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Changes in physical activity and sedentary behaviour following geriatric rehabilitation in older adults with stroke

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Abstract

Background Older adults recovering from stroke engage in low levels of physical activity and spend long periods in sedentary behaviour. Sedentary behaviour during geriatric rehabilitation is still poorly understood. The aims of this study were to quantify physical activity, sedentary behaviour and accompanying patterns of change during geriatric rehabilitation.

Methods Older adults (≥ 70 years) recovering from stroke in geriatric rehabilitation were included in this prospective cohort study. Patients wore an inertial measurement unit (IMU) on the ankle for 48 h, with data collected between 7am and 11 pm. Variables related to physical activity, sedentary behaviour and patterns of sedentary behaviour were calculated and analysed. Extracted principal components on admission and discharge were plotted in order to assess the individual degree of change.

Results In total, 53 patients with sufficient accelerometer wear time were included. The degree of change in physical activity and sedentary behaviour components was extremely diverse. Except for step count ($P = 0.01$), no significant changes were observed in any variable related to physical activity, sedentary behaviour or patterns of sedentary behaviour between admission and discharge.

Conclusions Older adults recovering from stroke during geriatric rehabilitation improve their functional performance, but show little change in physical activity, sedentary behaviour or patterns of sedentary behaviour. The degree of change in physical activity and sedentary behaviour was highly diverse.

Keywords Geriatric rehabilitation, Physical activity, Sedentary behaviour, Accelerometer, Stroke

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Introduction

The incidence of stroke among older adults is rising swiftly as the world's population ages [1]. Following stroke, older adults often face ongoing challenges such as functional or emotional issues, cognitive decline and fatigue [2]. Geriatric rehabilitation plays a vital role in the recovery of independence of older adults following stroke. Geriatric rehabilitation is a multidimensional approach comprising diagnostic and therapeutic interventions that focus on optimizing functional capacity, promoting activity and preserving functional reserves and social participation in older people with disabling impairments [3].

While promoting physical activity is a key concept during geriatric rehabilitation, several studies have reported that, post-stroke, many older adults engage in very low levels of physical activity and spend prolonged periods in sedentary behaviour [4, 5]. Physical activity, often categorized by intensity, refers to any body movement that raises energy expenditure above resting levels [6]. Sedentary behaviour is defined as behaviour resulting in energy expenditure ≤ 1.5 metabolic equivalents (METs) while in a sitting, reclining or lying posture [7]. High levels of sedentary behaviour are associated with a reduction in muscle mass and strength [8], increased risk of falls [9] and even mortality [10]. Recent studies have suggested that interrupting sedentary time with light activity is associated with better health indicators (e.g., cardiometabolic risk profile), which in turn could reduce the risk of recurrent stroke [11]. Therefore, gaining accurate insights into physical activity and sedentary behaviour during geriatric rehabilitation is crucial.

Most studies that have evaluated changes in sedentary behaviour during geriatric rehabilitation have concentrated on total sedentary time [12, 13]. However, as prolonged sedentary behaviour poses health risks regardless of total sedentary time, research has recently shifted focus to patterns of sedentary behaviour, as represented in the length and distribution of sedentary bouts [14]. The main advantage of this approach is its sensitivity when quantifying changes in sedentary behaviour, providing more robust insight into whether an intervention is effective [14, 15].

Finally, older adults recovering from stroke during geriatric rehabilitation are unlikely to represent a homogeneous group. Instead, they may exhibit diverse changes in physical activity and sedentary behaviour. A better understanding of the individual degree of change may contribute to the development of more effective, tailored interventions aimed at increasing physical activity and reducing prolonged sedentary bouts. Therefore, the primary goals of this study were to (1) quantify physical activity and sedentary behaviour, (2) Asses the difference in physical activity and sedentary behaviour between admission and discharge from geriatric rehabilitation (3) asses the individual patterns of change in physical activity and sedentary behaviour during geriatric rehabilitation.

