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ORIGINAL RESEARCH

Physical Activity and Sedentary Behavior From Discharge to 1 Year After Inpatient Rehabilitation in Ambulatory People With Spinal Cord Injury: A Longitudinal Cohort Study

Check for updates

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Abstract

Objective: To evaluate changes in duration of physical activity (PA) and sedentary behavior (SB) from discharge to 1 year after inpatient rehabilitation in ambulatory people with spinal cord injury (SCI).

Design: Longitudinal cohort study with objective measurements of physical behavior at discharge and at 6 and 12 months post discharge.

Setting: Three rehabilitation centers and the participant's home environment.

Participants: Participants (N=47) with ambulatory function were consecutively recruited from the self-management and self-efficacy in patients with SCI cohort (age 18 years or older, recent SCI, expected inpatient stay ≥4wk). Mean age was 54.5±12.9 years, all had incomplete lesions, 53% were men, 49% had tetraplegia, and 51% were community ambulators at discharge.

Interventions: Not applicable.

Main Outcome Measures: Duration (min) of PA (summed duration of walking, cycling, running, and wheeling) and SB (sitting/lying).

Results: Mean duration of PA increased by 21 min/d (95% confidence interval, 7-35) and SB decreased by 64 min/d (95% confidence interval, −94 to −35) from discharge to 6 months after inpatient rehabilitation. No changes were found in the second half-year. One year after discharge mean PA was 116±59 min/d and mean SB was 665±121 min/d. The increase in PA was the result of an almost doubling of time spent walking. Variability in physical behavior and its change was large. Older age and lower ambulation level were associated with lower PA, lower ambulation level with higher SB, and tetraplegia was associated with a reduced increase in PA.

Conclusions: At group level, duration of PA and SB improved following inpatient rehabilitation in ambulatory people with SCI. However, there were large differences between individuals. Levels 1 year after discharge were still unfavorable, particularly regarding SB.

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In the general population, higher levels of physical activity (PA) are associated with lower mortality and better health and well-being.[1-3] There are strong indications that this also applies to people with spinal cord injury (SCI).[2,4-8] However, research in people with SCI who depend on a wheelchair for their mobility shows that their levels of PA are extremely low not only compared

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with able-bodied people but also compared with people with other chronic conditions.[9-11] The early period after discharge from inpatient rehabilitation might be crucial in adapting a more active lifestyle because it has been found that, while PA increases during inpatient rehabilitation, it tends to decline shortly afterward.[12] This decline showed to be preventable with a behavioral intervention focusing on an active lifestyle.[13]

In recent years the number of people who regain ambulatory function after SCI has been increasing. Whether PA levels also decline shortly after inpatient rehabilitation in this subpopulation is unknown. Zbogar et al showed that objectively measured PA increased during inpatient rehabilitation, but this study did not evaluate the period after discharge.[14] One would expect ambulatory people with SCI to be more active than wheelchair users because of to their higher functional capacity. However, the scarce literature on PA in the ambulatory subpopulation suggests inactivity in the chronic phase as well.[15-19] Nevertheless, current literature reports on leisure time PA or stepping only, and the majority of findings are based on self-report measurements. Objective information on the course of all daily PA after inpatient rehabilitation can help optimize rehabilitation practice and lead to recommendations to improve activity and health in individuals with SCI.

Besides PA level, other aspects of physical behavior may be important.[20-22] That is, evidence is growing that reducing sedentary behavior (SB) (ie, any sitting or lying behavior with low energy expenditure during waking time)[23] and increasing light activities (such as standing) is favorable regarding health and mortality.[24,25] Also the distribution of PA and SB over the day may be important.[26,27] Furthermore, the type of activity (eg, walking or wheeling) may play a role in recovery of physical functioning, fitness, well-being, and participation in society.

