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Physical activity based on daily steps in patients with chronic musculoskeletal pain: evolution and associated factors

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Abstract

Background People with chronic musculoskeletal pain (CMSP) often have low physical activity. Various factors can influence the activity level. The aim of this study was to monitor physical activity, assessed by the number of steps per day, over time in people with CMSP and identify factors that could be associated with this activity feature.

Methods This prospective study involved people undergoing rehabilitation following an orthopedic trauma that had led to CMSP. At entry, participants completed self-reported questionnaires assessing pain, anxiety, depression, catastrophyzing, kinesiophobia, and behavioural activity patterns (avoidance, pacing and overdoing). They also underwent functional tests, assessing walking endurance and physical fitness. To determine daily step counts, participants wore an accelerometer for 1 week during rehabilitation and 3 months post-rehabilitation. The number of steps per day was compared among three time points: weekend of rehabilitation (an estimate of pre-rehabilitation activity; T1), weekdays of rehabilitation (T2), and post-rehabilitation (T3). Linear regression models were used to analyze the association between daily steps at T2 and at T3 and self-reported and performance-based parameters.

Results Data from 145 participants were analyzed. The mean number of steps was significantly higher during T2 than T1 and T3 (7323 [3047] vs. 4782 [2689], $p < 0.001$, Cohen's d = 0.769, and 4757 [2680], $p < 0.001$, Cohen's d = 0.693), whereas T1 and T3 results were similar ($p = 0.92$, Cohen's d = 0.008). Correlations of number of steps per day among time points were low ($r \leq 0.4$). Multivariable regression models revealed an association between daily steps at T2 and pain interfering with walking, anxiety and overdoing behaviour. Daily steps at T3 were associated with overdoing behaviour and physical fitness.

Conclusions Despite chronic pain, people in rehabilitation after an orthopedic trauma increased their physical activity if they were given incentives to do so. When these incentives disappeared, most people returned to their previous activity levels. A multimodal follow-up approach could include both therapeutic and environmental incentives to help maintain physical activity in this population.

Keywords Chronic musculoskeletal pain, Daily steps, Accelerometry, Patterns of activity measure-Pain (POAM-P), Overdoing, Avoidance, Pacing, 6-min walk test, Steep ramp test

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Background

Interdisciplinary rehabilitation with a biopsychosocial approach is recommended for individuals with chronic musculoskeletal pain (CMSP), particularly those whose condition does not respond to initial therapies [1]. Studies have shown that this approach, which includes physical activity (PA), therapeutic education, and cognitive-behavioural therapy, has positive effects on short and long-term pain intensity and disability. Additionally, it increases the likelihood of returning to work in the long term [1–6].

According to the World Health Organization definition, PA refers to any bodily movement produced by skeletal muscles that requires energy expenditure. This activity includes all movement during leisure time, transport to and from places, and activities related to a person's work [7, 8]. Although the results of studies are conflicting, in general, people with chronic pain have low PA levels [9–12]. Therefore, encouraging people with CMSP to be more active, in order to approach the WHO recommendations, and thus reduce the risks associated with a sedentary lifestyle and showing promise on health benefit [7], seems a desirable goal of care.

Walking is an activity common to all domains of physical activity - work, home life, transport, and leisure - and is therefore a good way of assessing PA [13]. Accelerometers are frequently used to objectively assess walking. The raw data can be transformed into various units, including the number of steps taken. Daily step is a widely used outcome that describes walking behaviour [14, 15]. It is associated with important health outcomes, including all-cause mortality [16].

In a previous study [17], we showed that people with CMSP walked less at home before starting an inpatient rehabilitation program than during the rehabilitation period. We also showed that weekend days during rehabilitation, which were days off, could be used as a proxy for pre-rehabilitation activity levels. However, limited information exists regarding the monitoring of PA after discharge from rehabilitation.

The primary objective of this study was to monitor PA, expressed as number of steps per day, over time (weekend during rehabilitation, weekdays during rehabilitation, post-rehabilitation phase) in CMSP individuals undergoing an interdisciplinary inpatient rehabilitation program. We hypothesized that three months after rehabilitation, the activity level would decrease because of reduced walking incentives but would remain higher than activity during a weekend of rehabilitation. The secondary aim was to explore associations between the number of daily steps and various factors. These items included self-reported factors such as pain severity and interference, anxious and depressive symptoms, fear of movement, catastrophic thoughts, pain behaviour patterns, and also performance-based factors such as walking endurance and physical fitness. We hypothesized that individuals with more favorable profiles of these factors during rehabilitation would have higher levels of walking activity. Lastly, we aimed to determine whether these factors could also predict the activity level at 3 months post-rehabilitation. We hypothesized that the variables associated with rehabilitation would also play a role in predicting the number of steps taken after completing the rehabilitation program.

