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Physical activity six months after a severe fall – moderating factors in older individuals

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Abstract

Background Severe falls in older individuals are a leading cause of emergency department (ED) visits and often result in long-term impairments that reduce physical activity (PA). Limited information exists on the characteristics of individuals who suffer from physical inactivity after such falls and the factors that influence it. This study investigates the association between potential moderators and changes in PA in older adults six months after a severe fall.

Methods Participants were recruited from the SeFallIED study (German Clinical Trials Register ID: 00025949). Moderators were evaluated through a home-based geriatric assessment conducted within four weeks of a severe fall with presentation to the ED. PA was quantified using both sensor-based ($n = 72$ men (75 years), $n = 106$ women (74 years) and self-reported ($n = 105$ men (74 years), $n = 174$ women (73 years) assessments. A Linear Mixed Model was used for analysis.

Results Sensor-based PA revealed a significant time effect for step count ($p = 0.006$), indicating an increase in PA six months after a severe fall. Fall history (95% CI: -1,009.5 – (-207.4), $p = 0.003$) and age (95% CI: -315.8 – (-82.5), $p < 0.01$) were significant negative moderators for changes in PA, only in women. No significant changes in self-reported PA were observed after six months ($p = 0.109$).

Conclusion Participants showed an increase in sensor-based PA six months after a severe fall, though this was negatively associated with age and fall history. Early identification of factors that affect PA recovery may help stratify individuals by risk and target those in need of secondary prevention.

Trial registration DRKS (Deutsches Register für klinische Studien, DRKS0 00259 49). Prospectively registered on 4th November, 2021.

Keywords Physical activity, Severe falls, Emergency department, Falls prevention

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Background

Around 40% of community-dwelling older individuals experience a fall once a year, which in 20–30% of the cases requires medical treatment in an emergency department (ED) [1, 2]. Falls often cause concerns about falling, impair activities of daily living, and reduce cognitive function and physical activity [3, 4].

Physical activity (PA) is defined as any bodily movement produced by skeletal muscles that demand energy expenditure and is often categorized into occupational, sports, conditioning, household or other activities [5–8]. Changes in PA following a fall often indicate the beginning of a downward spiral. Fall-related consequences, such as increased concerns about falling, may lead to activity avoidance. While this avoidance may reduce immediate risk exposure, it can have detrimental long-term effects by contributing to social isolation and the progressive decline of physical functioning [9, 10]. Monitoring PA offers valuable insights into early behavioral adaptations that may precede measurable declines in physical function such as balance and gait impairments. Especially in vulnerable populations, PA can serve as a proxy for early, modifiable changes that contribute to long-term functional decline [8]. Therefore, early identification of longitudinal changes in PA may help to appropriately target individuals at highest risk for further functional decline and recurrent falls.

PA in older adults with a history of falls has been investigated in previous literature cross-sectionally, with most of the studies using self-reported measures e.g., validated questionnaires [5, 6, 11]. Self-reported measures of PA underlie response bias as well as recall bias, which can affect data accuracy, and data collection is often challenging in vulnerable populations such as individuals with cognitive impairment. Contrary to validated PA-questionnaires wearable motion sensors provide an objective and more reliable understanding of PA in older adults [12, 13]. A recent systematic review provided a deeper insight into the usage of accelerometers to measure PA in community-dwelling older adults [14]. The authors identified seven studies, which assessed PA by using the ActivPalTM as a wearable motion sensor. The most common parameters used in these studies were step count, time spent walking, sit-to-stand transition, and sedentary time [14].

One of the longitudinal studies that utilized a wearable motion sensor to observe individuals with a history of falls, reported significant differences in PA after a three-year follow-up period, attributed to the initial fall event. Individuals who experienced an injurious fall reduced their average daily step count and daily activity minutes significantly more than those who did not experience an injurious fall over a three-year follow-up period [15]. Another study examined the moderating

factors of various PA components related to falls and concerns about falling in older adults, as well as whether participation in a physical exercise program could reduce these risks [16]. The study revealed a significant association between falls and one-leg standing time, long-term PA participation, fall history and concerns about falling. Additionally, concerns about falling were linked to age, sex, and different PA components [16]. However, evidence remains limited regarding the moderating factors that influence changes in PA following a fall, particularly in high-risk individuals. Previous studies have primarily focused on community-dwelling populations [9, 10], older adults recovering from injuries such as hip fractures [17], or those with glaucoma [15, 18]. According to the global guidelines for falls prevention, individuals presenting to the ED after a fall are classified as a high risk group [8]. However, this population is heterogeneous, and not all individuals follow the same post-fall trajectory. Identifying red flags – such as behavioral adaptations that precede measurable functional decline – can help refine risk stratification and guide tailored treatment approaches [19, 20].

Therefore, the aim of this study was to investigate whether clinically relevant moderators such as physical function, cognition, depressive symptoms, fall-related factors, and personal factors were associated with changes in sensor-based and self-reported PA, in older men and women six months after a severe fall with presentation to the ED.

Method

Participants

Participants were recruited from the SeFalled (“Sentinel Fall Presenting to the Emergency Department”) study, which is currently ongoing at the Carl von Ossietzky University Oldenburg, Germany [21]. Complete baseline data within four weeks after a severe fall (T1) and after six months (T2) from the observational, prospective part of the study were used. Participants enrolled between November 2021 and December 2023 were included in this sub-study. The study is in accordance with the declaration of Helsinki (1974), and its latest amendments, has been prospectively registered in the German Clinical Trials Register (DRKS-ID: 00025949) and was approved by the Medical Ethics Committee of the University Oldenburg (number 2021 – 120). Participants had to meet the following inclusion criteria: (1) age 60 years or above, (2) presented to the ED of the Klinikum Oldenburg or Evangelisches Krankenhaus Oldenburg after a fall and were discharged within 72 h, (3) informed consent. Exclusion criteria are as follows: (1) life expectancy of less than 3 months, (2) unstable medical, neurological or psychiatric condition, (3) bedridden or being unable to walk without support of another person, (4) residence more than

40 km away from the research center, (5) acute psychosis or social aggression, (6) inability to communicate verbally in German or English [21].

