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Using automated, unsupervised sensor based evaluation as a complement to PROMs to assess surgery outcomes

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Abstract

This study explores the use of automated unsupervised evaluations via wearable devices, to assess the success of hip and knee replacements as a complement to traditional PROMs.

A comprehensive analysis was conducted on data from 1144 TKA and THA patients utilizing a mobile application, with activity data collected through the Garmin Vivofit 4 wearable device. Key parameters, including daily Peak 6-Minute Consecutive Cadence (P6MC) and daily Peak 1-Minute Cadence (P1M), were computed pre and post surgery and analyzed to assess the efficacy of these metrics in monitoring the recovery progress and the surgery outcomes.

Cadence measurements, specifically P6MC and P1M, emerged as robust indicators. These metrics exhibited a superior level of responsiveness compared to traditional step-count measurements and showed good complementarity with PRO's traditionally used in clinical practices. Moreover, the capture of these parameters being daily, unsupervised, and automated gives the potential of offering more granularity and better compliance than PROMs, providing new insights to assess quality of new surgical techniques. Moreover, the growing ubiquity of smartphones and wearables makes the use of such metrics usable in daily practice.

1 Introduction

The use of technology-assisted rehabilitation is gaining popularity due to its ability to provide objective and automated assessments of patients' motor function and therapy adherence. Mobile health technologies, including wearable and portable sensors, are now being used to assess mobility in unsupervised, real-world situations, offering a more patient-relevant and ecologically valid approach compared to routine clinical tests [1].

Remote health monitoring, facilitated by non-invasive wearable sensors and modern communication technologies, ensures patient safety at home while enabling continuous data collection [2]. This data can detect even minor changes in a patient's status, providing more precise and sensitive outcomes, known as digital biomarkers [3]. They can reveal disease characteristics not easily observable in clinical settings. Digital biomarkers can be categorized as active (supervised) or passive (unsupervised) [4].

Recent research efforts have applied accelerometry techniques to individuals undergoing joint arthroplasty [3,5]. Encouragingly, the self-administered six-minute walk test (6MWT) has exhibited satisfactory accuracy, reproducibility, and acceptability in both healthy individuals and those with varying degrees of congestive heart failure severity [6]. Nevertheless, the exploration of unintentional walk testing, a method analyzing free-living physical activity data, remains an unexplored area in current research.

2 Methods

We conducted a retrospective observational study using anonymized depersonalized data from a cohort of 1144 patients who underwent elective total knee and hip arthroplasty.

All data collection was facilitated via the moveUP® application (moveUP®, Brussels, Belgium), which is registered as a medical device. The database comprises data from patients who underwent hip and knee arthroplasty across multiple centers in Belgium, France, and the Netherlands. This application operates on a smart virtual platform designed for digital monitoring, exploiting both objective and subjective patient data.

Objective data were collected using a commercial activity tracker (Garmin Vivofit 4) worn 24/7 by the patients. Objective data consist of the number of steps per day and the number of steps per minute throughout the day.

To explore the impact of quick or slow recovery trajectories on activity data, we used the Forgotten Joint Score (FJS) Minimal Clinically Important Difference (MCID) as a threshold at 3 months to divide the hip and knee patients into two groups: MCID achieved (MCID+) and MCID non-achieved (MCID-) (Figure 1).

To derive meaningful insights from the step-per-minute data, two key parameters were extracted: Peak 1-Minute cadence (P1M), and Peak 6-Minute consecutive cadence (P6MC). Those metrics were computed for each day of recording. Peak 1-min may represent one's 'best natural effort', or rather the maximum free-living walking cadence of which an individual is capable. The highest continuous activity during 6 minutes is detected in step data, using a sliding 6 min window with 1 min overlap [7].