Methods

Study design and setting

This was a prospective monocentric study with longitudinal follow-up conducted at the Department of Musculoskeletal Rehabilitation, which is specialized in caring for people with CMSP and persistent disability, in a Swiss rehabilitation center.

Participants

All participants were referred to the rehabilitation clinic by general practitioners, surgeons or insurance medical advisors because of unfavourable progression of their condition, preventing them from resuming their professional activities. They were admitted to an interdisciplinary inpatient rehabilitation program after an orthopedic trauma resulting from work, traffic, sport, or leisure accidents. Orthopedic trauma typically refers to an injury caused by an external force. These injuries occur in the musculoskeletal system, including bones, cartilage, joints, ligaments, muscles, or tendons. Participants were people of working age (18 to 65 years old), with persistent musculoskeletal impairments (lasting > 3 months), resulting in persistent activity limitations and vocational participation restrictions.

The rehabilitation program aimed to manage pain and improve function, activity, and participation, including facilitating a return to work (usual or adapted). This approach followed a multidisciplinary biopsychosocial framework consistent with recommended practices for patients with chronic pain [1]. Indeed, the program included a psychological component with sessions of cognitive behavioural therapy, social advice and vocational training as well as physical components including physical and occupational therapy. Representing 80% of the proposed therapies, the latter were organized in individual and group sessions, with graded exercises focusing on strength and endurance training, stretching, balance, walking and adapted physical activities. At the beginning of the rehabilitation stay, patients' functional abilities were assessed. Then, for each patient, an individualized program with objectives focused on graded activity was developed. These objectives were regularly adjusted during individual therapy sessions and weekly multidisciplinary meetings. The rehabilitation stay lasted 4 to 5 weeks, with 3 to 4 h of therapy per day (excluding weekends). Because of the program's vocational component, patients participated in 2 to 4 h of vocational workshops targeting activities related to their specific problems. These vocational workshops corresponded to workstations that allowed to assess and train patients' abilities to perform the activities required in their usual or adapted work. More details can be found in a previous publication [18].

The study protocol was approved by the Commission Cantonale Valaisanne d'Ethique Médicale, CCVEM034/12. Informed consent was obtained from all participants in the study and the study was performed in accordance with the ethical standards outlined in the 2008 Declaration of Helsinki.

Procedure

Upon arrival at the rehabilitation center, we collected personal characteristics from each participant, including age, sex, anthropometric data, native language (French vs. other), education level (compulsory school vs. higher education). Additionally, we gathered clinical data, which included injury site (upper extremity, lower extremity, trunk, multiple trauma), severity of injury based on the Abbreviated Injury Scale score [19], and time since injury. Before starting the therapeutic program, participants completed self-reported questionnaires. On the second or third day after admission, they performed a battery of functional tests under the supervision of a trained physiotherapist.

During the second week of rehabilitation, participants were instructed to wear a triaxial accelerometer (ActiGraph wGT3X-BT, Pensacola, FL, USA) [20] for 7 consecutive days, from Friday to the following Thursday, from awakening to bedtime, removing it only during showering or aquatic activities. The sensor (4.6×3.3×1.5 cm; 19 g; 4-GB memory; ± 8 g; 50 Hz) was placed on the right hip of the participant by use of an elastic belt.

Three months after discharge, we phoned participants to remind them of the study and ask if they still wished to wear the accelerometer. If they agreed, the device was mailed to their home, and they were invited to wear it again for 7 consecutive days before returning it via postal mail (Fig. 1).

Physical activity assessment

PA was expressed in daily number of steps. Data were processed using the manufacturer's step algorithm (ActiLife 6 software, v6.13.4, ActiGraph, Pensacola, FL, USA). Only days when the accelerometer was worn for at least 10 h were retained for analysis. During rehabilitation, the number of steps on weekdays and weekends, which were days off, were analyzed separately. Data from the weekend, 2 days, were used as a proxy for pre-rehabilitation PA (T1), as proposed by Terrier et al. [17], and weekday data, 5 days, were used to determine activity during rehabilitation (T2). At the third measurement time, data from all 7 days were used for analysis (T3). To account for daily variability in step counts, we calculated the median value at each time point for each participant.