Study overview

Subjects gave their written informed consent for further contact in the ED to a study nurse, who approached individuals meeting the inclusion criteria of the study. After being contacted via telephone, a trained member of the study team conducted a home visit to obtain informed consent for participation. The whole recruitment procedure has been described comprehensively in a previous article [19]. During the first home visit (T1), an extensive structured and standardized geriatric assessment was conducted. A list of the assessment battery has been published before, but included information about the participants, fall history, concerns about falling, depressive symptoms, activities of daily living, and functional performance [21]. Due to individual preferences, not all participants consented to wear the sensor used for measuring PA, and in a few cases, questionnaire data were incomplete. Sensor use was an additional source of data and required separate consent; participants who declined remained eligible for other study procedures. Consequently, sample sizes varied slightly across data sources, and a baseline comparison was performed to assess group comparability. The inclusion criteria were intentionally broad to capture a heterogeneous sample reflective of older adults typically presenting to the ED after a fall. This approach included individuals with cognitive impairment. In such cases, caregivers or family members supported data collection efforts, particularly for questionnaire-based assessment. The second home visit after 6 months (T2) was conducted similarly to the first home visit (T1).

Outcome measures

Physical activity

Sensor-based PA was measured using a three-axial accelerometer (activPAL4™, PAL Technologies Ltd., Glasgow, UK) [13], which was attached to the participants' right thigh by a trained member of the study team as part of the comprehensive assessment during both home visits (T1 and T2). An additional consent form was used concerning the collection of sensor data. If participants provided their consent, they were instructed to wear the sensor for seven consecutive days. A minimum of 24 h of data collection for at least five consecutive days was required for inclusion of the data in the analysis, as recommended by previous literature [22]. Parameters derived from the wearable device have been validated for measuring PA in community-dwelling older individuals [13]. Accordingly, we analyzed number of steps per day,

time spent walking (minutes), sedentary time (minutes) and the number of sit-to-stand transitions [14].

Additionally, self-reported PA was assessed using the German-PAQ-50+ [23] during both home visits (T1 and T2). The German-PAQ-50+ [23] is a well established questionnaire in individuals over the age of 50 years and a feasible measure of self-reported PA [24]. We used PAQ-50+-total scores to assess the total time spent on PA (minutes) for further analysis.

Moderators

Moderators were assessed as part of the comprehensive geriatric assessment at baseline (T1).

Cognitive function

Montreal Cognitive Assessment (MoCA) was used to assess cognitive function, which is a valid screening tool for global cognition with higher scores indicating better cognitive function [25]. The total score was used as a moderator.

Depressive symptoms

Depressive symptoms were either assessed by total score of the Depression in Old Age Scale (DIA-S) [26], ranging from 0 (no depressive symptoms) to 10 points (maximal amount of depressive symptoms) with cut-off for probable depressive symptoms at 3 points, or Cornell Depression Scale [27], ranging from 0 to 38 points with a score > 10 points indicating major depressive symptoms. The Cornell Depression Scale was used instead of the DIA-S, when participants had severe cognitive impairment (MoCA < 18 points). The Cornell Depression Scale was administered with the assistance of participants' family members or caregivers. For subsequent statistical analysis, a new variable, "presence of depressive symptoms" (yes/no) was created based on the participants' total scores from either the DIA-S or the Cornell Depression Scale.

Physical function

The Short Physical Performance Battery (SPPB) is a commonly used assessment to investigate lower extremity functioning in older adults [28]. The assessment consists of a parallel, semi tandem and a tandem stance for ten seconds to assess standing balance performance, a 4-meter walking test conducted at participants' usual pace to assess gait speed and a five times chair-stand test to assess the ability to get up as fast as possible from a chair without support of the arms. Adding the sub-scores of standing balance, walking, as well as chair-stand components of the SPPB (ranging from 0 to 4), builds the SPPB total score (ranging from 0 to 12), with lower scores indicating worse functioning [28]. Due to insufficient space at participants' homes, a modified version with a

three meter walk instead of four meters was conducted, which is in line with previous research [29, 30]. Participants' total score of lower extremity functioning and gait speed were included as moderators.

Grip strength, which is a proxy for muscle strength, was assessed using a Jamar® hand dynamometer, which has proven a good test-retest reliability, and inter-, as well as intra-rater reliability. Participants were instructed to sit on a chair with the elbow in 90° flexion, shoulder adducted and without support surface of the armrest, as described in the American Society of Hand Therapists (ASHT) grip-strength protocol [31]. Participants were instructed to squeeze the dynamometer as hard as possible for three alternating times. Mean grip score in kilograms from the three trials of the dominant hand were used for further analysis.

Fall-related factors

Fall history was assessed by asking participants, “how many falls have you experienced within the last 12 months?”. Therefore, fall history reflects the total number of falls in the last 12 months before attending the ED, while the initial fall leading to study inclusion was not included in that variable.

Concerns about falling were quantified by using the Short falls efficacy scale-international (FES-I) [32], which is a reliable and clinically practical measure. FES-I consists of 7 different items describing the presence of concerns about falling during daily activities for example while getting dressed/undressed or while getting in/out of a chair. Participants were advised to choose, whether they are not at all (1), somewhat (2), fairly (3), or very concerned (4) to fall during daily activities. Total score of FES-I with maximum score of 28 points indicating severe concerns about falling, were used for interpretation.

In addition to fall history and concerns about falling, “unrecovered” and “recovered” falls were determined by asking participants, if they were able to get up unaided (= recovered) after their severe fall leading to study inclusion, or whether they were unable to get up on their own (= unrecovered).

Personal factors

Age in years and body mass index, calculated from body mass in kilograms and body height in centimeters as part of the comprehensive geriatric assessment, were included into the statistical model.

Statistical analyses

In order to compare participants with valid accelerometer data and those with valid questionnaire data, participants' baseline characteristics were analyzed within and between groups using non-parametric Kruskal-Wallis-Test. Continuous variables of participants' baseline

characteristics were expressed as medians and interquartile ranges (IQR).

Participants were included in our statistical analyses if they had valid accelerometer data and completed questionnaires at both baseline (T1) and six months later (T2), as well as valid data for at least one of the predefined moderators at baseline (T1). Statistical analysis were conducted separately for participants with valid accelerometer datasets and those with only valid questionnaire data sets. Complete case analyses were used.

To identify the association between changes in sensor-based and self-reported PA, we conducted a Linear Mixed Model (LMM) analysis with sex (male and female) as a fixed between-subjects effect. Additionally, baseline cognitive function, depressive symptoms, physical function, fall-related factors, and personal factors were included as moderating factors. Age (in years) and number of previous falls before initial fall event leading to study inclusion (number of falls in the last 12 months) were dichotomized using the following cut-off values: <63 years \geq vs. 63 years and <1 fall vs. \geq 1 fall.