Following the above, the primary aim of this study was to objectively evaluate changes in duration of PA and SB from discharge to 1 year after inpatient rehabilitation in ambulatory people with SCI. Secondary, we evaluated changes in duration of standing, separate types of PA, distribution of PA and SB, and walking intensity. Finally, we studied possible predictors of low PA and high SB and of unfavorable change (decrease in PA levels and/or increase in SB levels).

Methods

This multicenter longitudinal cohort study, titled ActivWalkS[ci], is an extension of the self-management and self-efficacy in patients with SCI (SELF-SCI) study.[28] Measurements were performed within 2 weeks prior to discharge from the inpatient setting and at 6 months and 1 year post discharge.

Participants

Participants were recruited from 3 Dutch rehabilitation centers: Rijndam Rehabilitation (Rotterdam), De Hoogstraat Rehabilitation (Utrecht), and Rehabilitation Center Sint Maartenskliniek (Nijmegen). Inclusion criteria for SELF-SCI were age of 18 years or older, admission for inpatient rehabilitation with a clinically confirmed diagnosis of recent SCI, and an expected stay ≥4 weeks.[28] Exclusion criteria were limited life expectancy, language barrier, or severe cognitive or intellectual limitations. Participants were eligible for inclusion to the ActivWalkS[ci] study if they had acquired any walking capacity and were expected to use this capacity in their home environment after discharge from inpatient rehabilitation. This expectation was based on the experience of the treating physical therapist and was set 4 weeks prior to discharge. Based on similar research in manual wheelchair users, we aimed to include 45 participants.[12] The Medical Ethical Committee of Erasmus MC (Rotterdam, The Netherlands) reviewed the study protocol (MEC-2016-072) and concluded that this study was not within the scope of the Dutch Medical Research Involving Human Subjects Act. The study conformed to the Helsinki Declaration and was approved by all participating rehabilitation centers. All participants gave their written informed consent before entering the study.

List of abbreviations:

PA	physical activity
SCI	spinal cord injury
SELF-SCI	self-management and self-efficacy in patients with SCI
SB	sedentary behavior
TSI	time since injury

Physical activity and sedentary behavior

Physical behavior, comprising both PA and SB,[22] was objectively measured with Activ8 sensor(s)[a] set to store data in 30-second epochs. An Activ8 sensor contains a triaxial accelerometer and converts raw data (12.5Hz) automatically into classes of body postures and movements: sitting/lying, standing, walking, cycling, and running.[29] In the present study 1 waterproofed Activ8 sensor was attached with skin-friendly foil to the front of the upper thigh, allowing participants to perform all their activities, including bathing, swimming, and sports, as usual. Validity of this configuration has been demonstrated in people with gait impairments.[30-32]

In participants who used also a manual wheelchair, an additional Activ8 sensor attached to the wheel was used. Output of this sensor was used to detect wheeling (with a wheelchair or handcycle, using arm[s] and/or leg[s]). Activities causing only minor wheel movements, such as changing position in place, were classified as maneuvering. The detection method of wheeling and maneuvering was based on the previous development of the Activ8 wheelchair monitor and showed excellent validity for detecting different forms of wheeling.[33,34]

Participants were asked to continue measurements for 7 consecutive days without disconnecting the sensor at night. Going to sleep, wake-up time, nonwear time, use of full motor assist, being pushed in the wheelchair (not at all, <50%, ≥50% of the wheeling time), and unusual events such as illness were reported in a diary.

Data processing

Digitalized data from the diary and Activ8 sensor(s) were downloaded to a PC and processed using a custom-made MATLAB[b] program. Data during waking hours (wake up to going to sleep with exclusion of nonwear time) were analyzed when at least 4 valid days (≥11h of data and no illness) were available.[35] Output of the wheel sensor was neglected on days that people reported passive wheeling (use of full motor assist or being pushed ≥50% of the wheeling time) because this could not be distinguished from active wheeling.