Questionnaires and performance-based assessments

Validated questionnaires in French [21–25] were used to assess aspects of participants' health. The Brief Pain Inventory (BPI) was used to assess pain severity (Cronbach α: 0.90) and pain interference (Cronbach α: 0.92) using numeric rating scales (scores ranging from 0 to 10). Higher scores indicate higher severity or higher impact

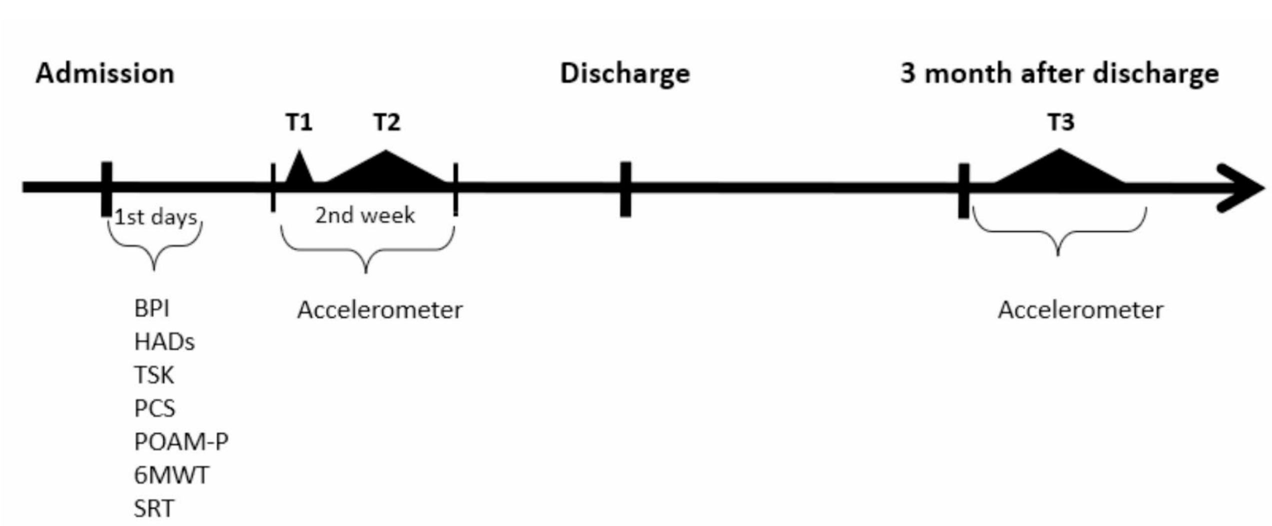

Fig. 1 Time points of data collection. BPI = Brief Pain Inventory, HADs = Hospital Anxiety and Depression Scale, TSK = Tampa Scale of Kinesiophobia, PCS = Pain Catastrophizing Scale, POAM-P = Patterns of Activity Measure-Pain, 6MWT = 6-min walk test, SRT = steep ramp test

of pain on daily functioning [26]. We also considered the specific item related to how pain interferes with walking ability.

The Hospital Anxiety and Depression Scale (HADs) was used to assess anxious and depressive symptoms. Scores for both subscales range from 0 to 21, with higher scores indicating greater depressive or anxious symptoms [27].

The Tampa Scale of Kinesiophobia was used to assess pain-related fears of movement and re-injury. Scores range from 17 to 68, with higher scores indicating greater fear [28, 29].

The Pain Catastrophizing Scale, with scores ranging from 0 to 52, was used to investigate catastrophic thinking. Higher scores indicate more catastrophizing thoughts [30].

The Patterns of Activity Measure-Pain (POAM-P) was used to characterize behaviour patterns in people with chronic pain. This questionnaire assesses three strategies: avoidance, characterized by the escape from or avoidance of pain-associated activities due to fear of movement or pain; pacing, characterized by alternating periods of activity and rest to control pain or fatigue; and overdoing, characterized by continuing activity despite pain, risking detrimental effects. The score for each component ranges from 0 to 40, with the highest rating reflecting a favorite, but not exclusive, behavioural pattern [31].

Functional tests were also performed [32]. The 6-min walk test (6MWT), which measures the distance a person can walk for 6 min as fast as possible, was conducted on a standardized 120-meter circuit. This test is a reliable and valid submaximal exercise test designed for adults with a disorder and chronic pain [33, 34].

The steep ramp test (SRT) was used to assess physical fitness. This test involves an incremental graded exercise performed on a cycloergometer; after a 2-min warm-up, the load increases every 10 s by 25 watts until the participant can no longer maintain a frequency of 60 rotations/min. The SRT provides an accurate estimation of maximal capacity in untrained individuals [35, 36].

Statistical analysis

Continuous data are expressed with mean (SD). The distribution of the number of steps was visually checked. Although slightly left-bounded, it was relatively normal. Categorical data are expressed with number (percentage). The number of steps per day was compared among the three time points by using the paired Student *t* test and correlation coefficients (T1 vs. T2, T2 vs. T3 and T1 vs. T3). Statistical significance was set at $p < 0.05$.

A linear regression model was computed to study the association between number of steps per day at T2 and self-reported factors (pain, anxiety, depression, catastrophic thoughts, kinesiophobia, activity patterns) and performance-based (walking endurance, physical fitness) factors. These associations were adjusted for age, sex, severity of injury, injury site and time since injury, which could be potential confounding factors [37]. We first ran univariable models with each potential predictor one by one to make a first selection of associated factors. Then, factors with $p < 0.15$ on univariable analysis were retained in a multivariable model, which was reduced by backward elimination until the Akaike information criterion was minimized. This allowed for identifying factors that were most associated. The adjusted R^2 value of the multivariable model was measured to assess the strength of the model. Standardized coefficients are also provided. These allow the effects of different predictor variables to be compared, regardless of measurement scales. The same procedure was repeated with the number of steps per day at T3 as an outcome. Predictors remained those measured at the beginning of the rehabilitation stay.

