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ORIGINAL RESEARCH

Objectively measured early physical activity after total hip or knee arthroplasty

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Abstract

Although reduced early physical function after total hip- and knee arthroplasty (THA/TKA) is well-described, the underlying reasons have not been clarified with detailed studies on pathophysiological mechanisms related to recovery, thereby prohibiting advances in rehabilitation. Thus, we aimed to describe early post-THA/TKA physical activity measured by actigraphy and potential underlying pathophysiological mechanisms related to recovery in a well-defined cohort of THA and TKA patients. Daytime-activity was measured from 2 days before until 13 (THA) or 20 (TKA) days after surgery. The primary outcome was individualized recovery in activity, with secondary analyses of activity-intensities and association to the perioperative factors: sex, age, BMI, hemoglobin (hgb), C-reactive protein and postoperative pain. Eighty-one THA/TKA-patients were examined. A large inter-individual variation in early physical activity was found. On a group level, activity was significantly reduced compared to preoperatively the first 2 (THA) or 3 (TKA) weeks after surgery (mean-difference -64 counts $\times 10^3$/day, $p < 0.001$ and -78 counts $\times 10^3$/day, $p < 0.001$, respectively). All activity-intensities were affected with the largest decline in high intense activity. A slight overall improvement in activity was seen during the postoperative phase [THA: 1%/day (SD 2.15); TKA: 0.7%/day (SD 1.04)], but approximately 30% of THA and 20% of TKA patients had reduced *and* declining activity. Hgb, CRP, BMI (THA) and postoperative pain (TKA) were only weakly associated with impaired physical activity. Physical activity was reduced the first weeks following THA/TKA, but with large inter-individual variations in recovery profiles. No single pathogenic factor was associated with a poor recovery. Early risk stratified interventions are needed in patients on a suboptimal course.

Keywords Knee osteoarthritis · Hip osteoarthritis · Total knee arthroplasty · Total hip arthroplasty · Postoperative recovery · Physical activity · Actigraphy

1 Introduction

Reduced physical function during the first weeks after total hip- and knee arthroplasty (THA and TKA) has been described and is considered "normal" without examining the underlying pathophysiological mechanisms. Furthermore, despite that THA and TKA are performed to relieve pain and increase physical function, an overall improvement in physical activity has been questioned [1–6], suggesting a need for improved and individually stratified rehabilitation strategies in patients at risk for reduced postoperative activity and function [7].

To identify patients with a suboptimal recovery and potential underlying modifiable pathogenic factors such as surgical stress-responses, postoperative pain and anemia [7–10], assessment of early postoperative physical function

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is pivotal. The optimal method remains debatable, and can be divided into three different assessments: (1) Subjective patient reported outcome measures of patients' perception of function (PROMs), (2) Objective assessment of physical capacity by performance based outcomes (PBOMs) and (3) Actual physical activity measured by actigraphy. However, the three assessments may not correlate well and measure different aspects of physical function [2, 11–14]. Since activity-related relief of joint-pain and stiffness [3], reduction in perioperative risks, common health and socioeconomic considerations [15–17] depend on improvements in actual physical activity, actigraphy based assessments might be advantageous in the evaluation of postoperative physical recovery.

Previous actigraphy-studies have mainly focused on maximum and average activity in the late postoperative phase with comparison to preoperative activity or general recommendations on physical activity [1–4]. However, data on early post-THA/TKA physical activity and pathogenic mechanisms are sparse [8–10, 18, 19], and without analyses for activity intensity or individualized physical recovery trajectories to guide future interventions [20]. Thus, we analyzed actigraphy data from a prospective cohort study aiming to describe individualized early postoperative physical activity after THA and TKA, and to explore the hypothesis that decreased activity was related to modifiable perioperative factors such as postoperative pain, inflammatory response and hemoglobin levels.

2 Materials and methods

This study presents secondary analysis of actigraphy-data from a prospective cohort study on "Subacute physical and cognitive function after total hip- and knee arthroplasty". Data comparing patient reported post THA/TKA physical function, physical capacity and actigraphy in the cohort have previously been published [11]. However, in the previous study only actigraphy-data from the last 2 days in the study-period were included, with analyses of average activity and not the complete actigraphy data with daily measurements including intensity stratification and recovery trajectories as presented here. The novel methodology of assessing physical activity used in this study has been discussed based on 10 patients from the cohort, but without assessment of clinical aspects [20].

The study was registered and described on ClinicalTrials.gov (NCT02137655) and approved by the Danish Regional Ethics Committee (Reg. nr. H-3-2014-005) and the Danish Data Protection Agency prior to patient enrolment. Patients were included consecutively from Gentofte University Hospital and Vejle Hospital, Denmark between May 2014 and January 2016, only limited by investigator- and actigraphy availability. It was continued until full data on physical and cognitive outcome measures were obtained from 40 THA- and 40 TKA patients. All participants gave written informed consent.

Eligible participants were patients scheduled for primary unilateral THA or TKA for osteoarthrosis, aged 55–80 years with ability to understand Danish and living within 50 km from the hospital (due to transportation costs). Exclusion criteria were previously diagnosed psychological or neurological disease hindering testing, allergies or contraindications toward the protocolled analgesic regime, alcohol abuse (> 21 units/week), immunodeficiency, preoperative potent anticoagulant treatment, diagnosed sleep-apnea, American Society of Anesthesiologists classification > 3 or planned discharge to a rehabilitation home.

2.1 Perioperative set-up

THA or TKA was performed in a standardized fast track set-up under spinal (bupivacaine) or general (propofol/remifentanil) anesthesia and a multimodal opioid-sparing analgesic regimen including 2 g slow release acetaminophen, 600 mg ibuprofen and 600 mg gabapentin preoperatively and slow release acetaminophen 2 g/12 h, ibuprofen 600 mg/12 h, gabapentin 300 mg/12 h and supplemental oxycodone as needed postoperatively. In TKA patients, an additional 125 mg i.v. methylprednisolone and local infiltration analgesia [21] were administered intraoperatively. Early mobilization was initiated on the day of surgery, and patients received daily physiotherapy during admission. Hospital discharge followed well-defined medical and physiotherapeutic fast-track criteria including pain < 6/10 during walk and < 4/10 during rest, satisfactory position of prosthesis (X-ray), able to walk on an even surface with two cruthches or less, able to climb stairs with handrail and one cruch or less, able to dress/undress unaided and without any other clinical signs (vital or cognitive) that contradicted discharge [22].

2.2 Outcomes measures

The primary aim of the study was to describe early physical activity measured by actigraphy 2 (THA) or 3 (TKA) weeks following lower limb arthroplasty, with individualized development in activity over the study period (recovery trajectory) being the primary outcome. Secondary aims were to explore the association between recovery trajectories and perioperative factors including sex, age, BMI, hemoglobin- and CRP level, postoperative pain and opioid-consumption.

