Integrated Patient-Reported Outcomes and Passive Mobility Monitoring Following Metastatic Bone Disease Surgery: A Prospective Study of Feasibility and Early Recovery Patterns

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Significance & Hypothesis

Metastatic bone disease (MBD) causes debilitating pain and functional impairment[1]. Post-operative recovery remains poorly characterized, as clinic-based patient-reported outcomes (PROs) may not capture dynamic functional trajectories, limiting understanding of perioperative recovery. We hypothesized that integrating longitudinal PROs with passively collected mobility data would be feasible and capture clinically meaningful recovery following MBD surgery[2].

Innovation

This study integrates remote digital administration of validated PROMIS short forms[3,4], with passively collected smartphone-derived mobility metrics (ACTIVATION Health) to enable high-resolution perioperative monitoring in surgical MBD patients.

Approach

In this prospective single-centre study, 40 patients undergoing appendicular or pelvic MBD surgery were enrolled (March 2025–March 2026); 30 contributed sufficient longitudinal data (mean age 63.0 ± 11.6 years; 57% male; 63% lower extremity; 60% pathologic fracture; median ECOG 2, IQR 1–2). Primary diagnoses included breast cancer (40%), renal cell carcinoma (20%), and multiple myeloma (17%). PATHfx v3.0[5] predicted median 3-month survival of 48.5% (IQR 37.2–62.8%). PROMIS domains (Physical Function or Upper Extremity Function, Pain Interference, Self-Efficacy, and Global Health) were collected preoperatively and at weeks 1–6, 12, and 24. A mobility tracking subset (n=10) provided perioperative iPhone mobility metrics. Wilcoxon signed-rank tests assessed change from baseline; linear mixed-effects models evaluated mobility-PRO associations.

Results

PROMIS completion rates were 96–100% at weeks 2–6. Pain Interference improved significantly from week 2 onward, reaching $\Delta T = -6.2$ ($p < 0.001$) at week 6 and $\Delta T = -11.0$ ($p < 0.001$) at week 12. Upper Extremity Function improved significantly from weeks 2–12 ($\Delta T = +8.7$, $p = 0.002$; $\Delta T = +14.2$, $p = 0.031$). Physical Function demonstrated an acute decline at week 1 ($\Delta T = -7.8$, $p < 0.001$), then significantly improved at week 12 ($\Delta T = +7.7$, $p = 0.009$). Both Pain Interference and Physical Function exceeded published PROMIS minimal clinically important differences for MBD[6,7]. Self-Efficacy and Global Mental Health remained stable. Higher PATHfx-predicted 3-month survival was strongly correlated with better baseline Physical Function ($\rho=0.611$, $p=0.009$, $n=17$).

In the mobility subsample, postoperative step counts were significantly lower than preoperative within a time-matched 4-week perioperative window (338 vs. 1,124 steps/week; $W=0$, $p=0.002$, $r=0.98$). By weeks 7–12, step counts partially recovered but remained below baseline (950 vs. 1,110 steps/week; $p=0.160$). Over 24 weeks, lower extremity patients demonstrated no significant difference from preoperative values (804 vs. 1,028 steps/week; $p=0.219$). Linear mixed-effects modeling demonstrated significant within-patient associations between step counts and Physical Function ($\beta=+7.79$ per 1,000 steps, $p<0.001$) and Pain Interference ($\beta=-2.85$ per 1,000 steps, $p=0.041$).

Discussion & Impact

Integrated digital monitoring following MBD surgery is feasible, with high longitudinal PRO adherence in a medically complex population. Patients demonstrated clinically meaningful improvements in pain and function by week 6, sustained through week 12. Mobility data revealed a trajectory of preoperative decline, postoperative stabilization of activity, and partial recovery, highlighting that objective and subjective recovery follow distinct trajectories. These data support further investigation of integrated digital monitoring to characterize recovery and inform perioperative care and postoperative recovery monitoring strategies in orthopedic oncology.