Methods

Design and population

For this prospective cohort study, participants were recruited at four geriatric rehabilitation centres in the Netherlands between September 2020 and December 2022. All participants were older adults (≥ 65 years) recovering from stroke and undergoing geriatric rehabilitation. Eligible participants were able to comprehend and sign the informed consent, were capable of understanding and performing simple tasks. Participants were excluded if they were medically unstable. All participants gave written informed consent. The Medical Ethical Review Committee of Utrecht approved the protocol (20–462/C). Data were collected by physiotherapists and transferred to the researchers as anonymized data untraceable to any individual person.

Assessments

Baseline characteristics assessed upon admission comprised age, sex, body mass index (BMI), time since stroke, type of stroke and hemiparetic side. The following assessments were registered at both admission and discharge: Activities of Daily Living functioning (ADL) were measured using the Barthel index (range 0–20, higher scores indicate a better ADL performance) [16], while balance was assessed using the Trunk Control Test (range 0–100, assesses trunk motor performance, consisting of three movement items and unsupported sitting) [17]. Ambulation mobility was evaluated using Functional Ambulation Categories (ranges from 0: non-functional walking to 5: independent walking outside) [18] and the USER subscale 'mobility', which consists of seven items (sitting, standing, transfers, indoor walking, outdoor walking, climbing stairs, wheelchair riding). Each item is scored on a 6-point scale (0–5) reflecting different grades of independence, use of aids and difficulty [19]. Balance was assessed every three weeks using the Berg Balance scale (range, 0–56, higher scores indicate a better balance) [20].

Movement variables

In addition to clinical instruments, physical activity and sedentary behaviour were quantified using an inertial measurement unit (IMU) (manufactured by Aemics b.v. Oldenzaal, The Netherlands). The IMU consisted of a triaxial accelerometer and gyroscope, which was placed above the unaffected lateral ankle. Movement variables included in this study were mainly derived from previous studies on this topic [14] and are described in further detail in Table 1.

Data collection and wear time

Data were collected in the first week after stroke (T0). Subsequent data collection (T1 to T3) occurred every third consecutive week, thus three, six-, and at discharge. The time of admission and discharge could differ between patients. Patients were instructed to wear the IMU on their ankle during the day for two consecutive days in each measurement period. As we aimed to

Table 1 Types of movement variables

Movement variables	
Steps	Total steps per 2 days (mean steps/2 days)
Light activities	Time spent in light activities (mean hours/2 days)
Moderate activities	Time spent in moderate activities (mean hours/2 days)
Sedentary behaviour variables	
Sedentary behaviour	A minimal duration of 1 min or higher in consecutive lying or sitting (mean hours/2 days)
Pattern of sedentary behaviour variables	
Sedentary bouts	A continuous period of sedentary time, with a minimal length of at least one minute (mean number bouts/2 days)
Sedentary breaks	The period between two sedentary bouts. An interruption in sedentary behaviour, such as standing or walking, with a minimal duration of 1 min (mean number breaks/2 days)
Half-life bout duration (W50%)	A weighted median bout duration in which the bout duration above and below half of all sedentary time is accumulated. Provides a good indication of centrality given the distribution of bout length (minutes) [15, 21]
Alpha	A scaling parameter that provides an indication of the distribution of sedentary bouts. A lower alpha indicates that sedentary time largely accumulates in long bouts (unit-less variable) [21]
Gini Index	A standardised statistic for comparing patterns of accumulation. This coefficient ranges from 0 to 1. A G index of 1 indicates that all of the sedentary time is attributable to a very small proportion of the longest sedentary bouts. Conversely a G = 0 indicates that all sedentary bouts length contribute equally to the total sedentary time [21]

capture the majority of daily activities, we included measurements lasting at least 10 h per day, as recommended [22]. Additionally, measurements were restricted to 7 AM and 11PM to avoid sleep periods.

Statistical analysis

Normality of data was tested using the Shapiro–Wilk test. Differences between patient characteristics and movement variables were evaluated using paired t-test paired for normally distributed data and are presented as means with standard deviations (±). The Wilcoxon signed-rank test was used for non-normally distributed data, which are presented as medians with interquartile ranges (IQR). Statistical analyses were performed using SPSS 25.0.