Actigraphy data were collected from 2 days before to surgery until day 13 (THA) or 20 (TKA) after surgery. The data collection period was timed with removal of surgical staples to minimize the patient's study-related appointments at

the hospital, and therefore differed between THA and TKA patients.

2.2.1 Post-operative physical activity (actigraphy data)

Level of actual physical activity was measured 24 h a day by an Actiwatch (Actiwatch Score, Philips Respironics, Murrysville, PA, USA). The device recorded activity as average counts in a 1-min time period (epoch length), and was worn on the non-dominant arm and only removed when at risk of getting wet. Daytime activity was defined as the period from 08:00 am until 10.00 pm to minimize the risk of including inactive periods due to sleep in the analyses, equal to 14 h/day. Missing data were defined as recordings with <820 epochs/day (having an epoch length of 1 min and allowing 2% missing epochs). The activity data were generated by the Philips actiware software (version 6.0.1) and were individualized to display the percentual change in physical activity after surgery as follows: *adjusted activity* $=(\text{activity}_{post}-\text{activity}_{pre})/\text{activity}_{pre}\times 100$.

Only patients with full actigraphy data (≥ 820 epochs/day) from 2 days before surgery until day 13 (THA) or 20 (TKA) were included in the analyses.

2.2.2 Intensity stratification of activity

To enable comparison of activity patterns, all daytime activity recordings were divided into four percentiles (25th, 50th, 75th and 90th), each representing a percentage of the day spent at the given activity intensity or less. Thus, a 25 percentile of 100 counts/min meant that the given patient spent 25% of the daytime at or below this count [20]. Reversely, a 90th percentile of 600 counts/min meant that the patient spent 10% of the daytime above this count. Furthermore, the highest 10% activity (90th percentile) represented the minimum activity count during the 84 min a day (10% of the 14 h of daytime recording) with the most intense physical activity.

2.2.3 Postoperative activity trajectories

For each individual patient, adjusted daily activity was plotted against the corresponding postoperative day. The slope of the regression line through the adjusted activities reflected the patients individualized activity trajectory. Accordingly, a negative gradient represented a patient with a tendency of decreasing physical activity through the study period and a positive gradient vice versa [20]. Activity trajectories were calculated for *adjusted total activity* and *adjusted 90th percentile*. The 90th percentile was chosen since it had the largest within group variation in the unadjusted results for all the percentiles, and a statistical significant improvement for this high intense activity through the study period was found.

2.2.4 Postoperative pain, CRP and hemoglobin

Patients reported postoperative pain (worst and average) and opioid-consumption in a diary from day 1 to day 13 (THA) or 20 (TKA) after surgery, and AUC for the postoperative period was calculated for each item. Hemoglobin and CRP were measured preoperatively and postoperatively on day 2 and day 14 (THA) or 21 (TKA) (Fig. 1).

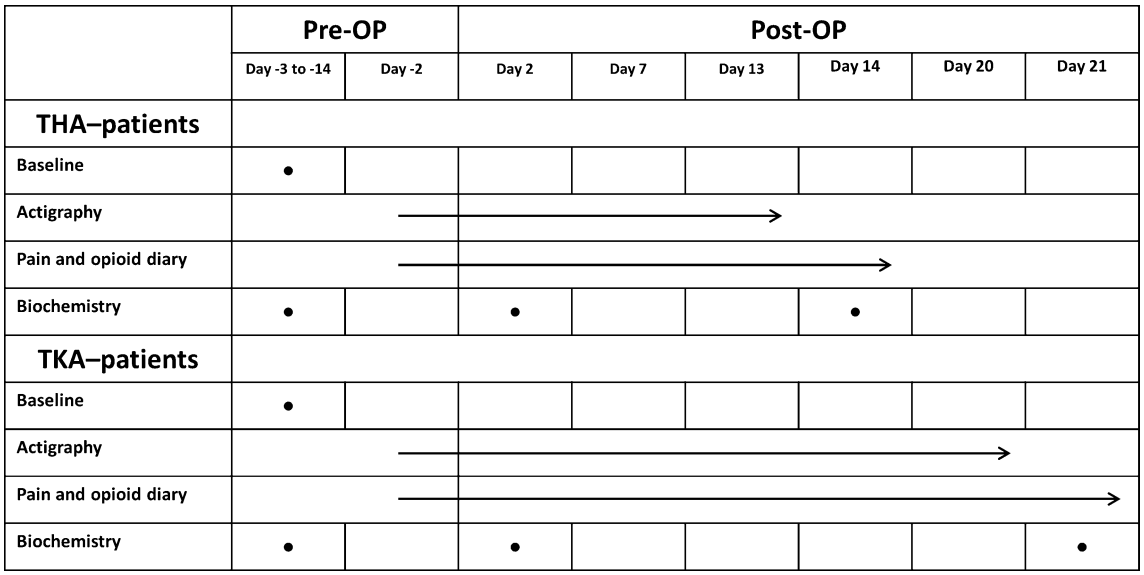

Fig. 1 Data collection

2.3 Statistical analyses

Continuous variables were tested for normal distribution using histograms, Q–Q plots and the Kolmogorov–Smirnov test. Accordingly, results are presented as means with standard-deviations (± SD) or medians with interquartile range (IQR). Changes in unadjusted activity and intensity (percentiles) were tested with the paired t-test and presented as mean difference with 95% confidence intervals (95% CI).

Backwards multiple regression models were made for activity trajectories on total activity and the 90th percentile including explanatory variables on hemoglobin, CRP, post-OP pain and opioid-consumption with a significance level ≤ 0.2 in univariate testing.

All analyses were carried out as per protocol without imputation of missing data in SAS version 9.4 with a significance level of 5%.

2.4 Power calculation

The data used in this study were collected as part of a larger dataset and predefined to include 40 THA- and 40 TKA patients with complete data on multiple variables, including others than those used in the present study [11]. This resulted in some variables, including actigraphy, being obtained in more than 2 × 40 patients before the inclusion goal was reached.

Since the study is the first to describe early individualized activity and activity-trajectories to identify potential relevant factor for postoperative outcome, no formal power calculation was performed.

3 Results

In total, 60 THA- and 52 TKA patients were included in the overall study (Fig. 2). Of these, 40 THA- and 41 TKA patients had full actigraphy data (≥ 820 epochs/day from 2 days before surgery until 13 (THA) or 20 (TKA) days after surgery) and were included in the analyses. Of those not included, 23 patients had missing actigraphy data, four had perioperative complications (periprostetic fracture, hip dislocation, acute lymphatic leukemia and pneumothorax), two had their surgery postponed and two withdrew their informed consent (Fig. 2).