The primary outcome measures were the duration (min) of PA (summed duration of walking, cycling, running, and wheeling) and SB (sitting/lying). Secondary outcome measures were duration of separate types of PA, duration of standing and maneuvering, duration of prolonged active and sedentary bouts, PA and SB fragmentation indexes (measures for distribution), and walking intensity (counts/min). Prolonged bouts and fragmentation indexes were automatically calculated following predetermined processing rules (appendix 1). All outcome measures were averaged per day.

Participants' characteristics

Demographic and lesion characteristics were derived from the SELF-SCI database.[28] Ambulation level was self-reported based on the modified Hoffer-scale: (1) fully wheelchair-bound; (2) walking only during therapy; (3) walking indoors; wheelchair-use necessary for all activities outdoors; (4) walking independently outdoors with or without assistive devices; wheelchair-use only necessary for long distances; and (5) walking outdoors without assistive devices; no wheelchair-use.[36] People scoring classes 1-3 were considered noncommunity ambulators and those scoring classes 4 and 5 community ambulators.

Statistical analysis

All statistical analyses were performed with SPSS version 24.[c] Level of significance was set at $P = .05$. Because the majority of data were normally distributed, outcomes are expressed as mean ± SD. To compare characteristics between participants and eligible people who were not included (nonparticipants) and between people with complete data sets and people with missing data we used independent Student t tests (continuous data) and chi-square tests (categorical data).

Generalized estimating equation analysis with an exchangeable correlation structure was used to study changes over time. Separate models were made for each outcome measure with the measurement time points (as factor time) entered as independent variables. Although the season of the year is known to influence level of PA,[37] analyses showed no effect on change in PA and SB. Therefore, and because measurements were spread evenly over the year, models were not corrected for season.

To identify predictors of low PA and high SB, we added baseline characteristics (sex, age, tetraplegia/paraplegia, traumatic/nontraumatic cause, time since injury [TSI], and community/noncommunity ambulators) 1 by 1 as covariates to the models of PA and SB. The interaction between these

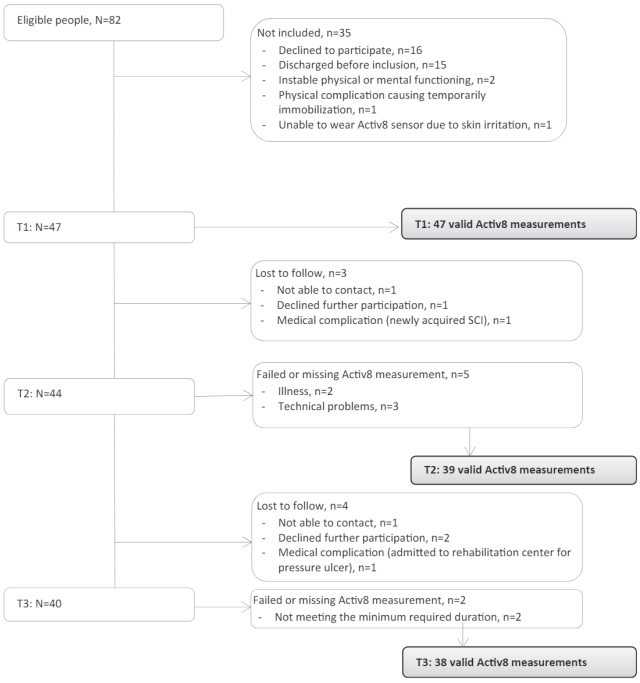

Fig 1 Flowchart inclusion.