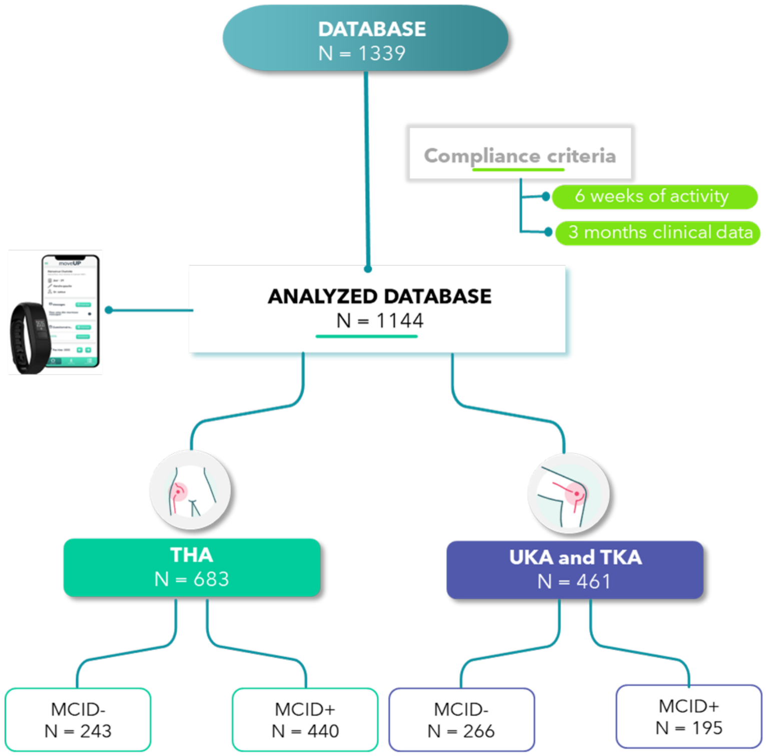

Figure 1: Data flowchart

3 Results

When comparing the time needed to get back to initial (pre-operative) values, important differences were observed for the computed outcomes (see Figure 2).

For THA, for the number of steps a difference of 7 days is observed (33 days for MCID+ and 40 days for MCID-), for the P6MC a difference of 6 days (26 days for MCID+ and 32 days for MCID-), for P1M the MCID+ regains the initial value after 35 days while the MCID- did not reach the initial value after the 60 days of follow-up.

For TKA, for the number of steps only the MCID+ group reaches the initial value after 40 days, for the P6MC a difference of 10 days (29 days for MCID+ and 39 days for MCID-), for P1M a difference of 12 days (38 days for MCID+ and 50 days for MCID-).

When comparing the trajectory of the evolution in the different groups we observed that for both THA and TKA the newly developed outcomes, P6MC and P1M, allow for early identification of differences in comparison with the total number of steps per day.

