Clinical Anchored Benchmarks for Gait Improvement after Total Hip Arthroplasty

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Introduction: It is well known that total hip arthroplasty (THA) does not fully restore normal gait mechanics.[1] This is a problem because abnormal gait mechanics are associated with worse patient-reported gait function,[2] and functional improvement is prioritized by patients as highly or even more highly than pain relief.[3] Thus, while the longstanding calls in the literature for new ways to improve gait mechanics are justified, we unfortunately do not yet have a definition of what constitutes an acceptable or good gait outcome. This means that we do not know what appropriate targets of surgery and rehabilitation should be with respect to gait function. “Normal” walking mechanics may not be an attainable goal because of the significant impairment that is present before surgery. Normal walking mechanics may also not be desirable, because higher values of certain gait parameters may increase potentially damaging implant forces.[4] Finally, normal walking mechanics may or may not correspond to the functional outcomes prioritized by patients.

The purpose of this study was to establish attainable, clinically relevant benchmarks for gait outcomes. This was done using the concept of Minimal Clinically Important Improvement (MCII), by anchoring postoperative gait variables and pre-to-post change in gait variables to successful clinical outcomes using the Harris Hip Score (HHS). The gait variables of interest here were the sagittal plane dynamic hip range of motion (HROM) and peak external hip adduction moment (a reflection of dynamic abductor function), because deficits in these variables have been consistently reported.[1] A secondary goal was to determine whether or not preoperative age, sex, body mass index (BMI), or HHS are associated with attaining minimal clinically important gait outcomes.

Methods: An IRB-approved data repository was queried for subjects who underwent gait analysis both before and ~1 year after primary unilateral THA. 145 subjects were identified (age 61± 10 yrs, BMI 28.5 ± 5.0 kg/m2, 68 female, Preoperative HHS 56.5 ± 14.0, Postoperative HHS 91.7 ± 10.5, follow-up time 15 ± 4 months). The HHS was administered at each gait analysis evaluation. Gait analysis was conducted using standard published methods.[5] Preoperative and postoperative HROM and hip adduction moments, normalized to subject body weight and height (%BWxHt), were averaged from trials collected at each subject’s self-selected normal walking speed. The pre-to-postoperative changes in both variables were calculated.

To identify the minimal clinically important postoperative value and relative improvement for each gait variable, a previously published anchoring method was followed.[6] By convention, an HHS ≥ 80 is considered “good” so this value was selected as the anchor to determine clinically relevant gait outcomes. The cumulative percent of patients with postoperative HHS ≥ 80 was plotted vs. the gait variable of interest. Next, a logistic function was fitted to the data (e.g. Figure 1, left) The 75th percentile approximates the point at which this curve flattens,[6] this is the point at which most patients can be considered to have had a good clinical outcome.[6] Therefore, the value of each gait variable at the percentile point was considered the minimal clinically important outcome and the 95th percent confidence intervals were calculated. Finally, logistic regression analyses were used to determine
whether age, sex, BMI, or preoperative HHS were associated with having an minimal clinically important outcome or change for the selected variables.

**Results:** HROM improved by $9.3^\circ \pm 5.7^\circ$ (range $-9.7^\circ$ to $23^\circ$), from $16.3^\circ \pm 6.0^\circ$ to $25.7^\circ \pm 5.9^\circ$ (paired t-test $p < 0.001$). The minimal clinically important value of postoperative HROM was $30.0^\circ$ ($29.4^\circ$, $30.7^\circ$) and was attained by 19.3% of subjects. Female subjects (OR 7.2, $p = 0.001$) and subjects with a lower BMI (OR = 0.888, $p = 0.040$) were more likely to reach this benchmark. Age, sex, and preoperative HHS were not associated with attaining the benchmark ($p \geq 0.237$). The minimal clinically important change in HROM was $13.3^\circ$ ($12.1^\circ$, $14.8^\circ$) and was attained by 18.5% of subjects. Preoperative HROM was higher for the subjects who failed to attain the MCII ($17.4 \pm 5.9$ vs $11.6 \pm 3.8$, $p < 0.001$) but postoperative HROM was lower ($24.8 \pm 5.8$ vs. $29.4 \pm 4.5$, $p = 0.001$). Age, sex, and BMI, were not associated with attaining a minimal clinically important improvement for HROM ($p \geq 0.098$), but subjects who failed to achieve this benchmark had higher preoperative HHS ($58 \pm 14$ vs. $52 \pm 13$, OR 0.965, $p = 0.042$). The hip adduction moment improved by $0.04 \pm 1.15\% BWxHt$ (range $-2.68$ to $3.99 \% BWxHt$), from $3.39 \pm 1.1$ to $3.43 \pm 0.96\% BWxHt$ ($p = 0.423$). The minimal clinically important postoperative value was $4.15\% BWxHt$ ($3.95$, $4.35$), which was attained by 21% of subjects (Figure 1, right). Lower BMI was associated with greater likelihood of attaining this outcome (OR = 0.876, $p = 0.015$). There were no associations with age, sex, and HHS ($p \geq 0.135$). The minimally clinical important improvement threshold was $0.87 \% BWxHt$ ($0.57$, $1.17$) and was attained by 23% of subjects. The preoperative adduction moments were higher for subjects who did not meet the threshold ($3.6 \pm 1.0$ vs. $2.6 \pm 0.9\% BWxHt$, $p < 0.001$) but the postoperative moments were lower ($3.2 \pm 0.9$ vs. $4.1 \pm 0.4\% BWxHt$, $p < 0.001$). Age and BMI were not associated with having a minimal clinically important improvement ($p \geq 0.233$). Failing to achieve the threshold was, however, associated with male sex (OR 2.4, $p = 0.031$) and higher preoperative HHS ($58.2 \pm 13.6$ vs. $51.5 \pm 14.4$, OR = 0.964, $p = 0.012$).

**Discussion:**
For the first time, this study establishes some preliminary benchmarks for clinically meaningful recovery of two important aspects of gait after THA. The benchmarks identified were less than the control values for these gait variables reported in the literature,1 which suggests that clinically important gait recovery can still be different from “normal”. As in the clinical literature, better preoperative HHS or gait variables were associated with not having clinically meaningful improvement. However, the calculations were not adjusted for baseline status; higher functioning preoperative patients may have a different threshold for meaningful recovery. Similarly, from this analysis it is not possible to determine whether sex is truly a risk factor for poor outcomes, or if men and women should have different recovery targets. Another potential limitation of this approach is that the patient’s on appraisal of their symptoms, so-called patient acceptable symptom state (PASS) is the preferred anchor for calculating clinically important benchmarks. It is not known whether an HHS ≥ 80 corresponds to the PASS for THA. Despite these limitations, this study should advance THA gait, rehabilitation, and outcomes research by preliminarily providing some clinically meaningful benchmarks for recovery and a framework for identifying clinically relevant benchmarks that can be replicated by others. Further validation of gait benchmarks will also expand the potential for wider clinical use of gait analysis in this population.

**Significance:** Around 25% of THA patients report persistent functional limitations.[7] Having clinically relevant benchmarks for gait improvement will help the development and evaluation of new interventions to improve functional outcomes.
Figure 1. (Left) Cumulative percent of subjects with a good clinical outcome as a function of the hip adduction moment. The 75th percentile represents the minimal clinically important outcome based on methods of Tubach et al. [6] (Right) Histogram of the hip adduction moment. Vertical line indicates MCII.