Table 1 Characteristics at discharge from inpatient rehabilitation (n=47)

Variables	Values
Men, n (%)	25 (53.2)
Age (y), mean ± SD	54.5±12.9
Lesion level, tetraplegia, n (%)	23 (48.9)
Tetraplegia AIS C, n (%)	1 (2.1)
Tetraplegia AIS D, n (%)	22 (46.8)
Paraplegia AIS C, n (%)	3 (6.4)
Paraplegia AIS D, n (%)	21 (44.7)
Traumatic cause of SCI, n (%)	22 (46.8)
Time since injury (d), mean ± SD	89.6±36.0
Ambulation level, n (%)*	
Noncommunity ambulators	23 (48.9)
Nonambulator	1 (2.1)
Exercise ambulator	8 (17.0)
Household ambulator	14 (29.8)
Community ambulators	24 (51.1)
Community ambulator	18 (38.3)
Normal ambulator	6 (12.8)

Abbreviation: AIS, American Spinal Injury Association Impairment Scale.
* Self-reported ambulation level based on the modified Hoffer scale.

characteristic and time was added to identify predictors of unfavorable change.

Results

Between January 2016 and October 2017, a total of 47 people were included (fig 1). Demographics and lesion characteristics of the participants (table 1) did not differ from those of the nonparticipants. Ambulation level was equally divided into noncommunity and community ambulators (see table 1). In total, 124 of 141 (88%) planned Activ8 measurements were used for analysis. The majority of these measurements lasted 6 or 7 days (95%). People with 1 (n=7) or 2 (n=5) missing measurements did not differ significantly in demographic and lesion characteristics from people with 3 measurements. In 9 measurements, the output of the wheel sensor was neglected at 1 or more days because of reported passive wheeling (18d in total).

Observed outcomes at each time point are presented in table 2. The duration of PA and SB changed between discharge and 6 months later by 21 min/d ($P=.004$) and −64 min/d ($P<.001$), respectively; it remained stable in the second half year (table 3). Regarding separate types of activity, the duration of walking and standing increased in the first half year, while wheeling and maneuvering decreased. Walking intensity was the only outcome that increased in the second half year. Duration of running, cycling, prolonged bouts, and fragmentation indexes did not change over time.

The largest proportion of PA consisted of walking and this increased over time from 60% to 84% (observed data), while the proportion of wheeling decreased from 24% to 3%. In addition, the number of people who spent time wheeling decreased from 31 people (65%; mean duration, 32.2±16.9min/d) to 7 people (18%; mean duration, 20.5±13.8min/d).

The SDs and 95% confidence intervals presented in tables 2 and 3 show that there were large differences between individuals at each time point and in change over time. To illustrate this, the duration of PA ranged between 10 and 258 min/d 1 year after inpatient rehabilitation, and 8 people (21%) were active <60 min/d. The change between discharge from inpatient rehabilitation and 1 year later

Table 2 Observed outcomes at each measurement time point

Variables	Discharge From Inpatient Rehabilitation (N=47)	6 mo Post Discharge (n=39)	1 y Post Discharge (n=38)
Waking time (min/d)*	891.0±50.5	904.0±44.2	913.3±52.6
Duration measures			
Physical activity (min/d)†	88.7±36.1	112.4±61.6	116.0±59.2
Walking (min/d)	53.6±39.1	92.6±61.8	96.9±59.1
Running (min/d)	0.3±1.1	0.3±1.9	0.4±1.5
Cycling (min/d)	13.6±8.0	15.0±14.0	15.0±11.8
Wheeling (min/d)‡	21.2±20.6	4.6±11.3	3.8±4.9
Standing (min/d)	65.1±41.5	127.1±76.3	130.9±71.3
Maneuvering (min/d)‡	4.7±4.9	1.8±4.1	1.4±3.6
Sedentary behavior (min/d)	732.4±81.9	662.8±129.5	665.0±121.3
Distribution measures			
Prolonged (>10min) active bouts (min/d)‡	12.9±11.5	13.0±14.2	12.1±12.7
Prolonged (>30min) sedentary bouts (min/d)‡	455.4±132.6	426.3±157.1	420.2±156.1
Physical activity fragmentation index§	0.22±0.07	0.23±0.08	0.25±0.08
Sedentary behavior fragmentation index§	0.04±0.01	0.04±0.01	0.04±0.01
Intensity measure			
Walking intensity (counts/min)	1255.6±268.1	1270.0±221.2	1334.3 ±235.0

NOTE. Data are presented as mean ± SD.
* Time between self-reported wake up and going to sleep with exclusion of nonwear time.
† Summed duration of walking, running, cycling, and wheeling.
‡ These outcomes were not normally distributed.
§ Active or sedentary bouts divided by total time active or sedentary bouts. A higher fragmentation index indicates that time is more fragmented with shorter periods of uninterrupted PA or SB.

