Aims
Total hip arthroplasty (THA) has well known subjective benefits, but little is known objectively about the recovery of mobility in the early post-operative period.

Patients and Methods
A total of 33 patients aged > 60 years who underwent elective primary THA had their activity monitored for 30 days post-operatively using an at-home (Fitbit) ankle accelerometer. Their mean age was 70.7 years (61 to 86); 15 (45.5%) were female. The rate of compliance and the mean level of activity were determined. Comparisons between subgroups based on age, body mass index (BMI), surgical approach, and the destination of the patients when discharged were also performed.

Results
The mean compliance over the 30 days was 26.7 days (16 to 30; 89%) of use. The mean number of steps increased from 235 (5 to 1152) to 2563 (87 to 7280) (p < 0.001) between the first and the 30th post-operative day. Age < 70 years and an anterior surgical approach were significantly associated with higher levels of activity (1600 to 2400 (p = 0.016 to 0.031) and 1000 to 1800 (p = 0.017 to 0.037) more steps per day, respectively) between the second and the fourth week post-operatively. There was also a trend towards higher levels of activity in those who were discharged to their home rather than to a nursing facility (a mean of 1500 more steps per day, p = 0.02). BMI greater or less than 30 kg/m² was not predictive of activity (p = 0.45 to 0.98).

Conclusion
At-home remote mobility monitoring using existing commercially available technology is feasible in patients who have undergone THA. It showed a clear trend towards increased activity with the passage of time. Additionally, the remote device was able to detect differences in levels of activity clearly between patients in relation to variables of interest including age, BMI, surgical approach, and the destination of the patient at the time of discharge from hospital. Such monitoring may allow for the early identification and targeted intervention in patients who recover slowly.

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provide patients and surgeons with a more accurate and objective measure of functional recovery.

The purpose of the current study was thus to examine the feasibility (compliance) of a remote mobility monitoring programme for the first 30 days after THA, to define the typical pattern of the recovery of mobility in these patients and to examine objectively risk factors thought to be related to functional recovery (age, body mass index (BMI), surgical approach, and the destination of the patients at the time of discharge (disposition)) after THA.

**Patients and Methods**

After obtaining ethical approval, a single centre, multi-surgeon prospective cohort study was performed. English speaking patients undergoing elective primary THA who were aged > 60 years and were mobile pre-operatively were recruited. Age, gender, BMI, surgical approach, length of stay (LOS), and discharge disposition were extracted from the medical records.

All patients were asked to wear a Fitbit wireless accelerometer for 30 days after discharge. The accelerometer consists of a single sensor worn at the ankle on the operated side, 24 hours a day, however, the device was removed when the patient washed. Patients were provided with the device during their time in hospital and trained in their use. The accelerometers provide step counts for the monitored ankle. The wireless accelerometer was blue-tooth equipped and transmitted data either to a computer or a mobile device that was configured with the Fitbit software (although the patients did not know their counts at any point). For those without a mobile device, a smart phone and data plan were provided for the duration of the study. The patient’s computer or mobile device transmitted data to a web-services database that was accessible by the investigators who reviewed the data each day. After discharge, if there was a failure to transmit data, patients were telephoned in order to deal with technical problems. Patients were withdrawn from the study if they failed to transmit data for seven consecutive days.

A mean step count was obtained for all patients on each post-operative day from days one to 30 in order to define the pattern of recovery. Subgroup analyses were based on age (< 70 years versus ≥ 70 years), BMI (< 30 kg/m² versus ≥ 30 kg/m²), surgical approach (direct anterior versus mini-posterior), and disposition (home versus nursing facility). For the subgroup analysis, step counts were compared at weekly time points between the first and fourth weeks post-operatively.