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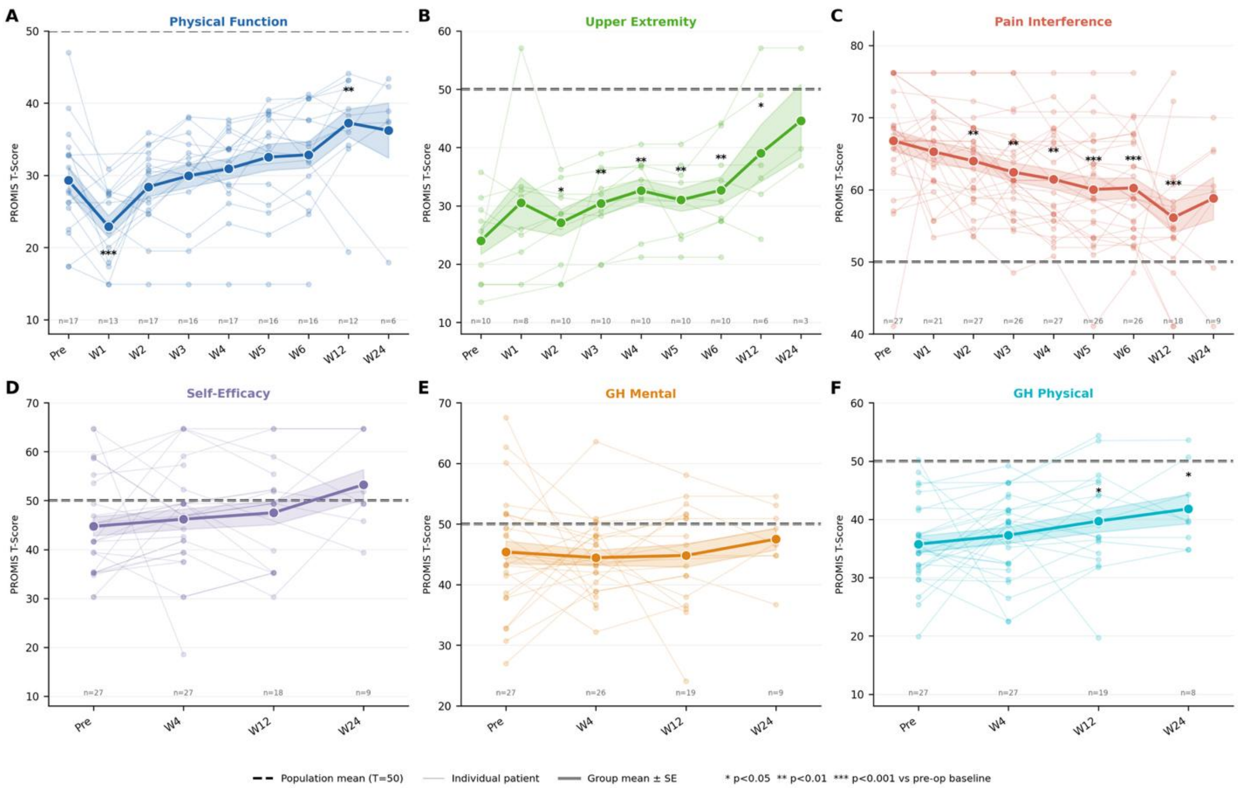

Figure 1. Longitudinal PROMIS T-score trajectories following surgical management of metastatic bone disease (n = 30). Panels show changes in **A)** Physical Function (lower extremity patients), **B)** Upper Extremity Function (upper extremity patients), **C)** Pain Interference, **D)** Self-Efficacy, **E)** Global Mental Health, and **F)** Global Physical Health. Faint lines represent individual patient trajectories; bold lines and error bars represent group mean ± standard error. The dashed line indicates the general population mean (T=50). Significance markers denote Wilcoxon signed-rank test (* p<0.05, ** p<0.01, ***p<0.001). Sample sizes at each timepoint are shown below each panel.

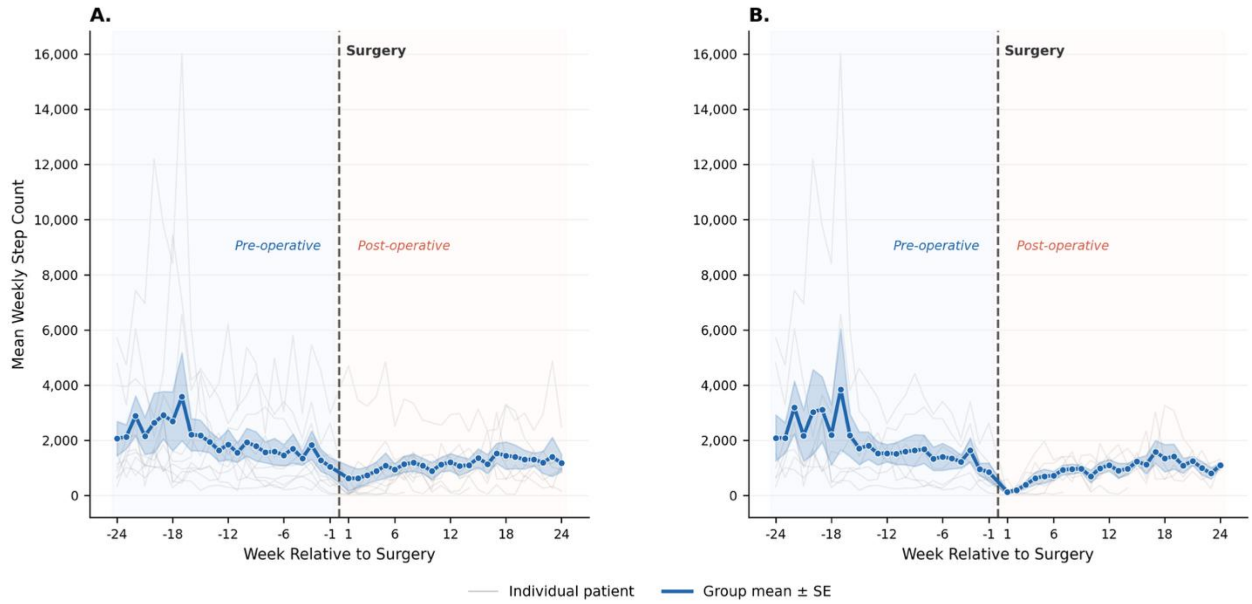

Figure 2. Perioperative iPhone-derived step count trajectories in the mobility subsample. A) Mean weekly step count (± standard error) across a 48-week perioperative window (weeks −24 to +24 relative to surgery) for all patients (n=10). **B)** Mean weekly step count (± standard error) for lower extremity patients only (n=7). In both panels, grey lines represent individual patient trajectories and the blue line with shaded band represents the group mean ± standard error. The dashed vertical line marks the time of surgery. Background shading distinguishes preoperative (blue) and postoperative (red) periods.