Table 3 Results of longitudinal generalized estimating equation analysis (124 data points)

	Discharge to 6 mo Post Discharge				6 mo to 1 y Post Discharge				Discharge to 1 y Post Discharge			
Variables	β	95% CI		*P* Value	β	95% CI		*P* Value	β	95% CI		*P* Value
Waking time*	12.7	−1.7	27.0	.084	9.9	−2.8	22.5	.128	22.5	8.4	36.6	.002†
Duration measures												
Physical activity‡	20.9	6.8	35.0	.004†	4.7	−8.1	17.4	.473	25.5	10.5	40.6	.001†
Walking	35.7	19.5	51.8	<.001†	5.3	−6.9	17.4	.396	40.9	24.6	57.2	<.001†
Running	0.1	−0.5	0.6	.834	0.0	−0.1	0.2	.664	0.1	−0.3	0.5	.671
Cycling	1.1	−3.2	5.3	.622	−0.6	−4.2	2.9	.731	0.4	−3.3	4.1	.818
Wheeling	−16.2	−21.7	−10.7	<.001†	−0.1	−2.3	2.0	.894	−16.3	−21.7	−11.0	<.001†
Standing	58.5	41.1	75.9	<.001†	2.9	−14.8	20.6	.749	61.4	41.7	81.1	<.001†
Maneuvering	−2.7	−3.8	−1.7	<.001†	−0.1	−0.6	0.4	.695	−2.8	−3.9	−1.7	<.001†
Sedentary behavior	−64.1	−93.5	−34.7	<.001†	2.5	−26.6	31.7	.864	−61.6	−92.9	−30.2	<.001†
Distribution measures												
Prolonged (>10min) active bouts	−0.22	−4.81	4.37	.924	−1.09	−5.24	3.05	.606	−1.31	−6.17	3.54	.596
Prolonged (>30min) sedentary bouts	−22.88	−61.08	15.33	.241	−8.48	−47.81	30.85	.673	−31.36	−75.13	12.41	.160
Physical activity fragmentation index§	0.011	−0.013	0.035	.378	0.016	−0.006	0.038	.159	0.027	−0.005	0.058	.095
Sedentary behavior fragmentation index‖	−0.001	−0.005	0.002	.515	0.001	−0.003	0.005	.680	0.000	−0.005	0.004	.860
Intensity measure												
Walking intensity	−1.8	−60.2	56.6	.951	68.4	19.6	117.2	.006†	66.6	1.9	131.2	.044†

Abbreviation: CI, confidence interval.

* Time between self-reported wake up and going to sleep with exclusion of nonwear time.

† $P<.05$.

‡ Summed duration of walking, running, cycling, and wheeling.

§ Active or sedentary bouts divided by total time active or sedentary bouts. A higher fragmentation index indicates that time is more fragmented with shorter periods of uninterrupted PA or SB.

Table 4 Associated factors ($P<.10$) of physical activity and sedentary behavior

	Physical Activity				Sedentary Behavior			
Independent Variables	β	95% CI		*P* Value	β	95% CI		*P* Value
Ambulation level (community ambulator)	38.2	12.4	53.9	.002	−108.5	−155.6	−61.3	<.001
Age at discharge (y)	−1.2	−2.1	−0.3	.006	1.8	−0.1	3.6	.059
Time since injury (d)	−0.3	−0.6	0.0	.075	0.6	−0.1	1.3	.092
Interaction lesion level (paraplegia) × time (t1-t3)	29.2	1.0	57.4	.043	−37.5	−99.8	24.8	.238
Interaction time since injury (d) × time (t1-t2)	−0.4	−0.7	−0.1	.003	0.7	0.0	1.4	.048

Abbreviations: CI, confidence interval; t1, discharge; t2, 6 mo post discharge; t3, 1 y post discharge.

ranged between −45 and 184 min/d; in 12 people (32%) PA declined.