Not all participants completed all questionnaires and functional tests, particularly the POAM-P, which was not administered at the beginning of the study. Individuals with missing information are known to have poor treatment outcomes [38], so data are not missing completely at random. Consequently, relying only on a complete-cases analysis could lead to biased results and loss of statistical power [39]. Nevertheless, the factors known to be associated with non-response are all measured and considered in the statistical models, so the assumption of missing at random is plausible, and multiple imputation should reduce the risk of bias. We used 50 imputed datasets, obtained using multiple imputation by chained equations with the “mi impute chained” command of Stata [40]. Continuous variables were imputed with linear regression models; logistic regression models were used for binary variables, and multinomial logistic regression for nominal variables. Analyses were also performed on complete-case data only in a sensitivity analysis.

All statistical analysis involved using Stata/SE 17.0 (StataCorp, College Station, TX, USA).

Results

A total of 298 participants were recruited for this study. However, some didn't have sufficient accelerometric data at T2, and some did not wear the accelerometer at T3 (Fig. 2). Ultimately, data for 145 participants were included in the final analysis.

Table 1 provides participants' sociodemographic characteristics, along with the results of the questionnaires and functional tests. Most participants were middle-aged men with >9 years of education. Upper-limb injuries and moderate severity of injury were the most common. The median time after the accident was 13.3 months (interquartile range 8.3–25.3). On average, pain intensity and interference were moderate, level of kinesiophobia was