To assess the degree of change of physical activity and sedentary behaviour during geriatric rehabilitation, we analysed data from patients who had measurements on both admission and discharge. We then conducted a one-way ANOVA for normally distributed data and the Kruskal–Wallis test for non-normally distributed data to determine whether there was a significant difference in movement variables (described in Table 1) between admission and discharge. If the data exhibited a normal distribution at one measurement point and a non-normal distribution at another, the Mann–Whitney U test was used. In order to assess the individual patterns of change in physical activity, sedentary behaviour and sedentary behaviour patterns during geriatric rehabilitation, a principal component analysis (PCA) was performed to reduce the number of dimensions of the included movement variables (described in Table 1) while maintaining maximum information [23]. Prior to analysis, the Keiser-Meyer-Olkin (KMO) measure was used to assess the suitability of the overall PCA model. Individual movement variables with at least one correlation coefficient greater than 0.3 and a (KMO) measure greater than 0.6 were included in the PCA (Statistics, 2015). Components with eigenvalue ≥ 1 were used for extraction. The extracted components on admission and discharge were plotted to gain insight into the individual degree of change during geriatric rehabilitation.

Results

Of the 79 eligible patients, 53 had at least two IMU measurements of 10 h and were included in the study. Patient characteristics are described in detail in Table 2. Among the 53 patients, 42 had both admission and discharge measurements and could be included in the analysis of assessments and movement variables between admission and discharge.

Movement variables

Movement variables per measurement are described in Table 3. Visualization of percentage sedentary behaviour, light activities and moderate activities per measurement point are presented in Fig. 1.

Change of SB and PA during geriatric rehabilitation

In total, 42 patients were included in the analysis regarding assessments and movement variables between admission and discharge. The mean wear time was 13.8 (SD 1.7) hours. Differences in assessments and

Table 2 Baseline general characteristics (Mean ± SD, Median (IQR))

Characteristics	All patients (n = 53)	Admission – discharge[a] (n = 42)
Age (y)	77.7 ± 9.9	76.6 ± 9.9
Sex, male (%)	28 (52%)	22 (52%)
BMI (kg/m2)	25.9 (21.5–28.0)	24.7 (22.6–28.0)
Type of stroke		
Ischemic	43 (80%)	33 (79%)
Haemorrhagic	10 (18%)	8 (19%)
Subarachnoid	1 (2%)	1 (2%)
Hemiparetic side		
Left	25 (46%)	19 (45%)
Right	18 (33%)	13 (31%)
Both sides	2 (4%)	2 (4%)
Other	9 (17%)	8 (19%)
Time since stroke (days)	16.0 (12–20)	15.0 (12–21)
Length of stay rehabilitation (days)	35.0 (26.6–62.0)	35.5 (27.2–61.5)
Barthel Index	11.7 ± 4.4	11.7 ± 4.2
Berg Balance scale	37 (22.5–48.0)	38.0 (22.0–49.3)
Trunk Control Test	100 (87–100)	100 (93.5–100)
Functional ambulation classification		
Non ambulatory (FAC 0)	8 (15%)	6 (14%)
Dependent (FAC 1–3)	22 (42%)	16 (37%)
Independent (FAC 4–5)	20 (38%)	17 (40%)
USER mobility	17.1 ± 8.9	16.4 ± 8.4

USER Utrecht Scale for Evaluation of Rehabilitation, *FAC* Functional Ambulation Classification

[a] Patients in the group admission—discharge had an IMU measurement both at admission and discharge

Table 3 Movement variables per measurement point (Mean(SD) ±, Median IQR)