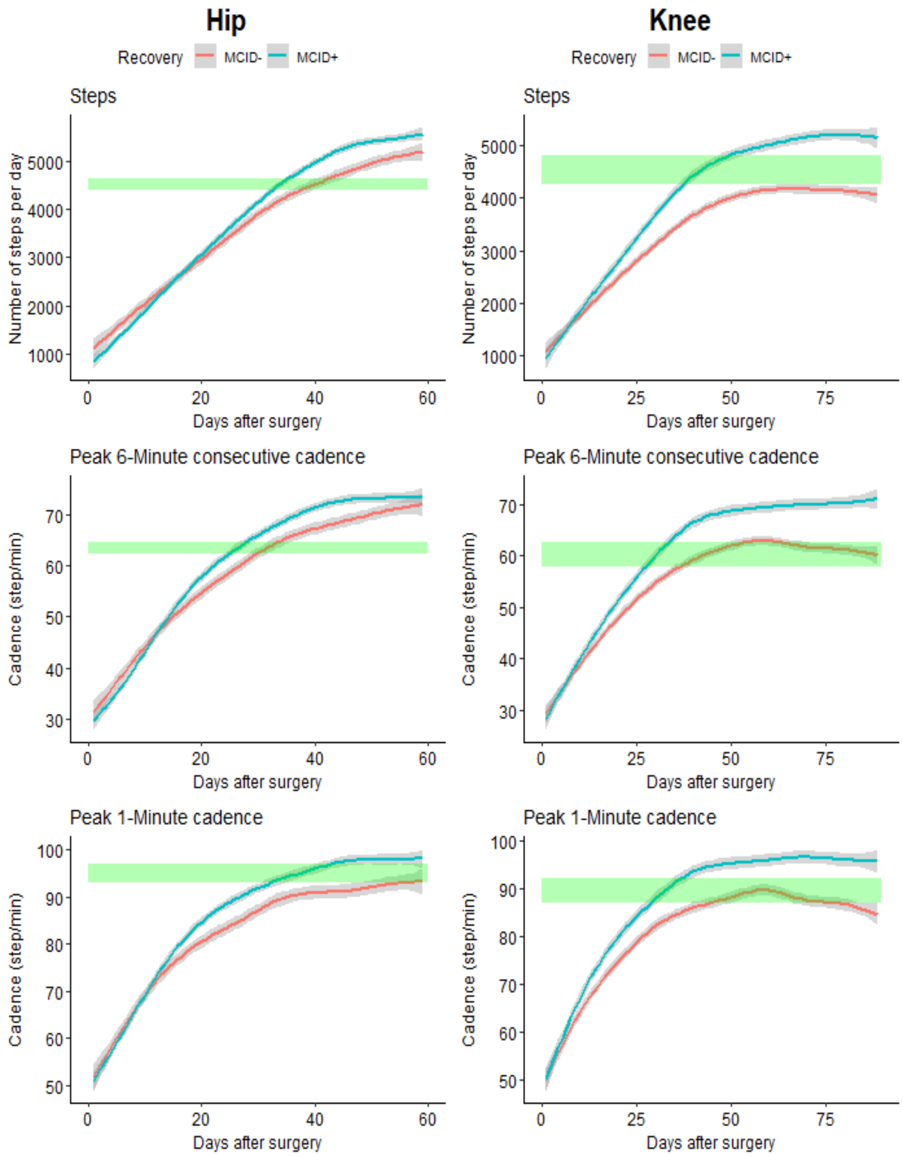

Figure 2: Evolution of studies parameters for Hip and Knee according to recovery. The green rectangles indicate the pre-operative values (with 95% CI).

4 Discussion

Patients' trajectories following arthroplasty display considerable variability, and extensive discussions have revolved around categorizing individuals as slow or quick progressors. Notably, these discussions have primarily centered on patient reported outcome measures [8]. The substantial variability in physical activity among patients has prompted calls for the development of stratification tools [9]. In our study, we categorized the patient population based on MCID of the FJS at the three-month mark. This point aligns with routine medical consultations. Our analysis demonstrates that activity data holds the potential to partially predict which patients will achieve this milestone early in the recovery process [10].

Significant differences were observed in the recovery trajectories, with the cadence metrics (P6MC and P1M) showing early identification of differences compared to the total number of steps per day. These results highlight the potential of P6MC and P1M as sensitive measures for assessing the rehabilitation progress in both THA and TKA patients. The median value for P1M is similar to normative value identified in older adults (106±16 and 97±20 for male and female respectively) [11]. The cadence is often regarded as a reasonable proxy-indicator of ambulatory intensity, with a cadence value of ≥100 steps/min in adults consistently identified as a heuristic for *'good walking'* [12,13]. The newly introduced metric, P6MC, as compared to P1M, exhibits an intriguing difference, wherein P6MC values are 20 to 30 steps lower than P1M, highlighting the distinction between these metrics.

The utilization of wearable sensors for assessing knee arthroplasty procedures is becoming increasingly prevalent [14]. However, the discernible clinical value of this technology is still a subject of ongoing investigation.

Our results underscore the significance of cadence measurements, particularly the P6MC and P1M, in tracking recovery after hip and knee arthroplasty. These indicators exhibit heightened sensitivity, outperforming the traditional total step count, providing valuable insights into patients' functional capacity and rehabilitation progress. The adoption of technology-driven, self-directed evaluations marks a fundamental shift in rehabilitation approaches, promising enhanced accuracy, personalized treatments, and increased patient engagement.

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