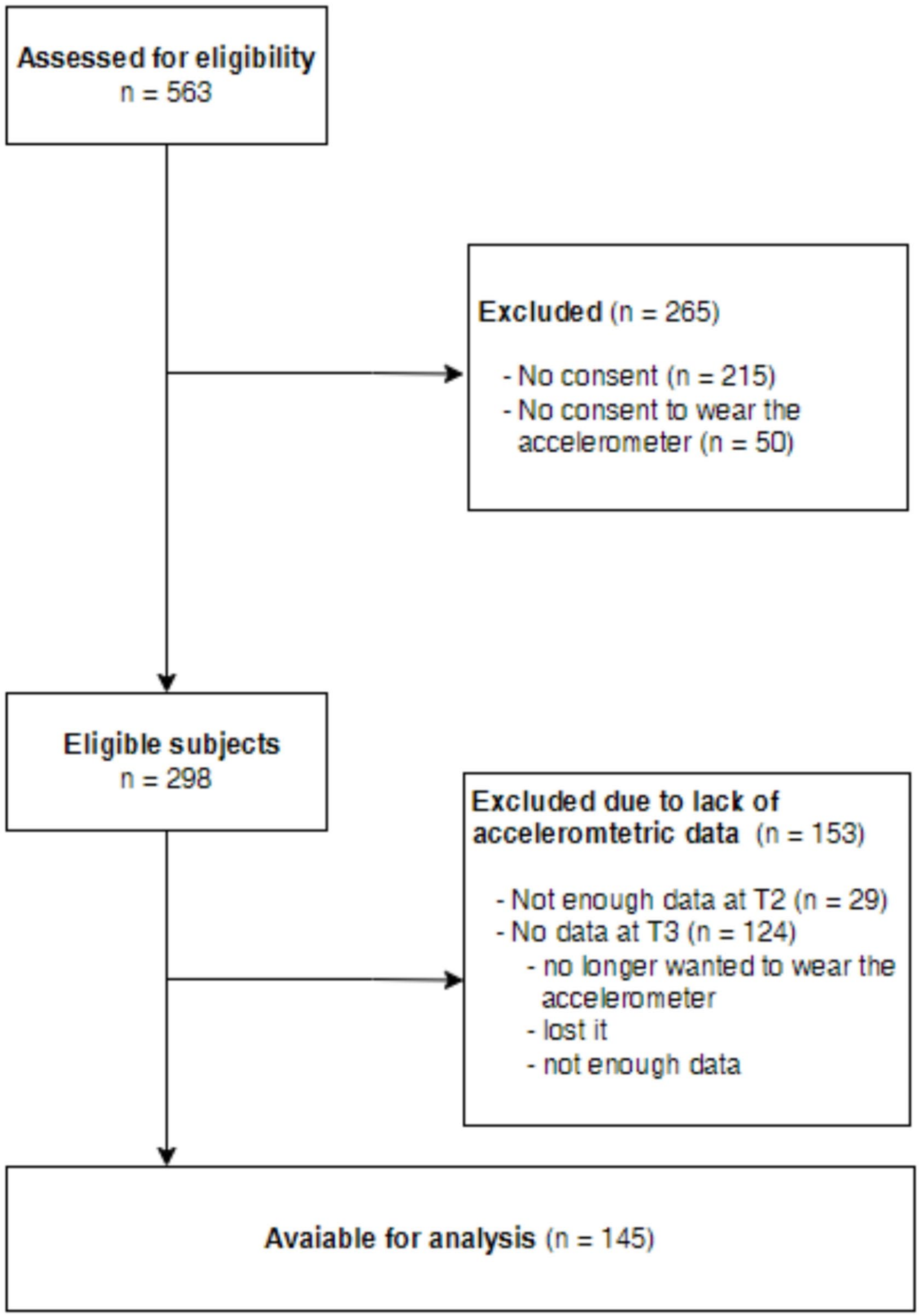

Fig. 2 Flowchart of participants in the study

Table 1 Participant characteristics and results of questionnaires and functional tests for included and excluded individuals with chronic musculoskeletal pain who were in a rehabilitation program

			Included individuals (N = 145)		Excluded individuals (N = 153)	p-value
Age			47 (11)		41 (12)	**< 0.001**
Body height (cm)			172 (8)		173 (8)	0.45
Body mass (kg)			82 (16)		81 (17)	0.78
Body mass index (kg/m^2)			28 (5)		27 (5)	0.48
Sex	Male		116 (80%)		116 (76%)	
	Female		29 (20%)		37 (24%)	0.39
Native language	French		95 (66%)		92 (60%)	
	Other		50 (34%)		61 (40%)	0.29
Education level*	Low		62 (43%)		72 (47%)	
	High		83 (57%)		81 (53%)	0.40
Injury site	Upper limb		68 (47%)		60 (39%)	
	Lower limb		44 (30%)		54 (35%)	
	Trunk		28 (19%)		39 (25%)	
	Multiple areas		5 (3%)		-	0.05
Severity of injury	Minor		56 (39%)		52 (34%)	
	Moderate		69 (47%)		81 (53%)	
	Severe		19 (13%)		18 (12%)	
	Unknown		1 (3%)		2 (1%)	0.54
SELF-REPORTED QUESTIONNAIRE VARIABLES		**N**		**N**		
Brief Pain Inventory (/10)	Severity	144	4.5 (2.0)	153	4.8 (2.0)	0.33
	Interference	144	4.5 (2.2)	153	5.0 (2.1)	**0.03**
	Interference in walking	144	3.7 (3.1)	150	4.2 (3.3)	0.28
Hospital Anxiety and Depression Scale (/21)	Anxiety	143	9.2 (4.1)	151	10.2 (3.9)	0.05
	Depression	143	6.7 (3.8)	151	7.6 (4.2)	0.05
Tampa Scale of Kinesiophobia (/68)		144	43.1 (7.8)	152	45.3 (7.9)	**0.02**
Pain Catastrophizing Scale (/52)		143	21 (11.6)	152	24.8 (12.6)	**0.01**
Patterns of Activity Measure-Pain (/40)	Avoidance	107	26.4 (9.4)	106	28.8 (7.9)	**0.05**
	Pacing	107	24.5 (8.6)	106	25.7 (9.1)	0.29
	Overdoing	107	22.3 (8.3)	106	21.5 (8.3)	0.45
functional tests						
6-min walk test (m)		121	511 (129)	138	511 (123)	0.99
Steep ramp test (W)		109	200 (91)	121	206 (96)	0.60

Data are mean (SD) unless otherwise indicated. P-values are from Student t tests for continuous variable and chi-squared test for categorical variables. In bold: p-values < 0.05.

* compulsory school versus higher education.

moderate to high, anxious symptomatology and catastrophizing thoughts were mild, and depressive symptoms were low. Avoidance was the most prominent of the three types of behaviour. Individuals excluded because of lack of accelerometric data were significantly younger and had more pain interference, a higher level of kinesiophobia, more catastrophizing thoughts and a more pronounced avoidance pattern than included individuals.

Number of steps

The participants wore the accelerometer for a mean (SD) of 12.7 (2.2), 12.8 (2.2) and 13.3 (2.4) hours/day at T1, T2 and T3, respectively. The mean number of steps during rehabilitation (T2) was 7323 (3047) steps per day, 2541 more than at T1 (4782 [2689], $p<0.001$, Cohen's d = 0.769), and 2566 more than at T3 (4757 [2680], $p<0.001$, Cohen's d = 0.693). The difference between steps at T1 and T3 was not significant ($p=0.92$, Cohen's d = 0.008). Despite the small mean difference of 25 steps per day, the correlation between steps at T1 and T3 was only 0.40, was negligible between steps at T2 and T3 ($r=0.17$) and was low between steps at T1 and T2 ($r=0.34$).