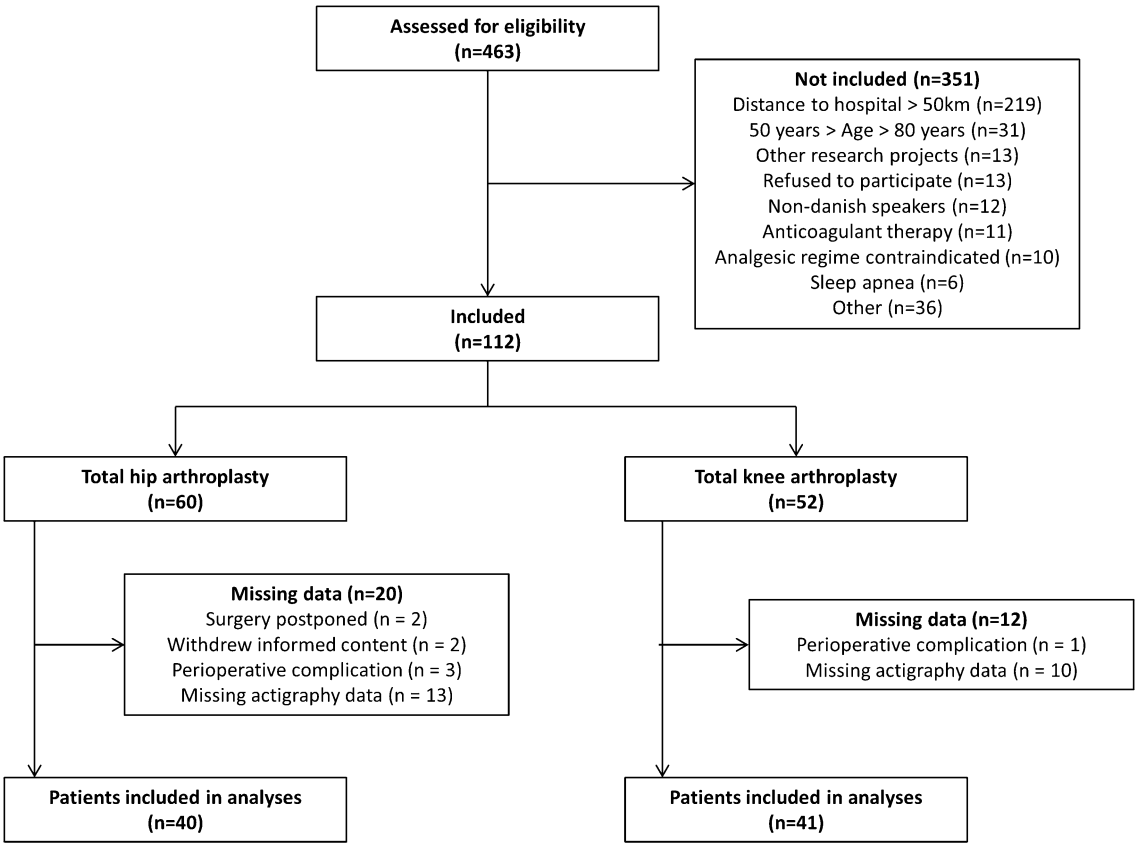

Fig. 2 Number of patients assessed for eligibility, included in the study and included in the final analyses. Patients were screened consecutively, only limited by equipment-(actigraphs) and investigator availability (not reported in figure)

THA patients had a mean age of 67 years (range 55–77) and 38% (15/40) were male. The majority (98%) had ASA classification ≤ II and 85% (34/40) were operated under spinal anesthesia. TKA patients had a mean age of 64 years (range 55–75) and 43% (17/41) were male. All patients had ASA classification ≤ II and 73% (30/41) were operated under spinal anesthesia.

Baseline characteristics for patients in- and excluded in the study are shown in Table 1, and baseline characteristics, pre- and postoperative data on hemoglobin, CRP and diary-reported pain-scores are given in Table 2. Preoperative CRP values were all below 10 mg/L.

3.1 Overall postoperative physical activity and activity percentiles

The mean daily postoperative physical activity remained lower than preoperative levels throughout the study period for both THA patients (mean difference from preoperatively until day 13 = − 64 counts × 10^3/day (95% CI − 29 to − 99), $p < 0.001$) and TKA patients (mean difference from preoperatively until day 20 = − 78 counts × 10^3/day (95% CI − 51 to − 105), $p < 0.001$). Intensity stratification of physical activity (percentiles) showed that all percentiles were significantly reduced compared to preoperatively, but with the greatest reduction in high intense activities (90th percentile). Both total activity and activity intensities had a trend towards improvement during the first two postoperative weeks with stagnation in the third postoperative week (TKA). Only total- and high intense activities improved sufficiently during the postoperative period to reach statistical significance, but were still at an overall lower level than preoperatively (Table 3; Figs. 3, 4).

3.2 Adjusted postoperative physical activity and activity trajectories

Overall, the individualized postoperative activity data showed a reduction in total physical activity of 28% for THA patients and 40% for TKA patients on the first postoperative day compared to preoperative levels, when assessed on a group level. By day 13 or 20 it was still reduced by seven and 24% (THA and TKA, respectively) compared to preoperatively (Table 4). The 90th percentile was reduced by 29% (THA) and 38% (TKA) on the first postoperative day and by 15 and 16% of preoperative levels by day 13 or 20 (THA and TKA, respectively). Additional adjusted activities are shown in Table 4.

Physical activity during the study period consisted of a large inter-individual variability. Thus, the activity trajectories showed that the adjusted postoperative activity improved on a group level for both total activity [mean

Table 1 Baseline characteristics for patients enrolled in the study

THA		
	Excluded patients (n = 18)	Included patients (n = 40)
Sex (male/female)	7/11	15/25
Age (years) (range)	66 (59–74)	67 (55–77)
BMI (kg/m^2)	26.3 ± 4.1	26.5 ± 3.5
Pre-THA use of daily opioids (%)	6	5
ASA (group I/II/III)	7/11/0	20/19/1
Anesthesia (general/spinal)	2/14[a]	6/34
TKA		
	Excluded patients (n = 11)	Included patients (n = 41)
Sex (male/female)	5/6	17/24
Age (years) (range)	68 (58–74)	64 (55–75)
BMI (kg/m^2)	29.2 ± 6.7	28.8 ± 4.6
Pre-TKA use of daily opioids (%)	25	10
ASA (group I/II/III)	3/4/0	20/21/0
Anesthesia (general/spinal)	3/8	11/30

Baseline characteristics for all patients included in the study except two, who withdrew their informed consent. Data are expressed as full count or percentage, mean with standard-deviation or median with interquartile range as appropriate

ASA American society of anesthesiologists physical status, *BMI* Body Mass Index, *NSAID* non-steroid anti-inflammatory drug, *THA* total hip arthroplasty, *TKA* total knee arthroplasty

[a]n=16 for anaesthesia, since two patients had their surgery postponed beyond the study-period due to infection