For the analyses, we used SPSS for MacOS (version 28.0; SPSS Inc., Chicago, IL, USA) and R (R Core Team, 2023 Version 4.3.2 (2023-10-31)) with the ‘nlme’ package for LMM analyses with longitudinal measurements.

Inferential statistics are intended to be exploratory (hypothesis-generating) rather than confirmatory, and should be interpreted accordingly. No a priori power calculation was performed, as this study uses a sub-sample from the larger prospective study and analyses performed were exploratory. The local significance level is set at 0.05, and no adjustment for multiple testing is performed.

Results

Participant characteristics

Out of 335 participants at baseline, 279 older adults ($n = 105$ male and $n = 174$ female participants) completed the PAQ-50+ at both time points. In total, 178 older adults ($n = 72$ male and $n = 106$ female participants) had complete accelerometer data for both time points. While $n = 131$ participants refused to wear an accelerometer either at T1 or T2, $n = 26$ data sets did not incorporate a full 24-hour cycle for 5 five consecutive days either at T1 or T2 (see supplementary Fig. 1). Within the PAQ-50+ group, women reported higher concerns about falling at baseline in comparison to men ($p = 0.035$). Cognitive function was significantly lower for men compared to women within the PAQ-50+ group ($p = 0.015$), as well as within the ActivPal group ($p = 0.031$), while between-group differences indicated lower cognitive function for men in the PAQ-50+ group than women in the ActivPal-group ($p = 0.007$). Hand grip strength differed between men and women in both groups ($p < 0.001$) (Table 1). No further differences were identified for age, body mass

Table 1 Participants' baseline characteristics divided into the groups with sensor-based (ActivPal) and self-reported (PAQ-50+) physical activity data and sex (men/women)

Characteristic	ActivPal		(n = 178)	p value	PAQ-50 +		(n = 279)	p value
	Men (n = 72)	Women (n = 106)	Men (n = 105)		Women (n = 174)			
	Median (IQR)	Median (IQR)	Median (IQR)		Median (IQR)			
Age (years)	75 (66–83)	74 (67–82)	0.881	74 (66–81)	73 (66–81)	0.911	Gr. 4–2: 0.589 Gr. 4–1: 0.521 Gr. 3–2: 0.702 Gr. 3–1: 0.620	
BMI (kg/m ²)	27.3 (24.2–29.2)	25.8 (23.5–29.1)	0.394	26.7 (24.6–29.1)	25.5 (23.5–29)	0.881	Gr. 2–4: 0.859 Gr. 2–3: 0.748 Gr. 4–1: 0.546 Gr. 3–1: 0.691	
Education (years)	10 (9–12)	10 (9–12)	0.339	10 (9–12)	10 (9–12)	0.468	Gr. 4–2: 1.000 Gr. 4–1: 0.295 Gr. 2–3: 0.517 Gr. 3–1: 0.710	
Number of diseases	2 (1–4)	2 (1–4)	0.867	2 (1–3)	2 (1–4)	0.295	Gr. 3–2: 0.287 Gr. 3–1: 0.260 Gr. 4–2: 0.886 Gr. 4–1: 0.757	
Fall history (number of falls within 12 months)	1 (1–2)	1 (1–2)	0.222	1 (1–2)	1 (1–2)	0.937	Gr. 4–2: 0.976 Gr. 4–1: 0.174 Gr. 2–3: 0.965 Gr. 3–1: 0.237	
Concerns about falling, FES-I score	8 (7–10)	9 (7–12)	0.120	8 (7–10.5)	9 (7–11)	0.035	Gr. 3–1: 0.873 Gr. 3–2: 0.058 Gr. 1–4: 0.091 Gr. 4–2: 0.991	
Cognition, MoCA score	23 (21–26)	25 (23–27)	0.031	23 (21–26)	25 (22–27)	0.015	Gr. 3–1: 0.780 Gr. 3–2: 0.007 Gr. 1–4: 0.066 Gr. 4–2: 0.557	
ADL	0 (0–3)	0 (0–2)	0.784	0 (0–3)	0 (0–3)	0.773	Gr. 1–3: 0.729 Gr. 1–4: 0.527 Gr. 2–3: 0.936 Gr. 2–4: 0.705	
Functional performance, SPPB total score	9 (7.5–10)	10 (8–11)	0.111	10 (8–11)	10 (9–11)	0.722	Gr. 1–3: 0.201 Gr. 1–4: 0.084 Gr. 3–2: 0.734 Gr. 4–2: 0.981	
Grip strength (kg)	41 (34.5–49)	24 (20–29)	<0.001	42 (34.5–49)	24 (20–29)	<0.001	Gr. 4–2: 0.931 Gr. 4–1: <0.001 Gr. 2–3: <0.001 Gr. 3–1: 0.656	

Gr.= group; Gr. 1 = ActivPal + Men; Gr. 2 = ActivPal + Women; Gr. 3 = PAQ50 + Men; Gr. 4 = PAQ50 + Women. Data represent medians (IQR = Interquartile Range: 25th–75th percentile); BMI, body mass index; FES-I [33], falls efficacy scale-international [33]; MoCA, Montreal Cognitive Assessment [34]; ADL, Activities of daily living according to Jonkman et al., 2018 [35]; SPPB, Short Physical Performance Battery [29]. Results of non-parametric Kruskal-Wallis-Test are presented; significant values are in bold

index, education, fall history and diseases, activities of daily living and functional performance (Table 1).

Main outcomes – LMM for sensor-based PA

The linear mixed model for sensor-based PA revealed a significant time effect for step count ($p = 0.006$) and stepping time ($p = 0.031$), indicating an increase in PA six months after a severe fall (T2). However, sit-to-stand

transitions ($p = 0.949$) and sedentary time ($p = 0.163$) did not change.