	T0 n = 35	T1 n = 25	T2 n = 22	T3 n = 17
Physical activity variables				
Steps (mean hours/2 days)	2068 (1191–2791)	1268 (868–3507)	2519 (1485–3345)	2561 (966–5053)
Light activities (mean hours/2 days)	2.5 (1.6–3.4)	3.3 (2.4–4.1)	2.7 (2.2–3.8)	2.9 (2.4–4.2)
Moderate activities (mean hours/2 days)	0.5 (0.3–0.8)	0.7 (0.3–1.1)	0.5 (0.4–1.1)	0.6 (0.2–1.0)
Sedentary behaviour variables				
Sedentary behaviour (mean hours/2 days)	10.2 (9.1–11.6)	9.6 (7.3–10.9)	11.0 (9.5–12.0)	10.8 (9.3–11.5)
Pattern of Sedentary behaviour variables				
Sedentary breaks (mean number breaks/2 days)	71.5 ± 28.2	86.4 ± 26.6	79.5 ± 23.9	79.9 ± 22.1
Half-life bout duration (mean minutes/2 days)	25.0 (15.0–36.0)	21.0 (11.5–27.5)	22.0 (14.5–30.2)	21.0 (16.5–37.0)
Alpha	1.6 ± 0.1	1.6 ± 0.1	1.6 ± 0.1	1.6 ± 0.1
Gini	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1

[a] T0 – T3: first week after stroke (T0). Subsequent data collections (T1 to T3) occurred every three consecutive weeks: three, six-, and nine-weeks post-stroke

movement variables between admission and discharge are shown in Table 4. Except for the Trunk Control test (P = 0.21), all assessments significantly improved between admission and discharge. Regarding movement variables, except for steps (P = 0.01) and moderate activities (P = 0.05), no significant change was

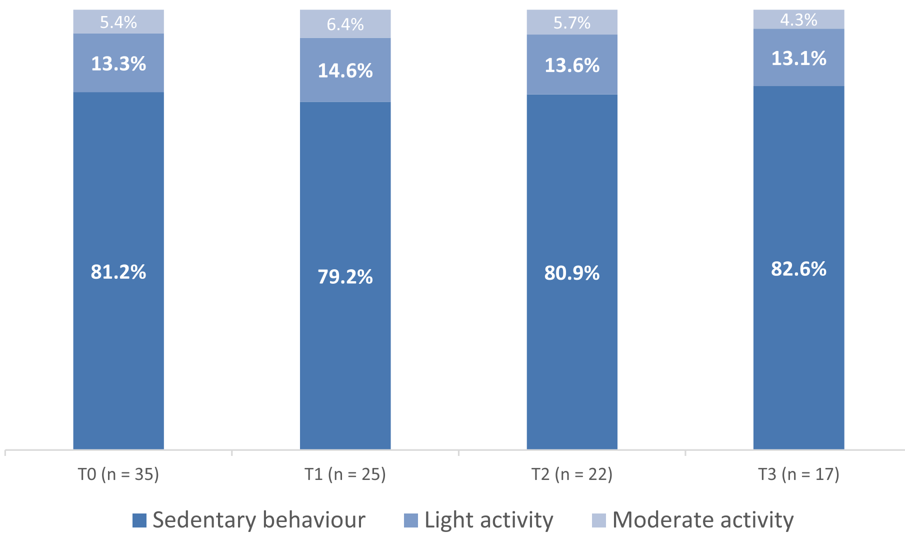

Fig. 1 Levels of physical activity and sedentary behaviour. *T0 – T3: first week after stroke (T0). Subsequent data collections (T1 to T3) occurred every three consecutive weeks: three, six-, and nine-weeks post-stroke

Table 4 Differences in assessments and movement variables between admission and discharge (Mean ±, Median (IQR))

n = 42	Admission	Discharge	*P*
Assessment			
Barthel index	11.5 ± 4.9	15 ± 7.1	0.01
Berg Balance scale	38 (22–38)	49.5 (41.8–54.0)	< 0.01
Trunk Control Test	100 (93–100)	100 (100–100)	0.21
Functional ambulation classification	3 (2–4)	5 (4–5)	< 0.01
USER mobility	17 ± 9.4	31 (25.5–34)	< 0.01
Physical activity variables			
Steps (mean steps/2 days)	1863 (919—2650)	2705 (1606–3968)	0.02
Light activities (mean hours/2 days)	2.6 (1.7–3.5)	3.0 (2.2–3.8)	0.27
Moderate activities (mean hours/2 days)	0.5 (0.2–0.9)	0.6 (0.3–1.0)	0.05
Sedentary behaviour variables			
Sedentary behaviour (mean hours/2 days)	10.3 (8.9–11.7)	10.6 (7.6–11.4)	0.46
Pattern of sedentary behaviour variables			
Sedentary breaks (mean number breaks/2 days)	75.1 ± 27.6	77.4 ± 25.9	0.57
Half-life bout duration (mean minutes/2 days)	26.5 (14.8–35.3)	22.5 (14.5–30.3)	0.09
Alpha	1.6 ± 0.1	1.6 ± 0.9	0.94
Gini	0.5 ± 0.7	0.5 ± 0.7	0.08

USER Utrecht Scale for Evaluation of Rehabilitation

observed in any movement variable or sedentary pattern variable.