A total of 35 patients undergoing elective primary THA were recruited into this pilot, feasibility study. Two withdrew leaving a total of 33 patients. Their mean age was 70.7 years (61 to 86), the mean BMI was 30.3 kg/m² (18.8 to 50.8); 18 patients were male and 15 female. In total 19 patients (57.6%) had their procedure performed through a mini-posterior approach, and 14 (42.4%) through a direct anterior approach. Most (26; 79%) were discharged home; the remainder were discharged to a nursing facility. The mean LOS in hospital was two days (1 to 4).

**Statistical analysis.** The mean steps per day was calculated on each post-operative day for the cohort as a whole and also for each subgroup as defined above. Comparisons between groups were performed using a Student’s t-test at weekly intervals starting on the seventh post-operative day. Statistical significance was set at a p-value < 0.05.

**Results**

**Compliance and mean step count.** Patient compliance was a mean of 26.7 of 30 days (89%; 16 to 30). As a cohort, the mean step count increased steadily during the first 30 days from 235 (5 to 1152) on post-operative day one to 2563 (87 to 7280) on post-operative day 30 (p < 0.001) (Fig. 1). **Risk factors.** Patients aged < 70 years (n = 15) were compared to those aged ≥ 70 years (n = 18). At all intervals, younger patients took more steps per day (Fig. 2). This difference became significant two weeks post-operatively (1015; 9 to 3838 versus 2608; 28 to 10484 mean steps per day, respectively; p = 0.016) and remained so at the three
Those with a BMI < 30 kg/m² (n = 20) had a trend towards more steps (1934 mean steps per day, 0 to 12 175) than those with a BMI ≥ 30 kg/m² (n = 13) (1630 mean steps per day, 5 to 13113) averaged over all time points (Fig. 3). However, the difference was generally small, was not true at all time points, and never reached statistical significance, between the first and fourth post-operative weeks (p = 0.45 to 0.98).

Those whose operation was undertaken through a direct anterior approach (n = 14) took more steps per day than those whose operation was undertaken through a mini-posterior approach (n = 19) at all time points, except post-operative days two and three (Fig. 4). This difference was significant at the second (2707; 9 to 10 484 versus 1126; 13 to 6911 mean steps per day, respectively; p = 0.033), third (3477; 23 to 9108 versus 1634; 9 to 7439 mean steps per day, respectively; p = 0.037), and fourth weeks (3129; 53 to 7581 versus 2153; 92 to 4931 mean steps per day, respectively; p = 0.017).

Those patients who were discharged directly to their home (n = 26) took more steps per day than those requiring discharge to a nursing facility (n = 7) at all times after the first and second post-operative days (Fig. 5). This difference, however, was only significant at the second post-operative week (604; 13 to 2602 versus 2179; 9 to 10 484 mean steps per day, p = 0.02).

Discussion
Despite being an extremely common procedure with known benefits, there are few objective data about the functional recovery when patients leave hospital after THA. In the first study of its nature, we found that after primary THA, patients steadily increase their activity from a mean of 235 steps per day on day one to 2563 steps per day on day 30. Moreover, our data suggest that increasing age, the use of the mini-posterior approach, and discharge to a nursing facility are factors associated with reduced early activity post-operatively.

The simplicity and ease of use of wearable devices such as accelerometers can transform the evaluation and management of patients following orthopaedic or other procedures, as it allows clinicians to evaluate functional status and recovery objectively between follow-up visits. Previous authors have shown a consistent lack of correlation between patients' self-reported pain, physical function, quality of life, physical activity and objectively measured levels of activity after total hip and knee arthroplasty.12-15 Such results highlight the potential benefits of the remote, objective monitoring of these patients. We found that remote monitoring of activity was feasible, even over a prolonged period of time. Despite the extended monitoring period of 30 days, the mean compliance was almost 27 days. This high rate of compliance with objective monitoring and the poor correlation of subjective reporting of levels of activity seen in the literature support the conclusion that remote monitoring may be a more reliable source of information on the level of activity of patients post-operatively.