LMM - step count

Notably, women significantly increased the average number of steps per day by +1,777.9 (95% CI: 292.2–3,263.7, $p = 0.019$) compared to male participants (Table 2). Regarding moderating factors, fall history (95% CI: -1,009.5 – (-207.4), $p = 0.003$), age (95% CI:

Table 2 Changes in step count and association with moderating factors six months after a fall

	Estimate	95% CI (lower)	95% CI (upper)	p value
Intercept	5763.7	4584.8	6942.7	1.28×10^{-16}
Change in step count (T2)	434.8	-9.4	879.0	0.055
Effect of sex (female)	1777.9	292.2	3263.7	0.019
Interaction:	83.8	-306.1	473.8	0.673
Male x fall history				
Interaction:	-608.5	-1009.5	-207.4	0.003
Female x fall history				
Intercept	6283.6	5388.9	7178.4	3.55×10^{-35}
Change in step count (T2)	545.8	150.5	941.1	0.006
Effect of sex (female)	332.3	-789.9	1454.7	0.560
Interaction:	-540.6	-2293.1	1211.9	0.544
Male x depression				
Interaction:	-546.9	-1859.7	765.8	0.413
Female x depression				
Intercept	6487.3	88.0	1288.6	0.046
Change in step count (T2)	414.9	-36.8	866.6	0.071
Effect of sex (female)	-688.9	-8351.5	6073.7	0.859
Interaction:	-21.1	-293.4	251.1	0.878
Male x MoCA				
Interaction:	35.9	-138.9	210.8	0.686
Female x MoCA				
Intercept	8202.9	5395.5	11010.4	<0.001
Change in step count (T2)	427.3	-19.7	874.2	0.061
Effect of sex (female)	0.5	-3321.5	3322.4	0.999
Interaction:	-248.9	-538.5	40.5	0.091
Male x FES-I				
Interaction:	-159.3	-319.6	1.1	0.051
Female x FES-I				
Intercept	12852.0	5154.6	20549.4	0.001
Change in step count (T2)	405.2	-42.9	853.4	0.076
Effect of sex (female)	4261.1	-5379.0	13901.3	0.385
Interaction:	91.4	-192.3	9.4	0.075
Male x age				
Interaction:	-139.8	-216.3	-63.5	<0.01
Female x age				
Intercept	8901.5	3910.1	13892.8	<0.01
Change in step count (T2)	404.6	-39.4	848.6	0.073
Effect of sex (female)	3096.2	-2853.1	9045.5	0.306
Interaction:	-108.7	-287.2	69.8	0.231
Male x BMI				
Interaction:	-199.2	-315.8	-82.5	<0.01
Female x BMI				
Intercept	6122.7	4835.4	7410.0	<0.01
Change in step count (T2)	541.9	80.4	1003.5	0.021
Effect of sex (female)	1835.8	55.1	3616.6	0.043
Interaction:	-1087.6	-3192.9	1017.7	0.310
Male x unrecovered falls				
Interaction:	-2654.3	-4281.5	-1027	0.001
Female x unrecovered falls				
Intercept	6221.8	445.4	7988.3	<0.01
Change in step count (T2)	341.4	-11.4	694.3	0.057
Effect of sex (female)	111.5	-2308.3	2531.4	0.927
Interaction:	-5.37	-71.1	60.4	0.872
Male x SPPB				
Interaction:	48.0	-50.3	146.4	0.337
Female x SPPB				

Table 2 (continued)

	Estimate	95% CI (lower)	95% CI (upper)	p value
Intercept	5050.2	3355.4	6745.0	<0.01
Change in step count (T2)	401.9	-56.1	859.9	0.085
Effect of sex (female)	1108.6	-1154.9	3372.2	0.336
Interaction:	41.1	-17.1	99.2	0.165
Male x grip strength				
Interaction:	36.6	-47.9	121.2	0.395
Female x grip strength				
Intercept	5074.9	1881.0	8268.9	0.001
Change in step count (T2)	299.7	-95.9	695.3	0.137
Effect of sex (female)	1782.4	-1940.1	5504.9	0.346
Interaction:	706.1	-2567.6	3979.9	0.671
Male x gait speed				
Interaction:	-27.1	-1945.9	1891	0.977
Female x gait speed				

95% CI = 95% confidence interval; BMI, body mass index; FES-I, falls efficacy scale-international [33];

MoCA, Montreal Cognitive Assessment [34]; SPPB, Short Physical Performance Battery [29]. Results of LMM are presented; significant values are in bold

-315.8 – (-82.5), $p < 0.01$), and unrecovered falls (95% CI: -4,281.5 – (-1,027.0), $p = 0.003$) were associated with a decrease in average number of steps, but this effect was observed only in female participants (Table 2).

LMM – stepping time

Fall history (95% CI: -9.4 – (-1.6), $p = 0.005$), age (95% CI: -2.6 – (-1.2), $p < 0.01$), BMI (95% CI: -2.8 – (-0.5), $p = 0.003$), and unrecovered falls (95% CI: -37.7 – (-8.8), $p = 0.001$), were associated with a reduction in stepping time, whereas grip strength (95% CI: 0.4–2.0, $p = 0.002$) was associated with an increase in stepping time, specifically in female participants. Moreover, concerns about falling were negatively associated with stepping time for both male (95% CI: -6.0 – (-0.9), $p = 0.007$) and female individuals (95% CI: -4.5 – (-1.2), $p < 0.01$; Table 3).

LMM – sedentary time

For sedentary time, we could identify a positive association with fall history (95% CI: 1.0–10.2, $p = 0.016$), concerns about falling (95% CI: 2.5–25.9, $p = 0.017$), age (95% CI: 0.1–4.6, $p = 0.037$), BMI (95% CI: 2.7 – 9.1, $p < 0.01$), and unrecovered falls in female (95% CI: 12.4–100.7, $p = 0.012$), but not in male individuals (Table 4). Additionally, female participants exhibited a decrease in sedentary time by -54.1 min at T2 in comparison to male participants (95% CI: -96.8 – (-11.43), $p = 0.013$).

LMM – sit to stand transfer

A negative association between number of sit to stand transfer was found for BMI (95% CI: -0.8 – (-0.4), $p = 0.006$), but only for women (supplementary Table 1).

Main outcomes – LMM for self-reported PA

In contrast to sensor-based PA, we did not observe any changes in self-reported PA in older adults six months

after a severe fall ($p = 0.109$). For female participants, fall history (95% CI: -13.9 – (-0.1), $p = 0.047$) was negatively associated with self-reported PA, while physical function showed a positive association (95% CI: 0.4–3.5, $p = 0.01$). Concerns about falling (M: 95% CI: -11.2 – (-4.6), $p < 0.01$; W: 95% CI: -1.7 – (-1.7), $p < 0.01$), age (M: 95% CI: -4.6 – (-1.6), $p < 0.01$; W: 95% CI: -5.0 – (-2.7, $p < 0.01$), and unrecovered falls (M: 95% CI: -78.2 – (-19.0, $p = 0.001$; W: 95% CI: -48.2 – (-3.5), $p = 0.023$) were negatively associated. While cognition (M: 95% CI: 1.9–9.9, $p = 0.003$; W: 95% CI: 2.2–7.6, $p < 0.01$), and grip strength (M: 95% CI: 1.2–2.9, $p < 0.01$; W: 95% CI: 0.3–2.9, $p = 0.01$) were positively associated with self-reported PA in both, men and women (Table 5).