Table 2 Factors for impaired early post-THA/TKA physical activity

THA (n = 40)					
		Total activity trajectory		90th percentile trajectory	
		Univariate analysis (p-value)	Multiple regression (p-value)	Univariate analysis (p-value)	Multiple regression (p-value)
Sex (male/female, nb)	15/25	0.785		0.683	
Age (years, range)	67 (55–77)	0.511		0.913	
BMI (kg/m^2)	26.5 ± 3.5	0.156*	n.s	0.020*	0.039
Preoperative Hgb (g/DL)	14.1 ± 1.0	0.706		0.560	
Hgb day 2 (g/DL)	11.7 ± 1.0	0.497		0.499	
Hgb day 14 (g/DL)	12.2 ± 1.1	0.060*	n.s	0.088*	n.s
Hgb decline (day 2-preOP) (g/DL)	− 2.3 (0.8)	0.169*	n.s	0.100*	0.036
Hgb increase (day 14–day 2)	0.4 (0.6)	0.190*	n.s	0.335	
CRP day 2 (mg/L)	46.4 ± 16.8	0.273		0.223	
CRP day 14 (mg/L)	17.5 ± 9.1	0.685		0.252	
CRP decline (day 14–day 2) (mg/L)	− 28 (19)	0.057*	n.s	0.024*	0.009
Worse pain (AUC)	45 (35–57)	0.116*	n.s	0.208	
Average pain (AUC)	31 (20–48)	0.214		0.427	
Opioid consumption (AUC)	25 (0–102)	0.300		0.463	
TKA (n = 41)					
		Total activity trajectory		90th percentile trajectory	
		Univariate analysis (p-value)	Multiple regression (p-value)	Univariate analysis (p-value)	Multiple regression (p-value)
Sex (male/female, nb)	17/24	0.753		0.711	
Age (years, range)	64 (55–75)	0.282		0.211	
BMI (kg/m^2)	28.8 ± 4.6	0.575		0.837	
Preoperative Hgb (g/DL)	13.8 ± 1.3	0.238		0.450	
Hgb day 2 (g/DL)	11.8 ± 1.2	0.901		0.590	
Hgb day 21 (g/DL)	12.4 ± 1.2	0.405		0.443	
Hgb decline (day 2-preOP) (g/DL)	− 2.1 (1.4)	0.141*	n.s	0.136*	n.s
Hgb increase (day 21–day 2)	0.7 (0.9)	0.511		0.678	
CRP day 2 (mg/L)	24.1 ± 17.9	0.303		0.354	
CRP day 21 (mg/L)	10.1 ± 10	0.289		0.392	
CRP decline (day 21–day 2) (mg/L)	− 14 (13)	0.604		0.645	
Worse pain (AUC)	91 (71–115)	0.574		0.686	
Average pain (AUC)	66 (55–86)	0.046*	0.046	0.124*	n.s
Opioid consumption (AUC)	303 (108–578)	0.518		0.750	

Factors for impaired early post THA/TKA total and high intense physical activity assessed with univariate analyses and multiple regression. The univariate analysis is assessed with unpaired t-test (dichotomous variables) or simple logistic regression (continuous variables)

Trajectory Slope of a regression line through a given patients daily activities plotted against the corresponding postoperative day, *AUC* area under the curve, *n.s*. not significant

*The mulitple regression includes variables with a significance level < 0.2 in the univariate analysis

total activity trajectory THA: 1.1% of preoperative level/day (SD 2.2) and TKA: 0.7% of preoperative level/day (SD 1.2)] and high intense activity [mean 90th activity percentile trajectory THA: 0.8% of preoperative level/day (SD 1.9), TKA: 0.9% of preoperative level/day (1.0)]. However, there was a large inter-individual variation in activity trajectory (Table 4). Accordingly, 28% (11/40) of THA patients and 20% (8/41) of TKA patients had a negative total activity trajectory, and 30% (12/40) of THA patients and 20% (8/41)

Table 3 Early total activity and activity intensity after total hip- or knee arthroplasty

THA (n = 40)							
	Pre-OP Mean (SD)	Day 1 Mean (SD)	Day 7 Mean (SD)	Day 13 Mean (SD)	Pre-OP vs. day 1 Mean-diff (95% CI)	Pre-OP vs. day 13 Mean-diff (95% CI)	Day 1 vs. day 13 Mean-diff (95% CI)
Total daily activity (1000 counts/day)	263 (106)	162 (56)	189 (53)	199 (83)	− 101 (− 131 to − 71)***	− 64 (− 99 to − 29)***	37 (10 to 64)**
25th percentile (counts/min)	54 (62)	23 (42)	24 (27)	29 (38)	− 31 (− 54 to − 8)**	− 25 (− 46 to − 4)*	6 (− 7 to 20)n.s
50th percentile (counts/min)	202 (134)	116 (83)	115 (69)	117 (84)	− 86 (− 132 to − 40)**	− 85 (− 131 to − 40)**	1 (− 29 to 30)n.s
75th percentile (counts/min)	477 (201)	292 (125)	336 (133)	334 (176)	− 185 (− 246 to − 123)***	− 143 (− 225 to − 60)***	42 (− 20 to 104)n.s
90th percentile (counts/min)	779 (228)	537 (176)	614 (168)	620 (215)	− 242 (− 308 to − 175)***	− 159 (− 249 to − 68)***	83 (2 to 165)**
TKA (n = 41)							
	Pre-OP Mean (SD)	Day 1 Mean (SD)	Day 7 Mean (SD)	Day 13 Mean (SD)	Day 20 Mean (SD)	Pre-OP vs. day 1 Mean-diff (95% CI)	Pre-OP vs. day 20 Mean-diff (95% CI)	Day 1 vs. day 20 Mean-diff (95% CI)
Total daily activity (thousand counts/day)	304 (101)	171 (61)	204 (72)	224 (77)	227 (91)	− 133 (− 163 to − 103)***	− 78 (− 105 to − 51)***	56 (27 to 84)***
25th percentile (counts/min)	71 (53)	27 (37)	30 (31)	34 (42)	29 (48)	− 44 (− 61 to − 27)***	− 42 (− 59 to − 25)***	2 (− 15 to 20)n.s
50th percentile (counts/min)	252 (120)	119 (81)	140 (95)	154 (115)	139 (113)	− 132 (− 170 to − 95)***	− 113 (− 151 to − 75)***	19 (− 17 to 57)n.s
75th percentile (counts/min)	557 (195)	292 (107)	363 (155)	404 (184)	386 (182)	− 265 (− 324 to − 206)***	− 171 (− 229 to − 114)***	94 (37 to 151)**
90th percentile (counts/min)	876 (263)	518 (141)	671 (200)	733 (213)	730 (256)	− 358 (− 429 to − 287)***	− 146 (− 205 to − 88)***	212 (136 to 287)***

Change in activity assessed with the paired t test

SD standard deviation, *Mean-diff* mean difference, *CI* confidence interval, *n.s.* not significant

*p < 0.05, ** p < 0.01, *** p < 0.001

of TKA patients had a negative activity trajectory for the 90th activity percentile.

