WORKING TITLE: Using Wearable Technology Kinematics and Kinetics to Monitor Load When Returning to Physical Activity or Sport Following Knee Surgery: A Scoping Review

INTRODUCTION

Wearable technology (WT) describes a diverse group of electronic devices attached to or worn by users (Godfrey et al., 2018). Early concepts centred on packaging traditional desktop computing power into smaller information and communication devices (e.g. smartphones, smartwatches and smart-eyewear), allowing users uninhibited portability and mobility (Godfrey et al., 2018). WT products have targeted many niche markets; however, as these markets have matured, application to sports and fitness has become the most predominant (Berglund et al., 2016). The most common sport and fitness WT are smartwatches and smart jewelry such as fitness tracker bracelets (Berglund et al., 2016). Other devices have been embedded in belts, straps, vests, insoles and even garments such as shirts and pants (Berglund et al., 2016; Godfrey et al., 2018).

Smartphones and cloud-based applications instantly allow these devices to collect, transmit, and process physiological, biomechanical, bioenergy, and environmental data (L. Chen & Yang, 2021). For the general population, WT provides users instant feedback about their health and physical activity, which may help build motivation toward achieving a healthier lifestyle (Ananthanarayan & Siek, 2012). In sports, WT has the potential to match or even surpass traditional load monitoring and fitness tests, which can be helpful when adjusting training loads, avoiding excessive fatigue, and reducing injuries (L. Chen & Yang, 2021).

The growth of WT in healthcare has been slower to advance than in sports and fitness due to barriers such as big data concerns over security and ethics (Min Wu & Jake Luo, 2019). Still, reviews of WT in healthcare indicate a growing trend, especially for sports medicine and rehabilitation (Arlotti et al., 2022; Marques et al., 2022; Patel et al., 2012; Small et al., 2019).

Knee injuries are particularly suitable for WT integration as traumas to the meniscus, patella and knee ligaments are among sports medicine’s most frequently treated injuries (Bollen, 2000). These injuries often require surgery and lengthy rehabilitation (Ardern et al., 2014). In addition, knee injuries can have poor long-term outcomes, such as a high risk of re-injury, decreased participation in sports or other physical activities, and permanent disability, including Osteoarthritis (Ardern et al., 2014; Bollen, 2000; Woodhouse et al., 2016).

The rapid development of WT devices and metrics in the sports and fitness industry may prove valuable tools for sports medicine and rehabilitation, where post-surgical testing and assessments of functional tasks following knee injuries are already a critical component in reducing the risk of re-injury and improving long-term outcomes (Burgi et al., 2019; Burnham et al., 2018). For example, authors Marques et al. (2022) identified 11 studies that used WT to identify between-limb asymmetries while performing lab and field-based ACL-R return to sport assessments. Marques et al. (2022) cautioned that further validation of these assessments is required; however, reducing financial and accessibility constraints of traditional gold-standard lab-based testing are encouraging (Arlotti et al., 2022). Furthermore, WT use following knee injuries is not limited to traditional assessments and timeframes. Exploration of the use of WT in sports medicine and rehabilitation to monitor and assess the kinetics, kinematics, activity levels, and training loads of patients outside of the laboratory setting and beyond the typical follow-up period might help further reduce adverse outcomes.

The objectives of this study were to 1) determine how WT is used to assess kinetic and kinematic outcomes during physical activity or sport following knee surgeries; 2) determine if the outcomes provided by WT can are used to evaluate activity levels or training loads in comparison to healthy controls or pre-injury levels; 3) determine if WT can assess functional deficits of between-limb (involved and un-involved) and groups (healthy control vs injured) during physical activities or sport; and 4) report the methods used, participant characteristics, the functional tasks and physical activities assessed, outcome variables and WT specification.

METHODS

Previous reviews of WT in sports medicine and rehabilitation indicate that the subject is relatively novel and that researchers are exploring many potential applications (Arlotti et al., 2022; Burnham et al., 2018; S. Chen et al., 2016; Inan et al., 2018; Marques et al., 2022; Min Wu & Jake Luo, 2019; Patel et al., 2012; Rigamonti et al., 2020; Small et al., 2019). A scoping review was chosen due to the broad nature of the research question and expanded inclusion criteria than that of a traditional systematic review(Munn et al., 2018). A scoping review is advantageous because it explores, summarizes, and disseminates research findings and identifies existing gaps in the literature(Arksey & O’Malley, 2005). This review follows Arksey and O’Malley’s five stages methodological framework (Arksey & O’Malley, 2005) and guidance from the Joanna Briggs Institute Reviewer Manual(Peters et al., 2014). The PRISMA Extension for Scoping Reviews (PRISMA-ScR) was chosen to conduct and report this review(Tricco et al., 2018).

**Stage 1: Identifying the scope and inquiries**

The primary research question that guided this scoping review was:

Which kinematic and kinetic outcomes provided by WT are being evaluated in post-knee surgery patients returning to physical activity or sports?

Further, we examined the following:

Does WT provide the kinematic and kinetic outcomes used to assess activity levels or training load?