Ambulation level, age, interaction between lesion level and time, and interaction between TSI and time were significantly ($P<.05$) associated with PA; ambulation level and interaction between TSI and time were significantly ($P<.05$) associated with SB. No associations were found for sex and cause of lesion. Associations with $P<.10$ are presented in table 4 and illustrated graphically with dichotomized variables in figure 2.

Discussion

To our knowledge, this is the first study that objectively and comprehensively evaluated physical behavior and its changes from discharge to 1 year after inpatient rehabilitation in ambulatory people with SCI. Mean duration of PA increased by 21 min/d from discharge to 6 months post discharge; duration of SB in this period decreased by 64 min/d. In the second half year PA and SB remained stable. The increase in PA was the result of an almost doubling of time spent walking. Although PA and SB improved at group level, variation between individuals was large.

The average increase in PA after inpatient rehabilitation found in this study contrasts with the large decline in PA described previously in manual wheelchair users with SCI measured with a device based on similar principles as the Activ8.[12] Ambulatory people with SCI seem to be better able to maintain and expand their level of PA once they are at home. Their ability to stand and walk, even when limited, may facilitate engaging in regular daily activities such as self-care and household chores, and they may not experience the same limitations because of transportation and accessibility issues as wheelchair users.[38] Furthermore, functional recovery may have continued after discharge because all participants had motor incomplete lesions and the mean TSI at discharge was relatively short.

The differences between individuals in PA and SB and its changes were large. Some individuals seemed to improve well while others did not. Explorative analysis suggests that age and ambulation level are predictors of physical behavior, such that older people are at increased risk of low PA and noncommunity ambulators are at increased risk of low PA and high SB. Additionally, lesion level seems to affect the degree of change, such that PA in people with paraplegia increases more than in people with tetraplegia. TSI seems to affect the degree of change short-term, but not long-term. The latter suggests that early discharge may not have a negative effect on the long-term outcome.

Besides an increased duration of PA in the first half year after discharge, there was a clear shift in type of PA. That is, walking duration increased largely while duration of wheeling declined. Interestingly, walking intensity was the only outcome measure that changed in the second half year after discharge. These findings suggest that walking continued to improve over a long period after inpatient rehabilitation, first in duration followed by changes in speed. Notably, not all participants who ended up with little time walking continued wheeling. Several of these persons used passive modes of mobility, such as powered wheelchairs and scootmobiles.

Comparison between studies concerning physical behavior needs to be done with caution because different measurement instruments and protocols can cause large variations in results.[39,40] Nevertheless, results of the present study strongly suggest that ambulatory people with SCI in the chronic phase are, as a group, more active than manual wheelchair users with SCI (116 vs 49min/d 1y after inpatient rehabilitation as measured with devices based on similar principles).[12] This is in agreement with findings in an older (>50y) population with SCI[15] but contrasts with other populations with SCI.[16,17] However, these studies used different measurement instruments (self-reported), reported on leisure-time PA only, included people many years post injury, and defined "ambulatory" differently. SB 1 year after inpatient rehabilitation (665min/d) was comparable with manual wheelchair users with chronic SCI studied by Montesinos-Magraner et al (631min/d)[7] but lower than a similar group studied by Ferri-Caruana et al (778min/d).[11]