Patterns of change in PA and SB during geriatric rehabilitation

PCA revealed two components that had eigenvalues ≥ 1 and which together explained 66% of the total variance. The other 34% percent was distributed among eight components. The Kaiser–Meyer–Olkin for the complete PCA model was 0.74, indicating that the model was middling (Kaiser, 1974). The first component (accounting for 52% of variance) mostly included movement variables related to physical activity, and exhibited strong positive loadings for mean steps per two days, mean time spent in light activities, mean time spent in moderate activities, (more) sedentary breaks, and alpha (indicating sedentary time is largely spent in smaller bouts). Negative loadings were observed for the mean time spent in sedentary behavior and half-life bout duration (W50%). Higher values on the physical activity component indicate more active behaviour. The second component (14% variance) included movement variables related to sedentary behaviour, and showed strong positive loadings for mean time spent in sedentary behaviour, number of sedentary bouts ≥ 60 min per day, Gini Index, and half-life bout duration (W50%), with negative loadings for sedentary breaks. Higher values on the sedentary behaviour component indicate more sedentary behaviour. A plot of component loadings is visualized in Figure A1 (additional file 1). Scatterplots depicting the change in extracted physical activity and sedentary behaviour components between admission and discharge are shown in Figs. 2 and 3. The scatterplots for both components depict a highly heterogeneous degree of change in physical activity and sedentary behaviour during geriatric rehabilitation.

Discussion

Principal findings

In this study of older adults recovering from stroke during geriatric rehabilitation, our three main findings were:

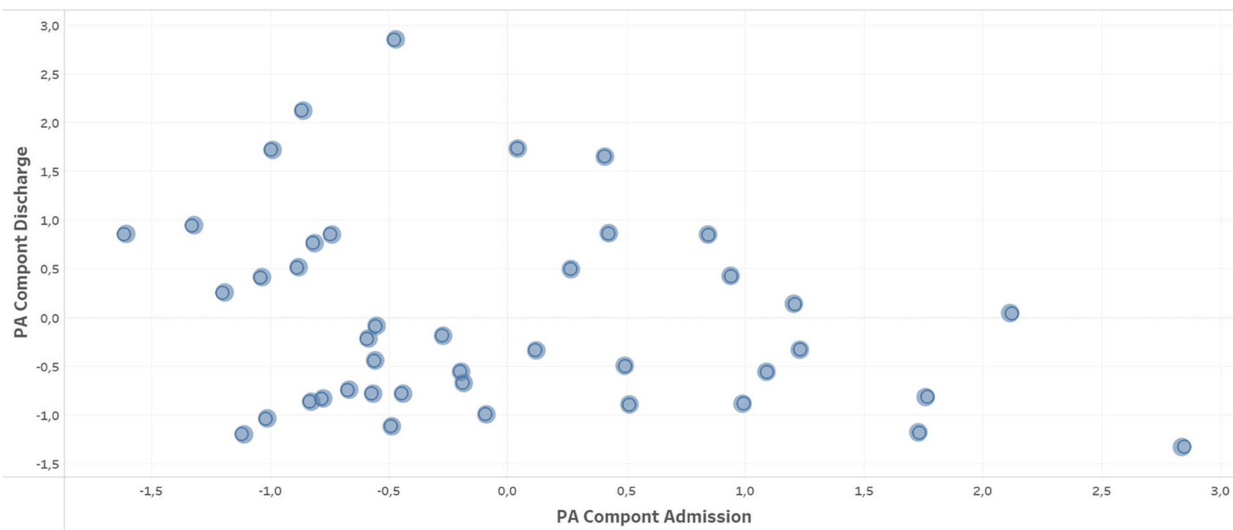

Fig. 2 Difference in physical activity component scores between admission and discharge. PA: Physical activity. Higher values on the physical activity component indicate more active behaviour