Can WT determine functional deficits between limbs or groups during physical activity or sports participation?

Eligibility criteria

The use WT as an accessible and cost-effective means to replicate traditional lab and field-based return to activity and sport assessments has been demonstrated (Marques et al., 2022; Small et al., 2019). Most of the eligible studies in these reviews assessed patients six months post-operatively during their return to physical activity or sport (Marques et al., 2022). However, functional deficits following knee surgeries can persist for up to two years in athletes who return to their prior level of sport and longer for individuals who do not return (Mardani-Kivi et al., 2020; Nawasreh et al., 2018). Therefore, this scoping review will attempt to include a wide range of WT kinetic and kinematic assessments related to physical activity and sport for up to two years following knee surgeries. The complete inclusion and exclusion criteria are reported in Table 1.

*Table 1: Inclusion and Exclusion Criteria*

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| --- | --- |
| Inclusion | Exclusion |
| Population | |
| * Human participants, males and females, age 12-50 years * Post-surgical following traumas to the meniscus, patella and knee ligaments * Returning to a sport or physical activity | * Animal models or cadavers * Studies where participants have other significant comorbidities, including musculoskeletal, neurologic and/or systemic disorders * Studies where participants underwent knee replacement/arthroplasty |
| Intervention | |
| * Traditional functional assessments (e.g. lab or field-based return to activity and sport assessments such as single-leg hops, jumps and landings) * Rehabilitation (e.g. strength training, neuromuscular training and functional movement tasks) * Activities of daily living (e.g. walking and climbing/descending stairs) * Physical activity (e.g. running, hiking and biking) * Sports (sport-specific drills, practice/training and competition) |  |
| Comparitor or Control | |
| * Studies where the affected limb is compared to the unaffected limb * Studies where participants are compared to a healthy control population * Studies where the participants are compared to pre-injury or normative values |  |
| Outcomes | |
| * Studies which report kinetics or kinematics assessed with WT * Studies which report physical activity levels or training loads are assessed with WT * Studies which report functional deficits (between limbs or groups) assessed with WT |  |
| Timing | |
| * Studies where patients are assessed post-surgery for up to 2 years |  |
| Study Design | |
| * Primary study design (quantitative & mixed methods) with original published data, randomized control trials, pilot studies, case studies, cohort studies and diagnostic studies | * Qualitative studies and not primary study design or original data (conference proceedings or abstracts, editorials, commentaries, opinion-based papers and systematic, scoping, or narrative reviews) |

**Stage 2: Identifying data sources and search**

Search strategy

With the help of an experienced librarian scientist (LD), we implemented a three-step search strategy. Step 1 was a limited initial search conducted through Scopus using the terms “wearable technology OR wearable computing OR wearable electronic device OR wearable sensor” AND “Knee-injury OR knee-surgery OR knee-operation.” Step 2 was analysis and discussions between the study team and research collaborators to refine our search terms and identify relevant records. In addition, a grey literature search of publicly available WT capable of kinetic and kinematic assessment was conducted, and product names were added as search terms. Step 3 was the execution of the final systematic search strategy. In June 2022, we searched the following electronic databases: MEDLINE, EMBASE, CINAHL, SPORTDiscus, Scopus, IEEE Xplore, and Compendex. These databases were searched since inception with no language limitations. The final list of systematic search terms is available in Appendix 1. Additional screening of the reference lists from critical systematic reviews was also performed. Finally, discussions with experts and colleagues familiar with the topic were completed to identify further articles not retrieved through our electronic database search.

**Stage 3: Record screening and study selection**

Records obtained from each electronic database were exported into the reference management software Covidence (Veritas Health Innovation, Melbourne, Australia; available at [www.covidence.org](http://www.covidence.org)), where duplicates were removed. At this stage, a single rater (EG) independently screened the titles and abstracts of 100 randomly selected articles to assess the appropriateness of the selection criteria. The study team made the final amendments to the selection criteria before the single rater (EG) completed the title and abstract screening. Then, two raters (EG & AP) determined the final study selections by independently performing the full-text reviews. Any disagreements on study eligibility between the two reviewers during the title and abstract or full-text review were resolved through discussion and inclusion remainder of the study team (HR, LB & MS) when necessary.

**Stage 4: Data Charting**

The two raters (EG & AP) extracted data into categories of interest during the review. Initially, the first rater (EG) randomly selected three studies for extraction to develop the extraction table template. These initial extractions were discussed between the two raters (EG & AP), followed by refinement of extraction criteria and charting. The remaining studies were divided between the two raters (EG, AP), who independently extracted all data.

**Stage 5: Collate, summarize, analyze, and report the results**

A descriptive analysis of the extracted variables was conducted with WT assessments categorized into traditional functional assessments, rehabilitation, activities of daily living, physical activity, and sports. The results were also catalogued by protocols of WT assessments, outcomes and participant characteristics, including the type of knee surgery. This final stage allowed descriptive analysis of the utility and appropriateness of different WT devices for a wide range of users during their return to activity or sport.