Compared to able-bodied people measured with similar devices as the Activ8, our participants seem to spend less time on PA (116 vs 140-173min/d).[41,42] Because stabilization in the second half year after discharge suggests that further improvement cannot be expected, our findings confirm previous conclusions of inactive lifestyles (based on step counts only) in ambulatory people with SCI in the chronic phase.[18,19] Current knowledge concerning the dose-response relationship between PA and health does not provide an optimal PA level. Previous research in able-bodied people shows that more is better and that small increases in the least active individuals may be beneficial.[2,3] Whether this also applies to people with gait impairments, such as in SCI, is unknown. Their energy cost and physiological strain during PA is probably higher, and therefore, overburdening may become a risk.[43] Nevertheless, our findings underline the importance of addressing PA in ambulatory people with SCI.[6]

Outcomes on SB were even more unfavorable in our participants (665 vs 474-519min/d in able-bodied people).[41,44] In the general population, a duration of ≥540 min/d is associated with increased risk of all-cause mortality.[24] In addition, the duration of prolonged sedentary bouts and SB fragmentation index suggest that SB was largely accumulated in long periods of uninterrupted sitting/lying, a pattern that is believed to be unfavorable for health.[26,27] Therefore, SB is, as in wheelchair users,[11] of great concern in ambulatory people with SCI.

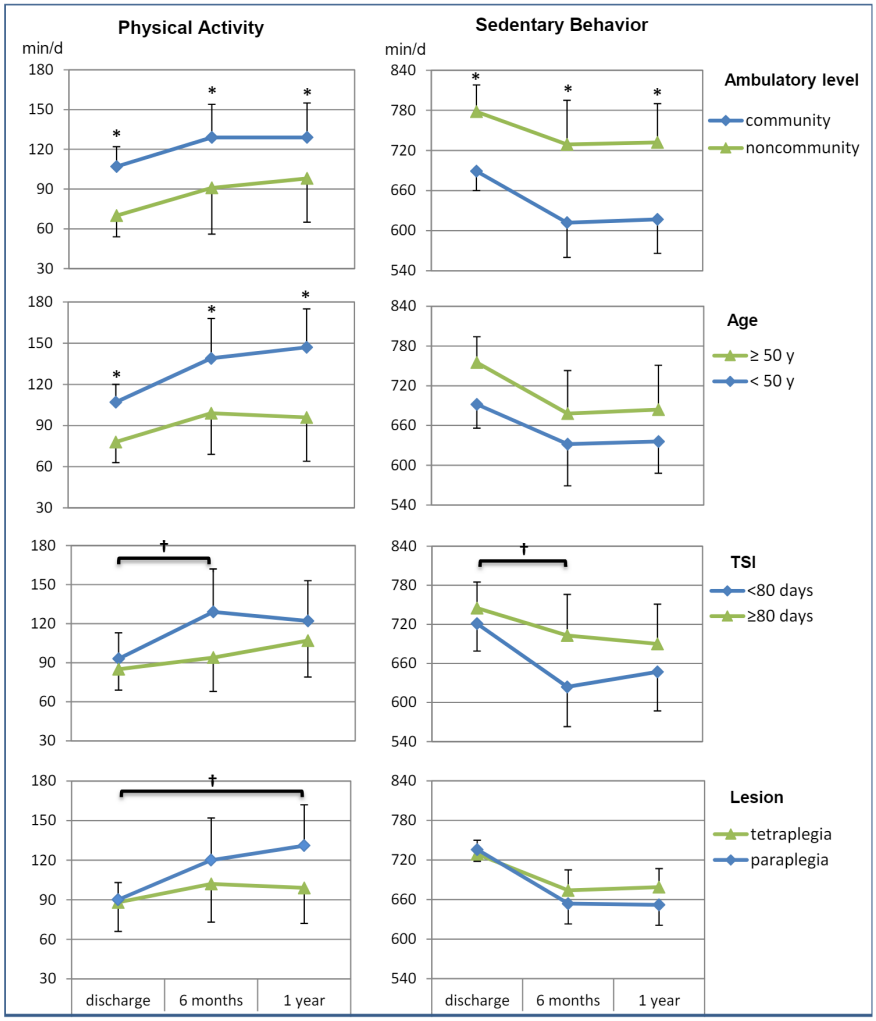

Fig 2 Graphic illustration of the association between PA/SB and covariates. *Significant cross-sectional differences ($P<.05$). †Significant difference in change over time ($P<.05$).