To exemplify, the activity trajectories for the four THA and TKA patients with the lowest and largest recovery trajectory of total activity are visualized in Figs. 5, 6, 7 and 8.

3.3 Factors for physical activity after THA

Neither demographics, postoperative pain, CRP nor level of hgb were significant factors for impaired recovery of *total activity* through the study period for THA patients in the univariate analysis. BMI and delayed normalization in CRP from postoperative day 2 until day 14 were significant factors for impaired recovery of *high intense physical activity* (90th percentile) (Table 2).

In the multiple regression analysis (Table 2), no factors were found significant for impaired recovery of *total activity*. BMI, increased fall in hgb from preoperatively until day 2 and delayed normalization in CRP from day 2 until day 14 were independently associated to impaired recovery of *high intense physical activity* (the 90th percentile recovery trajectory), collectively explaining 32% of the variance ($r^2 = 0.32$, $p = 0.005$).

3.4 Factors for physical activity after TKA

For TKA patients, the AUC for average pain from postoperative day 1 to day 20 was a significant predictor of impaired recovery of total activity in both the univariate analyzes and in the multiple regression, but only explaining 10% of the variance in the *total activity* recovery trajectory ($r^2 = 0.10$, $p = 0.046$), whereas none of the included variables were significantly associated with impaired recovery of *high intense physical activity* (Table 2).

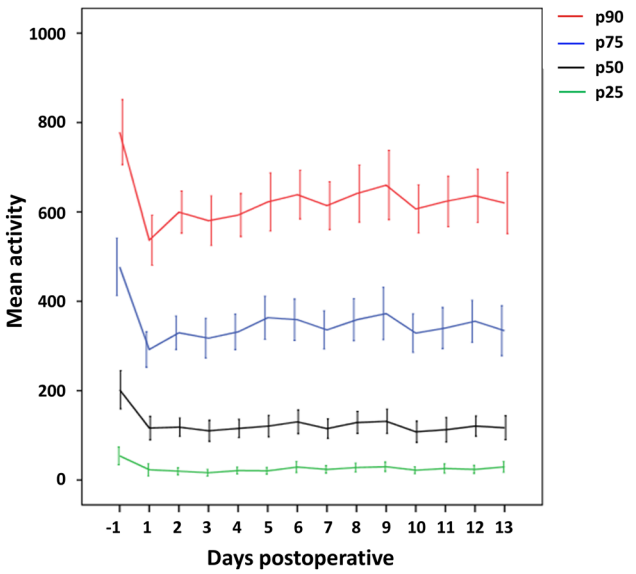

Fig. 3 Development in activity intensities following THA. Activity intensities represent a percentage of the day spent at the given activity intensity or less. E.g. a 25 percentile of 100 counts/min meant that the given patient spent 25% of the daytime at or below this count. Activity intensities are reported as counts/min. *P* percentile

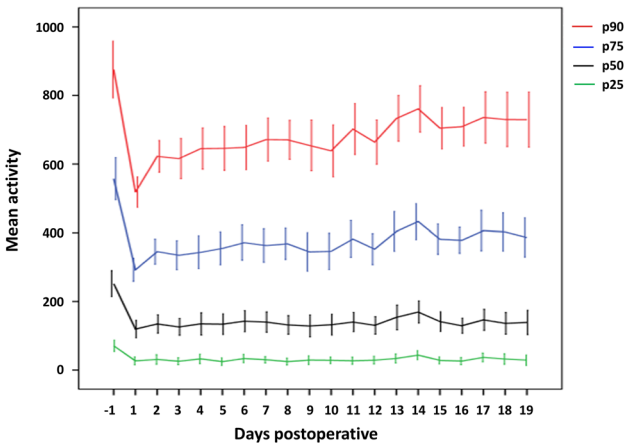

Fig. 4 Development in activity intensities following TKA. Activity intensities represent a percentage of the day spent at the given activity intensity or less. E.g. a 25 percentile of 100 counts/min meant that the given patient spent 25% of the daytime at or below this count. Activity intensities are reported as counts/min. *P* percentile

4 Discussion

Our study is the first to use a detailed actigraphy based assessment of early individualized physical recovery following THA/TKA with intensity-stratification. It revealed a significantly reduced total activity the first 2 (THA) and 3 (TKA) weeks following surgery, but with a slight gradual improvement over the study period on a group level. Analyses of activity patterns with stratification into activity intensities showed a postoperative decline in all activity intensities on postoperative day 1. They remained lower than preoperative levels throughout the study period, but with an improvement in high intense activity from day 1 until day 13. This implies that physical activity was significantly reduced the first weeks following THA/TKA, but with a slight improvement in high intense activity, corresponding to an increase in the most vigorous activities during the day and not only to reduced resting-time. No similar previous data on early post-THA/TKA physical activity with intensity stratification exist, but a comparable acute postoperative decline has been published, with a relative improvement within 6 days to 4 weeks, although remaining below preoperative levels [8, 19, 23].

The individualized actigraphy data revealed a large variation in activity profiles. While some patients surpassed their preoperative activity levels during the follow-up period, others had reduced activity throughout the study-period. Reduced activity in the early postoperative phase may be expected, but the individualized analyses of recovery trajectories through the study period showed that although increasing postoperative activity was found on a group level with an approximate daily improvement of 1%, about 1/3 of THA patients and 1/5 of TKA patients had an impaired recovery profile with declining total and high intense activity. That is, their physical activity deteriorated for 2–3 weeks after surgery. Thus, the use of activity trajectories to assess the development in activity in the early postoperative phase provides the possibility to differentiate between patients with an expected reduced but over time somewhat improving postoperative level of activity versus those with not only reduced but also decreasing activity.

One previous study has assessed individual development in activity-profile in the early postoperative phase by visual evaluation of the accelerometer curve [24]. Our new methodology, however, provides a quantifiable assessment of activity, potentially useful on large data-material in a clinical setting to direct individualized rehabilitation programs. In comparison to previous assessments of group level average activity over time [1, 2, 20, 23], activity trajectories may be applied in future physiotherapeutic intervention studies in specific high-risk patients with a suboptimal recovery profile, in contrast to the limited effect of physiotherapy on the overall population [25]. Whether poor early post-THA/TKA physical activity correlates to late functional impairments remains unknown, but it has been shown that only a few days of inactivity reduces lower limb muscle strength, and that recovery is prolonged in elder individuals matching the THA/TKA population [26].