Factors associated with PA during rehabilitation

The results of the linear regression model analysis are presented in Table 2. Univariable models showed a negative association between number of steps per day and pain interference in walking capacity (beta −153.69, $p=0.08$) and positive associations with anxiety level (beta

Table 2 Factors associated with daily steps during rehabilitation

	Univariable models			Multivariable model			
Factors	**Beta**	**95% CI**	***p*-value**	**Beta**	**95% CI**	**Beta stand**	***p*-value**
BPI-Severity	-159.50	-443.30, 124.29	0.27				
BPI-Interference	-140.72	-369.33, 87.89	0.23				
BPI-Walk	-153.69	-325.12, 17.73	**0.08**	-170.12	-342.56, 2.32	-0.17	0.05
HADs-Anxiety	100.50	-22.10, 223.09	**0.11**	144.55	18.92, 270.19	0.20	0.02
HADs-Depression	-37.52	-174.06, 99.02	0.59				
TSK	-7.84	-74.62, 58.94	0.82				
PCS	-19.67	-64.75, 25.41	0.39				
Avoidance	-39.54	-95.28, 16.20	0.16				
Overdoing	56.46	-13.92, 126.85	**0.11**	57.28	-17.63, 132.19	0.17	0.13
Pacing	-46.95	-111.73, 17.84	0.15				
6MWT	3.52	-1.05, 8.08	**0.13**				
SRT	3.59	-3.04, 10.22	0.29				

Regression models were adjusted for age, sex, severity of the injury, injury site and time since injury. The multivariable model involved both unstandardized (beta) and standardized (beta stand) outcomes. In bold: *p*-values < 0.15 on univariable analysis (factors retained in the multivariable model). BPI = Brief Pain Inventory, HADs = Hospital Anxiety and Depression Scale, TSK = Tampa Scale of Kinesiophobia, PCS = Pain Catastrophizing Scale, 6MWT = 6-min walk test, SRT = steep ramp test, 95% CI = 95% confidence interval

Table 3 Factors associated with daily steps at 3 months post-rehabilitation

	Univariable models			Multivariable model			
Factors	**Beta**	**95% CI**	***p*-value**	**Beta**	**95% CI**	**Beta stand**	***p*-value**
BPI-Severity	-243.85	-496.87, 9.17	**0.06**				
BPI-Interference	-167.66	-377.02, 41.7	**0.12**				
BPI-Walk	-90.93	-260.73, 78.87	0.29				
HADs-Anxiety	19.68	-91.39, 130.75	0.73				
HADs-Depression	-82.65	-205.54,40.24	0.19				
TSK	-22.51	-84.13,39.11	0.47				
PCS	-6.49	-47.10,34.12	0.75				
Avoidance	-27.85	-80.54,24.84	0.30				
Overdoing	66.37	-1.58, 134.32	**0.06**	60.80	-8.53, 130.12	0.20	0.08
Pacing	-33.68	-94.54, 27.17	0.27				
6MWT	1.56	-2.44, 5.57	0.44				
SRT	6.66	0.45, 12.88	**0.0**	6.15	0.02, 12.29	0.23	0.05

Regression models were adjusted for age, sex, severity of the injury, injury site and time since injury. The multivariable model involved both unstandardized (beta) and standardized (beta stand) outcomes. In bold: *p*-values < 0.15 on univariable analysis (factors retained in the multivariable model). BPI = Brief Pain Inventory, HADs = Hospital Anxiety and Depression Scale, TSK = Tampa Scale of Kinesiophobia, PCS = Pain Catastrophizing Scale, 6MWT = 6-min walk test, SRT = steep ramp test, 95% CI = 95% confidence interval

100.50, $p=0.11$), overdoing strategy (beta 56.46, $p=0.11$) and 6MWT distance (beta 3.52, $p=0.13$) during rehabilitation. The strongest multivariable model revealed associations of number of steps per day with pain interference in walking ability (beta −170.12, $p=0.05$), anxiety (beta 144.55, $p=0.02$), and overdoing behaviour (beta 57.28, $p=0.13$). The effect of each of these factors was similar, corresponding to a weak effect. The proportion of variation in number of steps per day predictable from these variables was poor, with an adjusted R^2 value of 0.09. A 1-point decrease in the numerical rating scale (0–10) for the question "How, during the past 24 hours, has pain interfered with your walking ability?" was associated with an expected increase of 170 steps. Similarly, an additional point on the HADs anxiety scale (0–21) or POAM-P overdoing scale (0–40) was associated with an expected increase of 145 and 57 steps, respectively.