LMM for cut-off values – sensor-based PA

The analysis identified critical cut-off values for sensor-based PA. Female sex combined with an age of 70 years or older was associated with a significant increase in sedentary time by +43.5 min per day (95% CI: 0.5–86.6, $p = 0.04$). Additionally, female sex and an age of 66 years or older were linked to a significant decrease in the number of steps per day by -2,205.7 (95% CI: -4,062.6 – (-348.8), $p = 0.02$).

Female sex and a fall history of at least one fall significantly reduced stepping time by -18.7 min per day (95% CI: -33.5 – (-3.9), $p = 0.013$), and number of steps per day by -1,847.8 (95% CI: -3,341.7 – (-348.1), $p = 0.015$). Moreover, female sex and a fall history of at least one fall significantly increased sedentary time by +47.1 min per day (95% CI: 4.4–89.8, $p = 0.0310$).

LMM for cut-off values – self-reported PA

An age of 61 years and above, combined with sex, significantly reduced total time spent on PA by -128.4 min in male participants (95% CI: -216.1 – (-40.8), $p = 0.004$)

Table 3 Changes in stepping time and association with moderating factors six months after a fall

	Estimate	95% CI (lower)	95% CI (upper)	p value
Intercept	81.6	70.5	92.8	3.56x⁻³⁷
Change in stepping time (T2)	6.2	0.5	11.8	0.031
Effect of sex (female)	12.3	-2.0	26.6	0.092
Interaction:	1.1	-2.6	4.7	0.571
Male x fall history				
Interaction:	-5.5	-9.4	-1.6	0.005
Female x fall history				
Intercept	87.1	67.1	98.2	3.06x⁻⁴²
Change in stepping time (T2)	13.3	-0.4	27.1	0.057
Effect of sex (female)	2.1	-12.1	16.1	0.779
Interaction:	-5.6	-28.3	16.9	0.622
Male x depression				
Interaction:	-8.5	-25.4	8.3	0.318
Female x depression				
Intercept	103.2	43.1	163.3	< 0.01
Change in stepping time (T2)	5.5	-0.24	11.2	0.061
Effect of sex (female)	-63.6	-136.7	9.5	0.088
Interaction:	-0.8	-3.6	-3.4	0.540
Male x MoCA				
Interaction:	1.9	0.22	0.2	0.027
Female x MoCA				
Intercept	117.3	91.0	143.5	< 0.01
Change in stepping time (T2)	5.9	0.3	11.7	0.039
Effect of sex (female)	-3.2	34.8	28.4	0.842
Interaction:	-3.7	-6.0	-0.9	0.007
Male x FES-I				
Interaction:	-2.8	-4.5	-1.2	< 0.01
Female x FES-I				
Intercept	144.5	71.2	217.8	< 0.01
Change in stepping time (T2)	5.8	0.1	11.4	0.045
Effect of sex (female)	80.6	-11.4	172.7	0.085
Interaction:	-0.8	-1.7	0.2	0.100
Male x age				
Interaction:	-1.8	-2.6	-1.2	< 0.01
Female x age				
Intercept	129.1	79.4	178.8	< 0.01
Change in stepping time (T2)	5.9	0.3	11.6	0.039
Effect of sex (female)	2.1	-56.8	60.8	0.945
Interaction:	-1.6	-3.4	0.1	0.067
Male x BMI				
Interaction:	-1.6	-2.8	-0.5	0.003
Female x BMI				
Intercept	87.2	76.1	98.4	6.03x⁻⁴⁰
Change in stepping time (T2)	7.6	1.8	13.4	0.010
Effect of sex (female)	10.3	-5.5	26.1	0.200
Interaction:	-16.3	-34.9	2.4	0.087
Male x unrecovered falls				
Interaction:	-23.3	37.7	-8.8	0.001
Female x unrecovered falls				
Intercept	87.9	71.0	104.8	1.38x⁻²¹
Change in stepping time (T2)	9.7	-4.9	24.3	0.193
Effect of sex (female)	-1.8	-25.5	21.7	0.876
Interaction:	-0.1	-0.6	0.61	0.907
Male x SPPB				
Interaction:	0.22	-0.7	1.20	0.647
Female x SPPB				

Table 3 (continued)

	Estimate	95% CI (lower)	95% CI (upper)	p value
Intercept	74.9	58.7	91.2	<0.01
Change in stepping time (T2)	5.7	-0.1	11.4	0.050
Effect of sex (female)	-8.2	-30.0	13.7	0.463
Interaction:	0.4	-0.1	0.9	0.140
Male x grip strength				
Interaction:	1.2	0.4	2.0	0.002
Female x grip strength				
Intercept	77.7	51.9	103.5	<0.01
Change in stepping time (T2)	3.6	-1.3	8.6	0.146
Effect of sex (female)	5.8	-25.5	37.3	0.713
Interaction:	5.3	-19.8	30.6	0.677
Male x gait speed				
Interaction:	4.5	-12.8	21.9	0.607
Female x gait speed				

95% CI = 95% confidence interval; BMI, body mass index; FES-I, falls efficacy scale-international [33];

MoCA, Montreal Cognitive Assessment [34]; SPPB, Short Physical Performance Battery [29]. Results of LMM are presented; significant values are in bold

and by -89.4 min in female participants (95% CI: -158.0 – (-20.7), $p = 0.01$).

Discussion

Older adults increased their sensor-based PA by 545.8 steps per day and 6.2 min of stepping time six months after a severe fall, whereas self-reported PA remained unchanged. In female participants, moderating factors such as one or more falls within 12 months preceding the severe fall requiring ED care, advanced age (66 years and older), and unrecovered falls were associated with decreased sensor-based PA by -2,205.7 steps per day over time following the severe fall. Irrespective of sex, cognitive and physical function were positively associated with changes in self-reported PA, whereas concerns about falling and unrecovered falls negatively impacted it over time.