A higher BMI, an increased postoperative fall in hgb and a prolonged high level of CRP were all independently associated with an impaired recovery trajectory of high intense

Table 4 Early adjusted total activity and high intense activity after total hip- and knee arthroplasty

THA (n = 40)					
	Day 1 Mean (SD)	Day 7 Mean (SD)	Day 13 Mean (SD)		Trajectory Mean (SD)
Daily activity (% of pre-OP activity)	− 28.0. (32.1)	− 15.1 (37.9)	− 7.4 (39.6)		1.08 (2.15)
90th percentile (% of pre-OP activity)	− 28.5 (21.1)	− 17.8 (23.3)	− 15.0 (30.4)		0.80 (1.85)
TKA (n = 41)					
	Day 1 Mean (SD)	Day 7 Mean (SD)	Day 13 Mean (SD)	Day 20 Mean (SD)	Trajectory Mean (SD)
Daily activity (% of pre-OP activity)	− 40.2 (24.7)	− 28.4 (24.8)	− 20.5 (30.7)	− 24.1 (25.8)	0.70 (1.21)
90th percentile (% of pre-OP activity)	− 38.3 (19.9)	− 21.5 (19.8)	− 13.2 (26.7)	− 15.8 (21.0)	0.93 (1.04)

Adjusted activity = postoperative total and high intense activity adjusted for preoperative level as follows: adjusted activity = $(\text{avtivity}_{post} - \text{activity}_{pre})/\text{activity}_{pre} \times 100$. Trajectory = Slope of a regression line through a given patients daily activities plotted against the corresponding postoperative day with a positive value reflecting an increasing physical activity during the postoperative study-period and a negative vice versa

SD standard deviation

activity following THA, and increased postoperative pain associated with impaired recovery trajectory of total activity following TKA. This corresponds to the sparse previous studies on early physical recovery, where post-THA anemia was found to be a significant, but weak association to impaired physical performance [8]. Also, an increased postoperative inflammatory response was associated with impaired post-THA recovery [27, 28], and acute post-TKA pain represent a continuing clinical problem with implications for physical recovery [29, 30]. Whether interventions in predefined risk groups to reduce postoperative anemia, modulate inflammatory response or improve analgesic treatment would improve post-THA/TKA physical activity remains to be established. However, since the regression models explain 30% (THA) and 10% (TKA) of the variation in recovery trajectory and since no single factor had major importance for both THA- and TKA patients activity, the multifactorial pathogenesis of recovery is stressed, presumably also including factors as psychological profile, expectations and motivational challenges [31–34].

Despite the strength of having a prospective study design with activity assessed by well-established actigraphy equipment, our study has limitations. Approximately one-third of patients were excluded from the analyses, the majority due to missing actigraphy data. However, since the used device was prone to being switched off unintendedly without visual warnings, we do not believe the exclusion was systematic, and no differences in baseline characteristics between in- and excluded patients were found. Likewise, the actigraphy data were collected as part of a comprehensive testing protocol, potentially causing selection of more resourceful participants with a resultant reduced variation of activity. Due to low power, we may also have overlooked other relevant explanatory factors for impaired physical activity, although we tried to counter the risk of a type II error by including variables in the regression analysis if they had a univariate p-value below 0.2.

In conclusion, physical activity was significantly reduced two (THA) and three (TKA) weeks following surgery compared to preoperatively. Slight postoperative improvements were seen for high intense activities, but with a large inter-individual variation. Approximately 30% of THA and 20% of TKA patients had reduced and declining activity throughout the study period, calling for early stratified physiotherapeutic interventions in this subgroup of patients. No single major factor for impaired postoperative physical activity was identified, although anemia, obesity, inflammatory stress-response (THA) and postoperative pain (TKA) were associated with poor recovery trajectories, and may be considered in future interventions trials in selected high-risk groups.

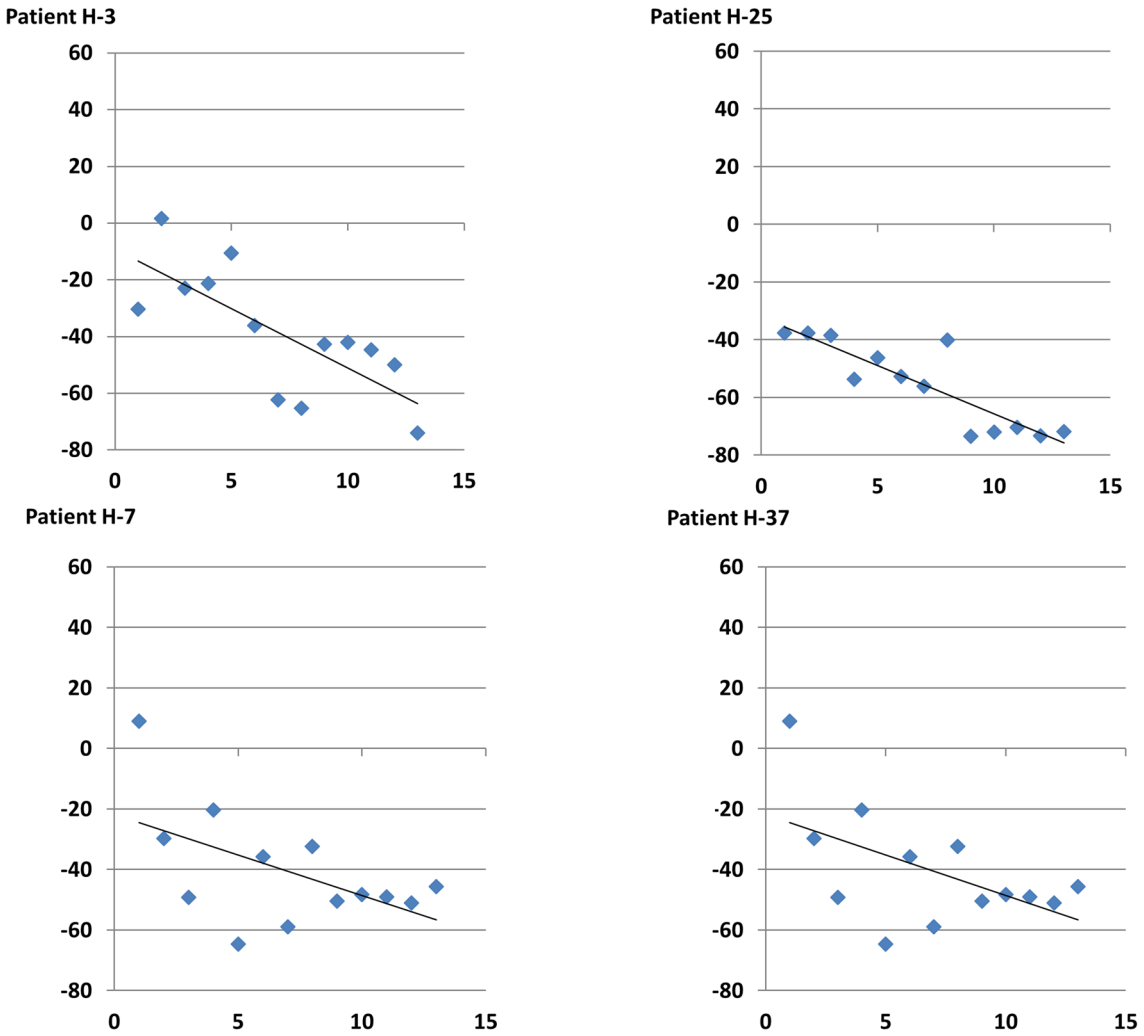

Fig. 5 Negative recovery trajectories following total hip arthroplasty. Examples of physical recovery following THA visualized with plotting of an individual patient's daily adjusted total activity (*y axis*) from postoperative day 1 to day 13 (*x axis*). The recovery trajectory is calculated as the gradient of the regression line drawn through the activities. The 10% highest and lowest recovery trajectories are presented

