

[13] Follis S, Chen Z, Mishra S, Howe CL, Toosizadeh N, Dohm M. Comparison of wearable sensor to traditional methods in functional outcome measures: A systematic review. J Orthop Res. 2021; 39(10): 2093-102.

[14] Christiansen CL, Bade MJ, Paxton RJ, Stevens-Lapsley JE. Measuring movement symmetry using tibial-mounted ac-

celerometers for people recovering from total knee arthroplasty. Clin Biomech (Bristol, Avon). 2015; 30(7): 732-7.
[15] Kwasnicki RM, Ali R, Jordan SJ, et al. A wearable mobility assessment device for total knee replacement: A longitudinal feasibility study. Int J Surg. 2015; 18: 14-20.
[16] van der Linden ML, Rowe PJ, Myles CM, Burnett R, Nutton RW. Knee kinematics in functional activities seven years after total knee arthroplasty. Clin Biomech (Bristol, Avon). 2007; 22(5): 537-42.
[17] Edwards PK, Ebert JR, Morrow MM, Goodwin BM, Ackland T, Wang A. Accelerometry evaluation of shoulder movement and its association with patient-reported and clinical outcomes following reverse total shoulder arthroplasty. J Shoulder Elbow Surg. 2020; 29(11): 2308-18.
[18] Huhn S, Axt M, Gunga HC, et al. The Impact of Wearable Technologies in Health Research: Scoping Review. JMIR Mhealth Uhealth. 2022; 10(1): e34384.
[19] Ghomrawi HM, Baumann LM, Kwon S, et al. Using accelerometers to characterize recovery after surgery in children. J Pediatr Surg. 2018; 53(8): 1600-5.
[20] Johnston W, Heiderscheit B, Coughlan G, et al. Concussion Recovery Evaluation Using the Inertial Sensor Instrumented Y Balance Test. J Neurotrauma. 2020; 37(23): 2549-57.
[21] Zarowin J, Warnick E, Mangan J, et al. Is Wearable Technology Part of the Future of Orthopedic Health Care? Clin Spine Surg. 2020; 33(3): 99-101.
[22] Kadakia K, Patel B, Shah A. Advancing digital health: FDA innovation during COVID-19. NPJ Digit Med. 2020; 3(1): 161.
[23] Gomes MM, dos Santos Silva SR, Padula RS. Prevalence and factors associated with low back pain in warehouse workers: A cross-sectional study. J Back Musc Rehab. 2023; 36(4).