Sensor-based PA

In our study, participants increased their PA six months after a severe fall based on accelerometer data. These results contrast with findings by Jian-Yu and colleagues, who reported that individuals who experienced an injurious fall, decreased their PA after one year [15]. Notably, the study by Jian-Yu et al. included pre-fall PA data, enabling within-subject comparisons that are not possible in our analysis. This fundamental design difference limits the direct comparability of our findings. Moreover, their study population – individuals with glaucoma – represents a more specific subgroup at high-risk, whereas our cohort reflects a broader, more heterogeneous population of older adults presenting to the ED after a severe fall. Despite these differences, both studies underscore the importance of personalized interventions, as both pre-existing conditions and the fall event itself relevantly shape subsequent PA trajectories [8].

The discrepancy between the studies may also arise from differences in methodological approaches. Our study assessed participants within four weeks after a severe fall requiring ED presentation, whereas Jian-Yu and colleagues evaluated participants with Glaucoma once a year over the course of four years. The immediate assessment of PA in our study does not represent a true baseline measurement, as PA might be acutely reduced due to fall-related injuries and the recent severe fall itself [33]. Consequently, the observed increase in sensor-based PA six months after a fall may reflect either a recovery from an initial, short-term decline in activity following the fall that prompted inclusion in the SeFallIED study, or the possibility that some participants resumed activity immediately, despite experiencing fall-related consequences such as pain or concerns about falling. A decrease in PA during the first six months after a severe fall could be particularly concerning, as it may signal the onset of future functional decline. Therefore, the early identification of longitudinal changes in PA—along with key moderating risk factors—is crucial for preventing social isolation and activity avoidance in older adults at high risk of falling. While a reduction in PA may, in some cases, reflect a behavioral adaptation to increased perceived or actual fall risk, it may also signify the onset of social withdrawal and a decline in functional independence. This dual interpretation highlights the complexity of post-fall behavioral responses, particularly considering previous findings suggesting a U-shaped association between PA levels and fall risk exposure [36]. To address this, tailored interventions—such as supervised exercise or the use of mobility aids—can support safe and sustained engagement in physical activity.

Our results extend previous findings by shifting from a cross-sectional to a longitudinal perspective on moderating factors of PA in older adults following a severe fall.

Table 4 Changes in sedentary time and association with moderating factors six months after a fall

	Estimate	95% CI (lower)	95% CI (upper)	p value
Intercept	656.0	621.8	690.2	8.81×10^{-127}
Change in sedentary time (T2)	-15.1	-63.3	6.1	0.163
Effect of sex (female)	-54.1	-96.8	-11.3	0.013
Interaction:	5.3	-5.9	16.5	0.354
Male x fall history				
Interaction:	14.2	2.5	25.9	0.017
Female x fall history				
Intercept	659.3	628.4	690.2	1.31×10^{-141}
Change in sedentary time (T2)	-13.2	-34.3	7.8	0.217
Effect of sex (female)	-36.5	73.8	0.7	0.055
Interaction:	7.5	49.6	64.7	0.795
Male x depression				
Interaction:	-11.0	-54.8	32.7	0.619
Female x depression				
Intercept	606.6	414.7	798.4	< 0.01
Change in sedentary time (T2)	-17.9	-39.54	3.6	0.103
Effect of sex (female)	54.5	-172.0	280.9	0.636
Interaction:	2.6	-5.4	10.7	0.522
Male x MoCA				
Interaction:	-1.4	-6.4	3.5	0.573
Female x MoCA				
Intercept	627.1	551.5	706.7	4.91×10^{-45}
Change in sedentary time (T2)	-13.6	-35.0	7.8	0.214
Effect of sex (female)	-60.5	-150.9	29.8	0.188
Interaction:	4.1	-3.5	11.7	0.286
Male x FES-I				
Interaction:	5.6	1.0	10.2	0.016
Female x FES-I				
Intercept	564.9	346.5	783.3	< 0.01
Change in sedentary time (T2)	-14.5	-35.8	6.7	0.180
Effect of sex (female)	-117.8	-393.7	158.1	0.402
Interaction:	1.3	-1.5	4.7	0.361
Male x age				
Interaction:	2.4	0.1	4.6	0.037
Female x age				
Intercept	591.7	449.3	734.1	< 0.01
Change in sedentary time (T2)	-15.9	-37.3	5.4	0.142
Effect of sex (female)	-127.4	-295.7	40.8	0.137
Interaction:	2.7	-2.4	7.8	0.291
Male x BMI				
Interaction:	5.9	2.7	9.1	< 0.01
Female x BMI				
Intercept	648.7	613.7	638.8	3.62×10^{-114}
Change in sedentary time (T2)	-18.6	-40.1	2.8	0.089
Effect of sex (female)	-51.6	-100.1	-3.1	0.037
Interaction:	55.9	-0.06	111.8	0.050
Male x unrecovered falls				
Interaction:	56.5	12.4	100.7	0.012
Female x unrecovered falls				
Intercept	665.6	617.8	713.5	2.33×10^{-78}
Change in sedentary time (T2)	-10.2	-32.9	12.5	0.376
Effect of sex (female)	-29.9	-94.8	34.5	0.364
Interaction:	-0.1	-1.9	1.6	0.869
Male x SPPB				
Interaction:	-1.7	-4.4	0.8	0.189
Female x SPPB				

Table 4 (continued)

	Estimate	95% CI (lower)	95% CI (upper)	p value
Intercept	699.5	653.7	745.3	1.11x⁻⁹⁷
Change in sedentary time (T2)	-18.4	-39.6	2.7	0.087
Effect of sex (female)	-82.9	-144.3	-21.5	0.008
Interaction:	-1.4	-2.9	0.2	0.083
Male x grip strength				
Interaction:	0.3	-2.0	2.6	0.807
Female x grip strength				
Intercept	703.8	617.0	790.6	1.23x⁻⁴²
Change in sedentary time (T2)	-9.3	-30.1	11.5	0.379
Effect of sex (female)	-101.3	-202.3	-0.2	0.049
Interaction:	-44.9	-133.3	43.5	0.318
Male x gait speed				
Interaction:	15.9	-35.4	67.2	0.542
Female x gait speed				

95% CI = 95% confidence interval; BMI, body mass index; FES-I, falls efficacy scale-international [33];

MoCA, Montreal Cognitive Assessment [34]; SPPB, Short Physical Performance Battery [29]. Results of LMM are presented; significant values are in bold

However, future studies may benefit from repeated or extended monitoring periods to capture day-to-day fluctuations and provide more stable estimates of PA [37, 38]. While continuous monitoring using everyday wearable devices – such as smartphones, smartwatches or fitness trackers – is becoming increasingly feasible [39], these technologies currently lack the precision and clinical validity of research-grade tools. Therefore, their integration into clinical practice should be approached carefully.