The subgroup analyses considering the effect of age, surgical approach, discharge disposition and BMI, could also be evaluated preliminarily. As might have been predicted, younger age appeared to be a reasonable predictor of increased activity. This finding is similar to that which has previously been reported. Measuring step counts in 105 patients after THA, Kinkel et al17 noted the highest level of activity in patients aged between 50 and 59 years with a constant reduction in the mean step count with each passing decade. Similarly, we found that the surgical approach was predictive of the level of activity, with patients treated using a direct anterior approach having increased levels of activity between the second and fourth weeks. Previous
authors have reached varying conclusions regarding post-operative recovery following a direct anterior approach. While some suggested that these patients more rapidly stopped requiring walking aids\textsuperscript{18,19} and have some early functional benefits as measured by the timed up and go (TUG) test\textsuperscript{20} and the motor component of the Functional Independence Measure (M-FIM),\textsuperscript{21,22} others have shown no advantage or even worse functional outcomes. Retrospectively comparing 126 patients who underwent THA via a direct anterior approach to 96 who underwent a mini-posterior approach, Poehling-Monaghan et al\textsuperscript{23} found no difference in the maximum number of feet walked in-hospital or in the use of walking aids, activities of daily living, or walking 0.5 miles at eight weeks. The current study does not have the power to examine objective levels of activity based on the surgical approach convincingly. It serves best as a pilot study to support the use of this technology in further investigating how this variable affects activity after primary THA. Disposition at discharge was also examined as a variable for post-operative levels of activity in this study. While Cook et al\textsuperscript{16} showed a relationship between the recovery of mobility and discharge disposition in cardiac surgery, we did not show a consistently statistically significant relationship here (\(p = 0.05\)), presumably because of the small number of patients (seven of 33) who were discharged to a nursing facility. Future studies in larger numbers, or monitoring for a longer period of time would probably be more revealing. Finally, BMI, while seen by many as a barrier to recovery, did not appear to be a significant predictor of post-operative activity in this study. The authors of two previous studies, performing a cross-sectional analysis of more than 1000 patients up to ten years post-operatively\textsuperscript{24} and a prospective analysis of almost 19 000 patients up to 15 years post-operatively,\textsuperscript{25} respectively, found that BMI was highly predictive of the level of activity. While the discrepancy between these studies and this study may be due to the different times at which the measurements were made, (the current study evaluating the first 30 days and the previous studies evaluating activity between ten and 15 years after surgery), it is also likely that the small numbers in this study simply did not allow it to show a difference in the levels of activity between the obese and non-obese groups. As with all subgroup analyses in this study, the current data support the continued investigation of these groups of patients using this technology more than any definitive conclusion about the affects of variables on post-operative functional recovery.

The current study has many limitations. The sample size was small and even smaller in the subgroup analysis, reducing the ability to show significant differences in the patients’ disposition at the time of discharge. The use of accelerometer data may also be questioned as an accurate marker of mobility. The Fitbit, like all commercially available accelerometers, has well-recognised limitations in its ability to detect steps; both very slow and very fast speeds can be read as zero.\textsuperscript{16} Additionally, accelerometers worn at the ankle cannot detect changes in position such as lying, sitting, or standing. It is possible that patients also change the proportion of time in these positions post-operatively, which could also account for a meaningful objective measure of functional recovery. Despite this, the prospective nature of the study, excellent compliance of the patients, and the continuous data stream provided by the devices all serve as strengths of the study and of this form of monitoring.

In conclusion, the monitoring of the pattern of activity in patients who have undergone elective primary THA is possible. It provides an easily understood objective measure of mobility that may be more reliable than patients’ subjective assessment, and can detect differences in activity based on some variables thought to correlate with recovery. Such data, on an individual patient level, may also discriminate between those not achieving the expected recovery. This may allow targeted intervention in those who recover slowly and potentially reduce the complications associated with low mobility.

Take home message:

At-home remote monitoring of patients following THA is feasible, is sensitive to patient variables of clinical interest, and may allow for targeted intervention for those recovering more slowly from surgery.

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References