Factors associated with PA at 3 months post-rehabilitation

Three months after rehabilitation, only the overdoing behaviour (beta 60.80, $p=0.08$) and SRT (beta 6.15, $p=0.05$) results were associated with a greater number of steps. For each 1-point increase on the overdoing scale, an additional 61 steps were taken. Regarding the SRT, an increase of one interval, equivalent to 25 additional watts, resulted in an additional 154 steps. The effect of both factors was weak, and only 5% of the variance in number of steps per day could be explained by these variables. Details of the regression models are in Table 3.

Discussion

During inpatient rehabilitation, people with CMSP increased their walking activity by 50%, demonstrating a medium effect size (Cohen's d=0.77), as compared with their days off activity. Our previous study, conducted partially with the same population but focusing on the duration of practice of moderate PA and walking as outcomes, also showed a similar difference and was further able to demonstrate that walking behaviour during the weekend of the rehabilitation stay, which was days off and when most participants returned home, was equivalent to pre-rehabilitation behaviour [17].

Several factors likely contributed to this observed increase in daily steps during the weekdays of the rehabilitation stay. The patients followed a structured daily therapeutic program primarily consisting of physical components, including physiotherapy and occupational therapy. In addition, the spatial organization of the clinic facilities encouraged them to walk to complete their rehabilitation program, even outside of their scheduled therapies. Patients also received regular advice or messages on how to be active in their daily lives, which aimed to encourage them to be more active in the medium to long term too. They also used a therapy diary of the planned therapies for each day, which may also have contributed to establishing a daily rhythm and limiting sedentary behaviour. Despite this structure and contrary to our initial hypothesis, we did not observe significant behavioural changes. Participants returned to a sedentary level of approximatively 4700 steps per day at 3 months after being discharged from the clinic. Notably, this step count corresponds to the range typically found in individuals with disabilities and/or chronic illness that may limit mobility and/or physical endurance [41]. Our findings agree with those of Larsson et al. [42], who implemented a person-centered progressive resistance exercise program for women with fibromyalgia and showed that 13 to 18 months after the program, the effects observed immediately after the intervention had reverted to baseline levels. This observation suggests that consistent guided exercise over the long-term is necessary to maintain health benefits.

The correlations between the different measurement times were low. Thus, individual responses to the measures taken during rehabilitation, despite their individualization, can vary significantly. Beyond psychosocial factors, which may have a significant impact on awareness and adherence to advice, environmental factors may also contribute to the divergence between home and rehabilitation observations. Once patients return home, social constraints, possible environmental barriers to PA, and the absence of incentives to limit sedentary behaviour can all affect the level of their PA. However, even when all these factors are taken into account, rehabilitation alone is not enough to bring about lasting changes in long-standing behaviours.

The factors associated with the number of steps varied depending on the time point. Only the overdoing behaviour was consistently associated with number of steps per day at both time points. However, the association between overdoing and physical functioning is not common across studies and may depend on the assessment method used [43]. Self-reported data and objective measures of PA can yield opposite results. For example, Huijnen et al. [44], using accelerometric measures of PA, found no difference in total PA between a population primarily using an avoidance strategy and one favoring an overdoing strategy. However, self-reported activity level was higher in the overdoing than avoidance group. Similarly, the duration of daily uptime, corresponding to the period between getting up and going to bed and measured by the time the accelerometer was worn, was more than 1 h longer for overdoers than avoiders. Overdoing behaviour, also known as "persistence" behaviour, can be considered multidimensional. Indeed, Kindermans et al. [45] identified three distinct types of persistence: task-contingent persistence (completing tasks despite pain), excessive persistence (doing too much and experiencing rebound effects) and pain-contingent persistence (with the level of pain determining the performed behaviour). The authors demonstrated that higher task-contingent persistence predicted lower disability levels. Given that the POAM-P overdoing scale mainly contains questions related to task-contingent persistence, our results confirm those of Kindermans et al. [45] and also align with the findings of Luthi et al. [46], showing an association between pronounced overdoing behaviour and observational measures such as the 6MWT, SRT and load carrying tests.

The number of daily steps was also associated with pain interference in walking ability and anxiety during the rehabilitation stay and by physical fitness at 3 months after rehabilitation. The association between number of daily steps and pain interference in walking ability seems understandable. The lack of association with total score of the BPI-interference scale may be explained by the fact that this scale assesses not only physical but also affective pain interference. Miettinen et al. demonstrated that individuals with chronic pain who scored high on activity pain interference had reduced PA [47]. Also, relatively short bouts, 5 to 20 min, of light and moderate intensity walking were associated with reduced pain interference, but daily steps were not associated [48]. In our previous study, we also found an association between pain interference and walking activity but only in patients with back pain [17]. As part of our actual study, our sample size was too small to consider the site of injury as a covariable.

In our data, the more anxious a participant, the more they walked. Others found opposite results among people with chronic pain, finding an association between lower anxiety and increased engagement in activity [49] or higher moderate to vigorous PA [50]. The association between anxiety and PA is probably not unambiguous. Anxiety can prevent engagement in activities, but activity can also be used to reduce anxiety [51].