Self-reported PA

While sensor-based PA increased, self-reported PA did not change for either male or female participants in our study. This discrepancy could be due to participants either not perceiving any impairments in PA, leading to an overestimation of PA at baseline, or underestimating their PA at follow-up. We speculate that overestimation at baseline is more likely, as older adults aged 65–84 years often overestimate their PA compared to sensor-based measured data. Previous studies have attributed this overestimation to social desirability response bias, where participants may exaggerate their PA due to the known benefits of PA and exercise [40, 41]. Furthermore, PA measured by a questionnaire represents a subjective estimation in a typical week. Therefore accuracy cannot be as high as data given by a sensor-based solution.

Moderating factors and sex-specific variations

In addition to consistent findings on advanced age [42], with 66 year identified as a critical cut-off in our sensor-based PA data, history of falls also emerged as a significant moderator. Given that a history of multiple falls has been identified as a significant risk factor for functional decline in the latest version of the global guidelines for falls prevention and management for older adults [8], it is important not only to confirm the initial fall that led

to the ED visit, but also to ask about previous falls within the past year. This information, which is often overlooked in acute care settings, provides critical insight into a patient's broader risk profile. Including a brief question about recent fall history is both time-efficient and easy to administer, and can help clinicians identify individuals who may benefit from targeted follow-up treatment [43, 44].

In our study, moderating factors in men were only associated with self-reported PA, while in women, they influenced both, self-reported and sensor-based PA. A previous study, which analyzed sex differences in PA, found that male participants, who experienced frequent falls significantly reduced their leisure activities (e.g., biking), and both light and heavy household chores (e.g., sweeping, washing windows) over time compared to those who fell less frequently or not at all. In contrast, women maintained similar levels of leisure activity and household work, showing no decline in PA. The authors proposed that women's engagement in these activities was not significantly affected by falls. Therefore, further differences between the PA assessments used in our study, may be explained by methodological variations.

Differences between sensor- and questionnaire-based PA

The ActivPal, used for sensor-based PA measurement, was attached to participants' right thighs and, thus, recorded only lower extremity movements. As a result, upper extremity activities, such as cooking or doing laundry, were not captured by the sensor, whereas these activities are included in the self-reported PA assessments. These discrepancies likely reflect the well-established divergence between self-reported and sensor-based methods of assessing PA, rather than indicating distinct types of PA. Self-reports are shaped by participants' perceptions, memory, and interpretation of what constitutes

Table 5 Changes in total time spent on PA (minutes) measured by PAQ-50+ [24] and association with moderating factors six months after a fall

	Estimate	95% CI (lower)	95% CI (upper)	p value
Intercept	109.4	90.2	128.6	1.11x⁻²⁵
Change in PAQ-50 + active (T2)	8.7	-1.9	19.3	0.109
Effect of sex (female)	-0.1	-24.6	24.5	0.996
Interaction:	-1.7	-8.3	4.9	0.623
Male x fall history				
Interaction:	-7.0	-13.9	-0.1	0.051
Female x fall history				
Intercept	109.4	92.7	126.1	4.49x⁻³³
Change in PAQ-50 + active (T2)	6.7	-2.9	16.7	0.172
Effect of sex (female)	-9.9	-30.2	10.3	0.333
Interaction:	-11.1	-42.6	20.3	0.486
Male x depression				
Interaction:	5.1	-19.7	30.1	0.682
Female x depression				
Intercept	-27.6	-120.7	56.4	0.559
Change in PAQ-50 + active (T2)	8.5	-2.28	19.3	0.121
Effect of sex (female)	9.8	-102.8	122.6	0.863
Interaction:	5.9	1.9	9.9	0.003
Male x MoCA				
Interaction:	4.9	2.2	7.6	< 0.010
Female x MoCA				
Intercept	138.2	148.0	218.4	3.55x⁻²²
Change in PAQ-50 + active (T2)	8.1	-2.5	18.7	0.135
Effect of sex (female)	-41.5	-86.6	3.5	0.070
Interaction:	-7.9	11.2	-4.6	< 0.010
Male x FES-I				
Interaction:	-4.3	-1.7	-1.7	< 0.010
Female x FES-I				
Intercept	339.6	229.3	449.8	< 0.010
Change in PAQ-50 + active (T2)	9.3	-1.3	19.8	0.086
Effect of sex (female)	51.3	-89.1	191.7	0.472
Interaction:	-3.1	-4.6	-1.6	< 0.010
Male x age				
Interaction:	-3.9	-5.0	-2.7	< 0.010
Female x age				
Intercept	135.3	49.8	220.7	0.001
Change in PAQ-50 + active (T2)	9.0	-1.6	19.7	0.095
Effect of sex (female)	-16.3	-116.4	83.7	0.748
Interaction:	-1.0	-4.0	2.0	0.511
Male x BMI				
Interaction:	-0.7	-2.6	1.1	0.419
Female x BMI				
Intercept	119.7	101.6	137.9	3.29x⁻³²
Change in PAQ-50 + active (T2)	10.1	0.3	19.8	0.444
Effect of sex (female)	-8.3	-33.1	16.6	0.513
Interaction:	-84.6	-78.2	-19.0	0.001
Male x unrecovered falls				
Interaction:	-25.8	-48.2	-3.5	0.023
Female x unrecovered falls				
Intercept	109.3	84.2	134.5	< 0.010
Change in PAQ-50 + active (T2)	8.6	-1.9	19.4	0.108
Effect of sex (female)	-34.9	-69.3	-0.6	0.046
Interaction:	0.1	-0.9	1.1	0.881
Male x SPPB				

Table 5 (continued)