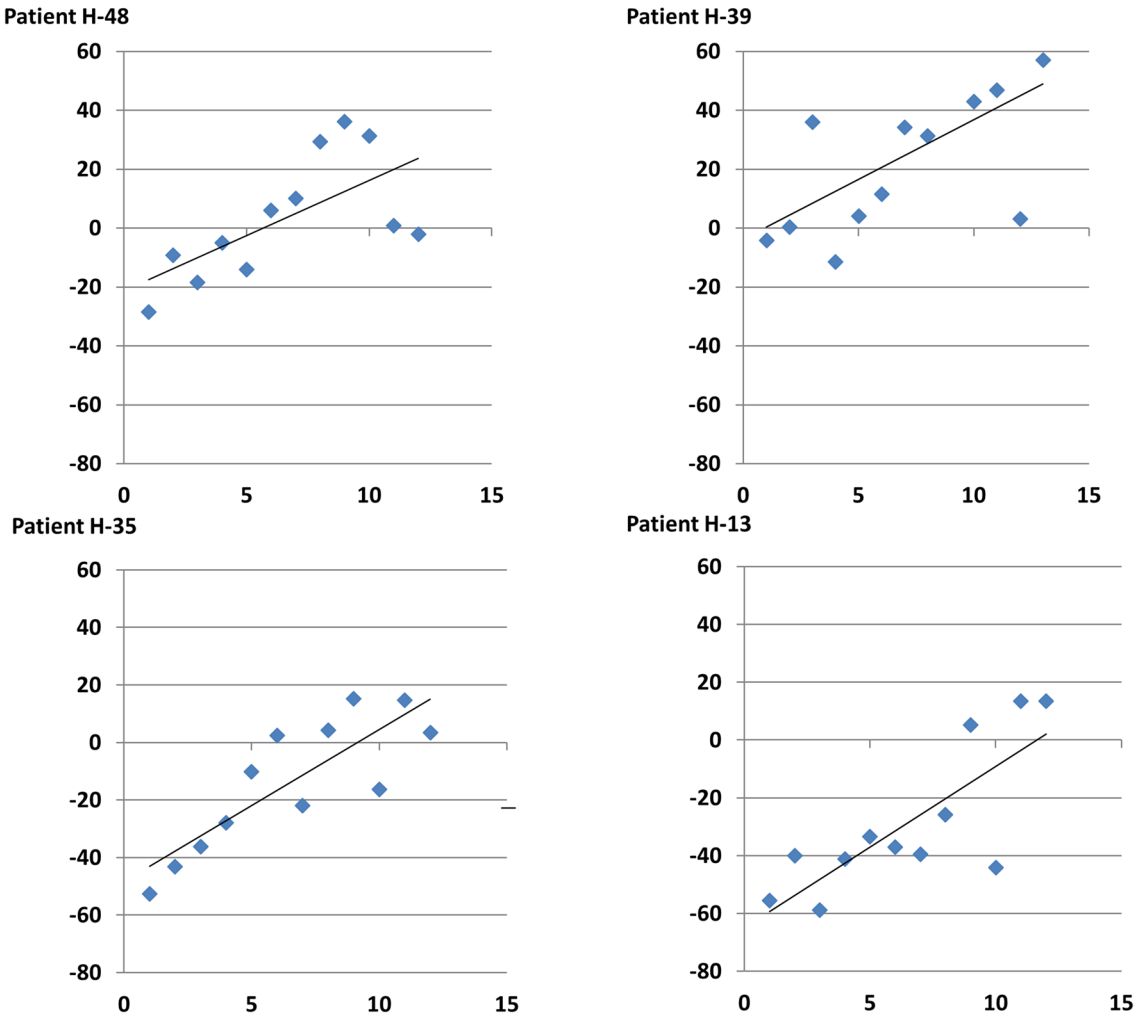

Fig. 6 Positive recovery trajectories following total hip arthroplasty. Examples of physical recovery following THA visualized with plotting of an individual patient's daily adjusted total activity (*y axis*) from postoperative day 1 to day 13 (*x axis*). The recovery trajectory is calculated as the gradient of the regression line drawn through the activities. The 10% highest and lowest recovery trajectories are presented