Study limitations

Physical behavior was measured objectively and longitudinally in a population that has, so far, been rather underexposed. Furthermore, measurements focused on several aspects of physical behavior. Because of the continuous wear protocol and the waterproofed fixation, little information was lost, and activities during self-care and swimming were also captured.

The study also has limitations. First, the sample size was limited and not all participants performed all 3 measurements. However, comparison between participants with complete data sets vs participants with missing data suggests that drop out was random. Second, device-based measurements may influence natural behavior. However, we expect that the influence of reactivity was small because wearing the Activ8 caused little burden, people received precise information and feedback only after the last measurement, and measurements lasted relatively long.

Clinical implications and future research

It is important that clinicians are aware of the risk of low PA and high SB in people with SCI, not only in manual wheelchair users but also in ambulatory individuals. Particularly people with advanced age, lower ambulation level, and tetraplegia may need special attention. Adding regular objective measurements to rehabilitation treatment may help identify individuals with unfavorable changes in physical behavior, increase awareness, and provide information to tailor interventions to promote a healthy lifestyle. As suggested by Manns et al, an approach focusing on reducing SB by increasing regular low intensive activities of daily life may be the best way to start in the most impaired individuals.[25] Additionally, choices concerning passive modes of mobility may have to be reevaluated or counterbalanced by other means of being active.

Future research in ambulatory people with SCI should focus on the dose-response relation between accelerometer-based measures of physical behavior on the one hand and functioning, well-being, health, and mortality on the other. Particular focus should be on which aspects of physical behavior (duration, type of activity, distribution, intensity) determine favorable outcome and which factors (physical as well as psychological) are of influence. Moreover, long-term (>1y post injury) physical behavior needs to be evaluated. This will ultimately lead to better treatment regarding physical behavior for the growing population of ambulatory people with SCI.

Conclusions

On average the duration of PA and SB improved between discharge to 1 year after inpatient rehabilitation in this group of ambulatory people with SCI. However, levels 1 year after discharge seem unfavorable, particularly regarding SB. There were large differences between individuals. Older age, lower ambulation level, and tetraplegia seem to predict unfavorable outcome.

Suppliers

a. Activ8, 2M Engineering Ltd.
b. MATLAB, MathWorks.
c. SPSS, IBM.

Keywords

Exercise; Physical activity; Rehabilitation; Sedentary behavior; Spinal cord injuries; Walking

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Appendix 1 Data Processing Rules for Determining Duration of Prolonged Bouts and Fragmentation Indexes

Description of data processing steps
Step 1: Pairs of 30-s epochs are merged into 1-min epochs. A 1-min epoch is identified as follows:
- Active: ie, ≥80% of time spent walking, running, cycling, or wheeling;
- Sedentary: ie, ≥90% of time spent sitting/lying;
- Neutral: ie, time intervals that are neither active nor sedentary.
Step 2: Subsequent active 1-min epochs are defined as an active bout. If active bouts are interrupted by a neutral 1-min epoch of which at least 70% of the time consists of walking, running, cycling, or wheeling, this neutral epoch is ignored and not considered as interruption of 2 active bouts.
Similarly, sedentary bouts being interrupted by 1-min neutral epochs of which at least 80% of the total bout duration consists of sitting/lying are defined as 1 sedentary bout.
Outcome measures:
Duration of prolonged active bouts = active bouts ≥10 min
Duration of prolonged sedentary bouts = sedentary bouts ≥30 min
PA fragmentation index = no. of active bouts divided by total time active bouts
SB fragmentation index = no. of sedentary bouts divided by total time sedentary bouts

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