	Estimate	95% CI (lower)	95% CI (upper)	p value
Interaction:	1.9	0.4	3.5	0.010
Female x SPPB				
Intercept	53.9	26.6	81.3	<0.010
Change in PAQ-50 + active (T2)	10.1	-0.7	20.8	0.067
Effect of sex (female)	15.4	-21.3	25.1	0.409
Interaction:	2.1	1.2	2.9	<0.010
Male x grip strength				
Interaction:	1.6	0.3	2.9	0.010
Female x grip strength				
Intercept	121.6	77.5	165.7	<0.010
Change in PAQ-50 + active (T2)	6.0	-4.8	16.9	0.278
Effect of sex (female)	-16.8	-66.9	33.1	0.507
Interaction:	-12.8	-54.4	28.7	0.545
Male x gait speed				
Interaction:	-7.4	-27.4	12.5	0.464
Female x speed				

95% CI = 95% confidence interval; BMI, body mass index; FES-I, falls efficacy scale-international [33];

MoCA, Montreal Cognitive Assessment [34]; SPPB, Short Physical Performance Battery [29]. Results of LMM are presented; significant values are in bold

activity, and are often influenced by social desirability or cognitive bias. In contrast, sensor-based data provide an objective account of movement patterns, but lack contextual nuance and may overlook activities perceived as meaningful by individuals. Rather than suggesting one method is inherently more valid, these findings underscore that the two approaches capture different facets of the same behavioral construct. This distinction is particularly important when assessing older adults, where subjective and objective experiences of PA may diverge due to mobility limitations, fall-related concerns, or cognitive factors. Therefore, both assessment types should be interpreted within their methodological contexts, and their combined use may offer a more comprehensive understanding of PA in clinical and research settings [45].

These differences in PA assessment, and in both men and women may explain some of the findings of our study and highlight the importance of considering sex when assessing PA after a fall. Besides sex, future analyses should also consider factors such as the living situation (e.g., living alone or with a relative) [46] and socioeconomic status [47] of an individual, as these may influence PA engagement post-fall, according to previous research.

To evaluate the impact of sensor-based versus questionnaire-based changes in PA on post-fall sequelae, PA assessments should be integrated with direct measurements of functional capacity over an extended observation period. This approach could enable future research to yield deeper insights into the distinct dimensions of PA and their respective utility in understanding post-fall recovery mechanisms in older adults.

Limitations

Given that fewer men than women were recruited in our study, it is important to increase sample sizes in future research, particularly when aiming to identify moderators specific to men. Additionally, extending the follow-up period beyond six months is warranted to gain further insights into the long-term effects and trajectories of PA and related factors in this population. Another limitation of this study was the presence of incomplete datasets, which restricted the statistical analysis and precluded the use of a comprehensive hierarchical model. This was primarily due to the acute aftereffects of the fall and unforeseen challenges during data collection in participants' home environments. Future studies should therefore aim to collect more complete and standardized datasets to enable more robust analytical approaches, including advanced variable selection procedures and multivariable modeling strategies. Moreover, the four-week interval before the first assessment was deliberately chosen to give individuals time to recover sufficiently to participate in a home visit, while still aiming to capture early post-fall behavioral adaptations. Although home visits were ideally scheduled within one week after the ED presentation, logistical and ethical considerations made flexibility necessary. As different time intervals may have influenced PA levels, future studies should consider more frequent and repeated assessments to better account for recovery trajectories and temporal variability in real-world clinical care settings. Although our inclusion criteria were intentionally broad to capture a heterogeneous and realistic population, this diversity may limit the precision of subgroup estimated and generalizability to more narrowly defined populations. Specifically, some participants with cognitive impairment were enrolled with the support of

caregivers or family members. Despite this proxy assistance, self-reported data remain vulnerable to recall and social desirability biases, which may have influenced the accuracy of the reported outcomes. Lastly, the observed change in sensor-based physical activity of 545.8 steps per day six months after a fall lies below reported lower-bound minimal clinically important differences of ~800 steps per day in a study with individuals with multiple sclerosis [34]. Given the demographic and clinical differences between populations, the applicability of this threshold is limited. Future studies should aim to define minimal clinically important differences specific for older adults following a severe fall with ED presentation.

Conclusion

Early identification of moderating factors associated with changes in PA in adults aged 60 years and above may help stratify individuals according to risk and identify those who require further treatment and prevent functional decline. Our findings identified a cut-off age of 66 years and a history of one or more previous falls as significant moderators in females for a reduction of PA. Additionally, unrecovered falls, diminished physical function and concerns about falling should also be considered as early warning signs for both male and female older adults after a severe fall. While our study offers initial insights into moderating factors influencing PA following a severe fall, the exploratory design and limited sample size preclude definitive recommendations for changes in routine ED care. Nonetheless, our findings highlight potential clinical relevance – particularly regarding early identification of high-risk individuals who may benefit from referral to specialized falls clinics for further comprehensive assessments and targeted falls prevention strategies. Future studies with larger populations are needed to validate these results and further explore sex-specific differences in PA trajectories. Feasibility studies should also assess how such approaches could be implemented into clinical workflows and identify barriers and facilitators to integration.

Abbreviations

PA	Physical activity
ED	Emergency Department
IQR	Interquartile Range
PAQ-50+	Physical Activity Questionnaire-50+
MoCA	Montreal Cognitive Assessment
DIA-S	Depression in Old Age Scale
SPPB	Short Physical Performance Battery
FES-I	Short falls efficacy scale-international
BMI	Body Mass Index
LMM	Linear Mixed Model
95% CI	95% confidence interval

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions

T.Z. and T.S. were responsible for conceptualization. T.Z. and T.S. were responsible for the investigation. L.H. and T.S. carried out data curation. L.H., T.S., and R.K. performed the formal analysis. L.H. and T.S. wrote the original draft of the manuscript and were responsible for visualization, while R.K. and T.Z. reviewed and edited the manuscript. All authors have read and approved the final version of the manuscript and agreed with the order of presentation of the authors.

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Data availability

The dataset used and analyzed during the current study will be made available by the corresponding author upon reasonable request. As public availability would compromise patient privacy, storing the data in a public repository is not possible. However, upon request and after approval by the local ethics board, it may be made available. To receive data, please contact the corresponding author.

Declarations

Ethical approval and consent to participate

The authors state that their research was conducted ethically in accordance with the Declaration of Helsinki. This study was approved and reviewed by the Medical Ethics Committee of the University of Oldenburg, approval number 2021–120. The participants or their legal guardian or family member provided their written informed consent to participate in the study.

Consent for publication

Not applicable in this section.

STROBE statement

The study adheres to STROBE guidelines and a checklist is available in supplement section.

Competing interests

The authors declare no competing interests.

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