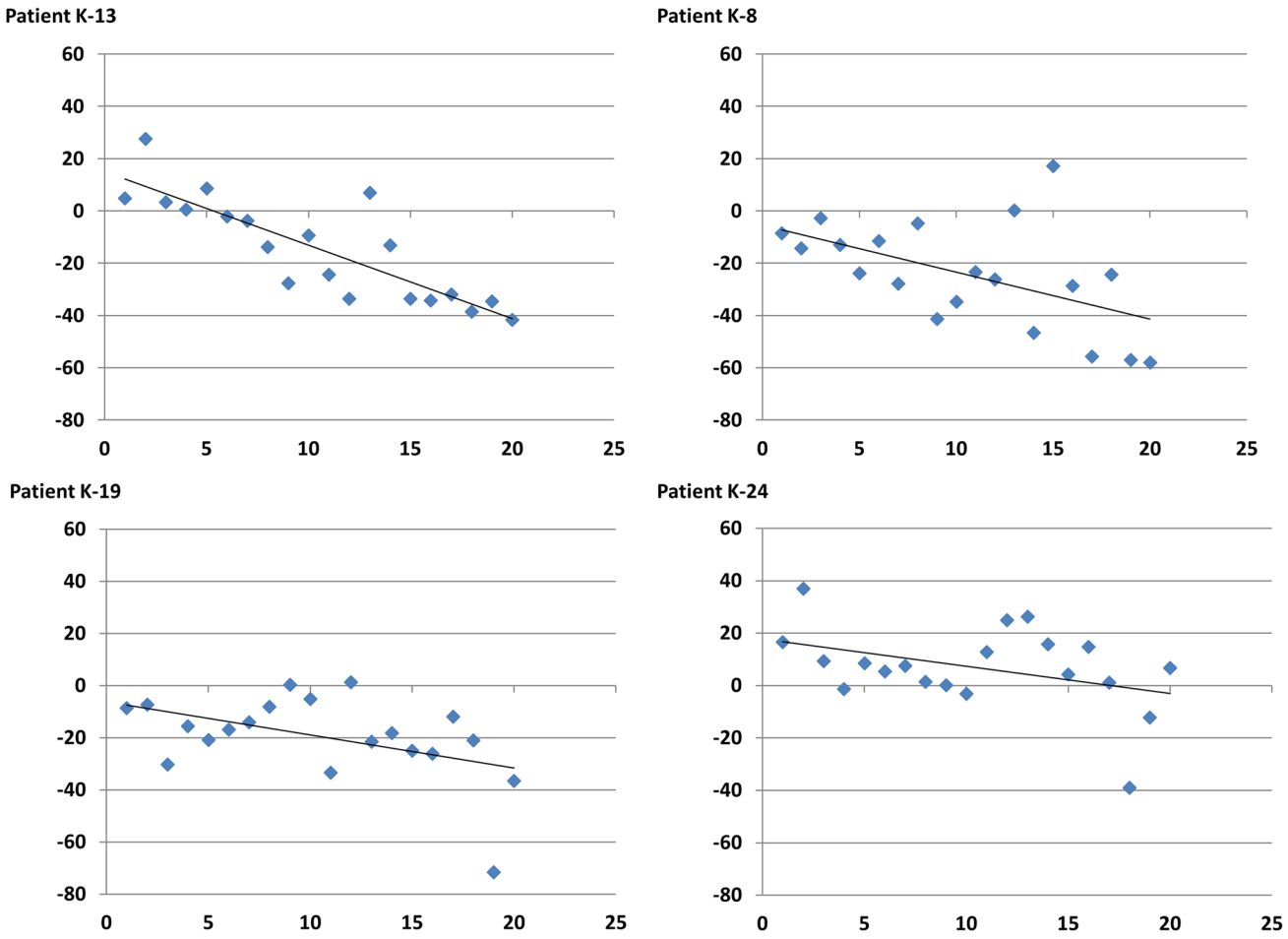

Fig. 7 Negative recovery trajectories following total knee arthroplasty. Examples of physical recovery following TKA visualized with plotting of an individual patient's daily adjusted total activity (*y axis*) from postoperative day 1 to day 20 (*x axis*). The recovery trajectory is calculated as the gradient of the regression line drawn through the activities. The 10% highest and lowest recovery trajectories are presented

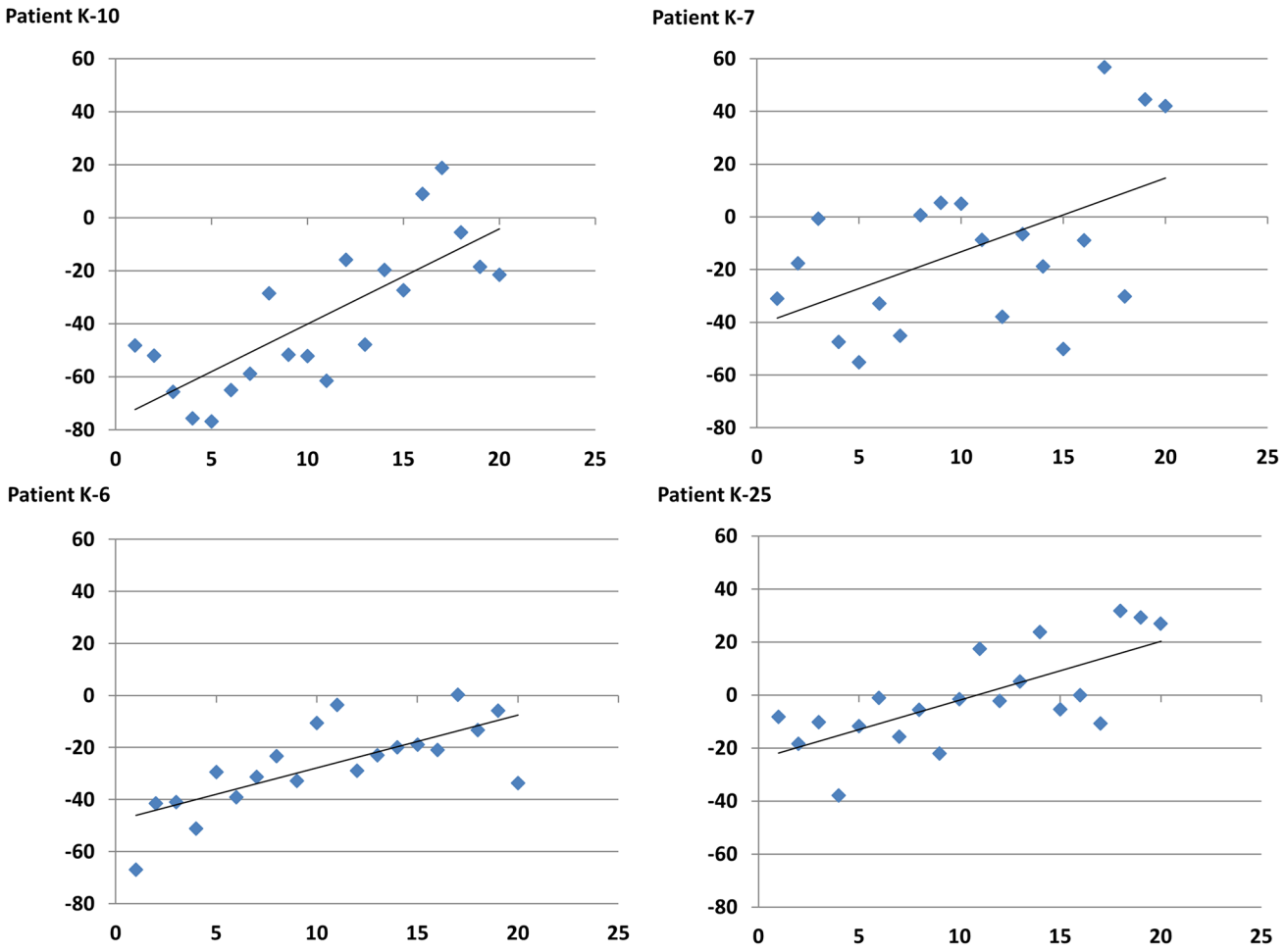

Fig. 8 Positive recovery trajectories following total knee arthroplasty. Examples of physical recovery following TKA visualized with plotting of an individual patient's daily adjusted total activity (*y axis*) from postoperative day 1 to day 20 (*x axis*). The recovery trajectory is calculated as the gradient of the regression line drawn through the activities. The 10% highest and lowest recovery trajectories are presented

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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