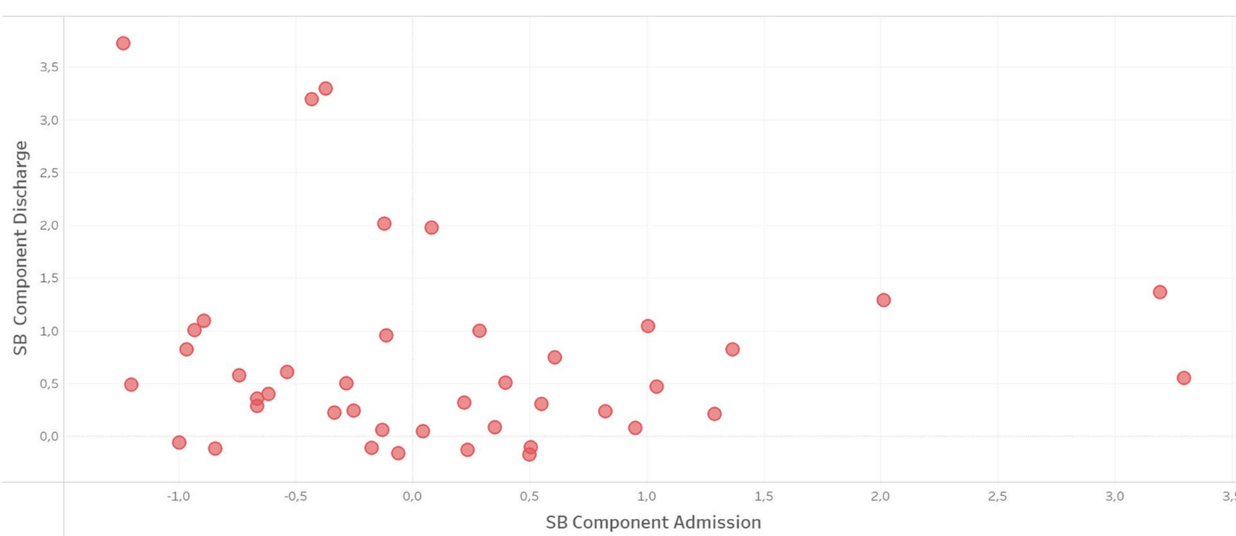

Fig. 3 Difference in sedentary behaviour component scores between admission and discharge. SB: sedentary behaviour. Higher values on the sedentary behaviour component indicate more sedentary behaviour

1) in this group most waking hours were spent in sedentary behaviour, 2) there was little change in physical activity and no change in sedentary behaviour or patterns of sedentary behaviour despite improvements in functional performance, and 3) the degree of change in physical activity and sedentary behaviour was highly diverse.

Comparison with previous studies

Utilizing accelerometery data, we found that older adults recovering from stroke spend approximately 80% of their waking hours in sedentary behaviour. Although our study focused on older adults after stroke, prior studies investigating sedentary behaviour during geriatric rehabilitation have reported similar findings, indicating that older adults tend to allocate a significant portion of their time to sedentary behaviour. Rojer et al. [13] reported sedentary behaviour averaging 23 h per day in older adults with various diagnoses, while Taylor et al. [24] documented a mean time of 22.3 h per day spent in sedentary behaviour among older adults recovering from hip fracture. Both studies included sleep time in their classification of sedentary behaviour. By contrast, our study aimed to minimize the impact of sleep by restricting the analysis to data recorded between 7 AM and 11 PM. This difference in methodology unquestionably influenced our results, with the observed amount of sedentary behaviour in our study being notably lower than that reported in the studies of Rojer et al. [13] and Taylor et al. [24].