In addition to psychological factors, physical fitness, as assessed by the SRT, was also associated with number of daily steps, but only at the follow-up assessment. People in good physical condition could find it easier to adhere to an exercise program or motivate themselves to go for a walk when they return home. Aerobic fitness level is associated with low back pain [52], and leisure-time PA level is also significantly linked to overall physical condition [53], results that agree with our findings.

In our multivariable models, the effects of factors on PA during and after rehabilitation were weak. Each significant factor contributed similarly, with standardized coefficients close to 0.20. The task-contingent strategy, probably measured with the overdoing POAM-P subscale, the only factor associated with both measurement times, had similar values at both time points: 57 versus 61 additional steps for a 1-point increase on the overdoing scale (0–40 points). Therefore, each of these factors could be addressed to reduce the pain interference in walking ability, which can be done with PA; promote functional overdoing (i.e., task-contingent and not excessive persistence); and instruct anxious people to practice regular PA and improve their physical condition to achieve a medium-term impact.

Limitations and strengths

Our study has several limitations. First, its unusual setting, with a sample composed mainly of men presenting late for rehabilitation after orthopedic trauma, may limit the generalizability of the results. Second, we exclusively used the number of steps per day to estimate daily PA. We did not consider the intensity (light vs. moderate vs. vigorous), which could have provided a more nuanced understanding of participants' PA patterns, although some authors [54, 55] have demonstrated correlations between number of daily steps and daily minutes of moderate-to-vigorous PA. Regardless, number of steps per day remains an objective and widely used indicator of PA, reflecting changes in individual behaviour and mobility and showing a dose–response relation with important health outcomes [16, 56]. We also did not analyze our data according to different times of day, which could have affected the association between number of steps per day and our self-reported and performance-based outcomes [57].

We found high intra-individual variability in step counts from one day to the next. During rehabilitation, the therapeutic program remained relatively similar during the days, which does not explain this variability. At 3 months, the variability was greater, which is less surprising. In fact, because a large proportion of the participants had not yet returned to work, their day was less time-structured than during hospitalization. We also opted to use a proxy to evaluate the number of steps per day at pre-rehabilitation stage rather than a direct measure, mainly for organizational reasons because the date of hospitalization of participants was not always known sufficiently in advance to send them the accelerometer.

Finally, we could have evaluated other factors, such as the role of self-efficacy. Indeed, self-efficacy regarding perceived function was found correlated with PA level at 1 year after rehabilitation in patients with chronic pain [58]. Similarly, health literacy is positively associated with level of PA [59].

Despite these limitations, one of the strengths of our study is its longitudinal and prospective design. This aspect reinforces the hypothesis of a possible causal link and not just an association between our predictors and walking behaviour.

Implications for practice and future research

From a clinical perspective, although the associations we found were weak, the predictors identified are all accessible to intervention or reinforcement within existing therapeutic programs. While a biopsychosocial approach has already been implemented by the interdisciplinary team during the rehabilitation stay, it seems important to further strengthen certain aspects. The implementation of therapeutic education programs, as well as personalized rehabilitation programs based on the patient's profile, seems necessary.

Subsequently, dedicated clinical follow-up, incorporating psychosocial aspects such as pain behaviour patterns, pain interference and anxiety management, along with a supervised exercise program, including aerobic fitness, could be essential to mitigate performance attrition.

From a research perspective, the high variability of our data could suggest the existence of different patient typologies. Including larger groups in future studies and tailoring interventions based on these typologies could allow for a more detailed exploration of this variability. Finally, a randomized controlled trial targeting the factors highlighted in this study could provide conclusive evidence regarding causality with PA.

Conclusion

Despite chronic pain, people can increase their PA when provided with incentives. However, rehabilitation alone is not enough to induce lasting changes. When incentives disappeared, most people returned to their previous activity levels. Follow-up with a multimodal approach (with therapeutic but also environmental incentives) could be proposed to maintain activity over time.

Abbreviations

BPI	Brief Pain Inventory
CMSP	chronic musculoskeletal pain
HADs	Hospital Anxiety and Depression Scale
PA	physical activity
PCS	Pain Catastrophizing Scale
POAM-P	Patterns of Activity Measure-Pain
SRT	steep ramp test
TSK	Tampa Scale of Kinesiophobia
6MWT	6-min walk test

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Author contributions
Conception and design of the study: BL, FL, FR.Data acquisition: JLC.Data analysis and interpretation: PV, FR, BL, FL.Writing original draft: FR.All authors reviewed the manuscript and approved the final version.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study protocol was approved by the Commission Cantonale Valaisanne d'Ethique Médicale, CCVEM034/12. Informed consent was obtained from all participants in the study.

Consent for publication
not applicable.

Competing interests
The authors declare that they have no competing interests.

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