We observed significant differences in step count and moderate activities between admission and discharge, whereas no significant differences were found in light activities. As step counts incorporate both light and moderate-to-vigorous physical activity [25], a reasonable interpretation is that older adults recovering from stroke devoted a substantial proportion of steps to moderate rather than light activity. Finally, older adults recovering from stroke often demonstrate an improvement in walking speed throughout the rehabilitation process, achieving more steps in the same amount of time. This improvement in walking speed typically results in a classification of moderate physical activity due to increased amplitude and acceleration [26].

Although significant changes in functional performance were observed between admission and discharge, no differences were found in variables related to sedentary behaviour. While the improved functional performance typically achieved during geriatric rehabilitation might be expected to reduce sedentary behaviour, those recovering from stroke do not consistently exhibit the expected change in behaviour, suggesting that sedentary behaviour is not solely dependent on improvements in functional performance. Previously, researchers identified several barriers that may hamper improvements in sedentary behaviour such as fatigue, lack of knowledge, lack of motivation or fear of falling [27, 28]. Utilizing theory-based behaviour change techniques, coupled with a gradual stepwise approach that addresses prolonged sedentary behaviour, might potentially overcome these barriers [29]. Moreover, most multidisciplinary rehabilitation programs primarily emphasize the promotion of physical activity, with insufficient attention devoted to addressing and reducing sedentary behaviour [30].

To our knowledge, this is the first study to evaluate the degree of change in physical activity and sedentary behaviour among post-stroke older adults during inpatient geriatric rehabilitation. We found highly heterogeneous changes in physical activity and sedentary behaviour during geriatric rehabilitation, with significant variation between individuals, particularly in terms of physical activity, and to a lesser extent, sedentary behaviour. These results support the observed differences between admission and discharge, which were characterized by small changes in physical activity and no changes in sedentary behaviour or patterns of sedentary behaviour.

Strength and limitations

A strength of this study was the use of an IMU to objectively assess physical activity, sedentary behaviour and the pattern of sedentary behaviour, with positioning at the ankle facilitating accurate assessment of posture and transitions. However, while data were only included if patients wore the IMU for at least 10 h during 2 days, this time period is a potential limitation, particularly regarding variables related to patterns of sedentary behaviour, where we observed little variability. While excluding data between 23:00 p.m. and 7:00 a.m. likely eliminated most sleep data, precisely differentiating sedentary behaviour from sleep was another limitation that may have impacted our results. Lastly, the small sample size may limit the generalizability of the results to the broader population of older stroke survivors in geriatric rehabilitation.

Implications for clinical practice and future research

One important conclusion that can be drawn from the current study is that each patient should be individually assessed at multiple time points when deploying interventions aimed at increasing physical activity and reducing sedentary behaviour. Accurate quantification of physical activity and sedentary behaviour through utilization of wearable sensors can aid understanding of each patient's unique digital phenotype [31], and facilitate the development of rehabilitation interventions tailored to improve physical activity and reduce sedentary behaviour.

Conclusion

In geriatric rehabilitation, older adults recovering from stroke devote a considerable amount of time to sedentary behaviour. Despite improvements in functional performance and physical activity, sedentary behaviour and patterns of sedentary behaviour did not change during geriatric rehabilitation. Furthermore, the degree of change in physical activity and sedentary behaviour during geriatric rehabilitation is highly diverse, particularly in physical activity and, to a lesser extent, sedentary behaviour.

We therefore recommend that multidisciplinary rehabilitation programs place greater emphasis on sedentary behaviour, not only though promotion of physical activity, but also through interventions aimed at reducing sedentary behaviour. These interventions should include use of wearable sensors to accurately quantify physical activity and sedentary behaviour, allowing interventions to be tailored to each patient's unique digital phenotype, and should also incorporate theory-based behaviour change techniques.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-025-06007-3.

Additional file 1: Figure A1. Loadings of the variables included in the principal component.

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Authors' contributions

J.J.M.K., M.P. and E.F.V.D.v.I. conceptualized the study. J.J.M.K. prepared the original draft and the visualization of data. J.J.M.K and M.P. conducted the analysis. All authors reviewed the draft and provided feedback. All authors have read and agreed to the published version of the manuscript.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The Medical Ethical Review Committee of Utrecht approved the protocol (20–462/C). All participants gave written informed consent. The study was performed in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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