Research Article

Accelerometer assessment of physical activity in individuals with paraplegia who do and do not participate in physical exercise

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Objective: Our main goal was to measure physical activity (PA) in people with paraplegia. Secondarily, we aimed to establish the relationship between being engaged in physical exercise (PE) and reaching the recommended moderate-to-vigorous physical activity (MVPA) level. We further analyzed the effect of being engaged in PE on the PA levels.
Design: Descriptive cross-sectional.
Setting: Spanish associations for individuals with spinal cord injury.
Participants: Ninety-six manual wheelchair users with chronic paraplegia.
Interventions: Participants wore a wrist accelerometer for one week.
Outcome Measures: Levels of PA and sedentary behavior. In addition, participants were classified into two groups, exercisers (EG) and non-exercisers (NEG) to analyze the effect of PE enrollment on the variables.
Results: For all participants, a mean (SD) of 5,341.70 (966.4) minutes per week were spent engaged in sedentary behaviors, 2,188.99 (723.9) minutes were spent engaged in light activity, and 206.24 (180.0) minutes were spent engaged in MVPA. There was a significant relationship between PE and reaching the minimum levels of MVPA recommended [x^2 (1) = 25.03, $P < 0.01$]. NEG showed a greater number of minutes per week for sedentary behavior [t (94) = 2.50, $P < 0.05$, $r = 0.25$]. The EG spent more than twice as much time doing MVPA than the NEG (263.8 min vs 114.3 min, respectively).
Conclusions: MVPA levels are low in manual wheelchair users who are not regular exercisers, but most of those who self-reported being regular exercisers reach the minimum levels recommended for health benefits. Sedentary behavior is a concern in this population.

Keywords: Spinal cord, Physical activity, Physical exercise, Sedentary behavior, Accelerometry

Introduction

People with spinal cord injury (SCI) tend to perform a lower amount of physical activity (PA) and, therefore, their energy expenditure is reduced.[1] It is well known that the lack of PA and sedentary lifestyles have adverse health effects, that become even more relevant in the SCI population. After the injury, a significant decrease in total lean mass, particularly in lower extremities, and an accompanying increase in fat mass occurs, which causes several metabolic-associated disorders related to the metabolic syndrome whose prevalence in the SCI population varies between 23% and 43%.[2,3]

Furthermore, sedentary individuals present an increased risk of obesity and obesity-related conditions such as diabetes and cardiovascular disease, the latter being the most common cause of death in people with chronic SCI, over 60 years of age or after 30 years following injury.[4,5]

Previous studies have concluded that engagement in physical exercise (PE) is associated with improved physical fitness and health in people with paraplegia,[6,7] and helps to reduce the impact of related pathologies.[8,9] PE

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also provides psychological benefits such as depression and anxiety reduction, improves quality of life, self-esteem and body image, reduces the need for medical care, and promotes a greater community involvement.[10]

Some authors recommend a minimum amount of 180 min of moderate-to-vigorous physical activity (MVPA) per week in order to obtain health benefits in the SCI population.[9,11,12] Nevertheless, PE performed by people with paraplegia may not be enough to achieve this level, as the energy expenditure (EE) during PE in this population is usually lower than in people without disabilities.[13–15] Therefore, it is important to determine whether this population is able to reach the recommended MVPA level with a certain amount of PE. Such information would likewise be useful for the purpose of planning rehabilitation programs for people with SCI.

Several previous studies have aimed to assess the amount of PA in the population with paraplegia and to establish PA patterns. Most of these studies used self-reported questionnaires or telephone surveys to obtain the data.[16–22] However, when recalling the amount of their PA, participants tend to overestimate the time spent doing MVPA[23] compared to the results obtained from other objective devices such as accelerometers. In this regard, although there are valid studies already reporting PA amounts using accelerometers,[24–32] only two designed specific equations for the SCI population[33,34] using a small sample size.

Therefore, our main goal was to measure the amount of PA that manual wheelchair users with chronic paraplegia perform. Secondarily, we analyzed the extent to which being engaged in PE affected the PA levels and EE. Furthermore, we aimed to establish the relationship between being engaged in PE and reaching the recommended MVPA.

Methods

Participants

The sample size calculation was based on recommendations for cross-sectional studies[35] using previous data from our pilot study in which we obtained a mean of 1.53 METs and a standard deviation of 0.12. We standardized the total range, set at 5% of the mean, and established a confidence interval of 99%.[36] The sampling plan required a sample of at least 66 individuals. Finally, 96 (83 males and 13 females) manual wheelchair users with chronic paraplegia were included in the study.

All participants provided written informed consent, and all procedures were conducted in accordance with the principles of the Declaration of Helsinki of the World Medical Association. The protocols were approved by the Ethics Committee of our institution.

Procedure

This was a cross-sectional study conducted in collaboration with health personnel from Spanish hospitals, university departments and sports associations experienced in research on people with paraplegia. All the collaborating institutions participated in the sample selection. The data collected from the various institutional centers were sent to the principal center with an alphanumeric code for identification (to preserve the privacy of the participants).

Individuals with a stable clinical condition (i.e. the event occurred more than one year before the study) with the injury located between T1 and T12 and all using a manual wheelchair as their primary means of mobility were eligible to participate in the study. The degree and extent of SCI were determined based on a complete neurological examination conducted by a medical specialist according to the American Spinal Injury Association Impairment Scale (AIS), and only patients graded A or B on this scale were selected. We used a check-list to ensure that participants met eligibility criteria provided by the National Center for complementary and integrative health (NCCIH) Clinical Research Toolbox.[37]

Furthermore, several briefings were held with the medical personnel to verify the exclusion criteria. None of the participants showed symptoms of cardiorespiratory disease or other pathological conditions, such as pressure sores or motor disabilities of their upper limbs that could affect their participation in physical exercise activities. We also excluded subjects whose main sport was swimming, as the accelerometers could not be used underwater. Data for this study were collected by trained researchers (i.e. physiotherapists, physical education and sports graduates and medical personnel) who participated in all stages of the study described below.

Physical activity assessment

An Actigraph accelerometer GT3X (Manufacturing Technology Inc., Fort Walton Beach, USA) was used to collect the data on the accelerations achieved by the patients over seven days. The accelerometer was a small, lightweight device (3.8 cm × 3.7 cm × 1.8 cm, weight 27 g) that did not interfere with the patients' daily routines. The accelerations collected were represented by the counts obtained. Counts are used extensively in this study, and they represent the amount of acceleration between two consecutive levels of quantization during the analog-to-digital conversion. This device was previously validated for this population ($r = 0.86$; RMSE = 2.23 ml kg^{-1} m^{-1}).[38]

Participants were instructed to wear the accelerometer for a typical week, secured to their non-dominant wrist using an elastic strap.[38] The monitor was worn night and day, and it did not need to be removed except during activities in which the accelerometer was likely to get wet. The acceleration signal was digitized with a frequency of one sample per second, recording every activity in counts. Data were saved to a hard disk for subsequent analyses.

Demographics, clinical data and grouping criteria

A personal interview was conducted with each participant, including questions related to age, weight, height, sex, time since injury and mode of mobility. Furthermore, the participants reported hours spent on PE per week as well as the type of PE performed.

Based on whether a participant performed PE more or less than 3 h per week,[39] they were classified into two groups: exercisers (EG) and non-exercisers (NEG). The purpose of this classification was to test whether the regular practice of PE had an impact on PA and on achieving the recommended level of MVPA. Further, we wanted to explore if regular exercise was enough to cover the MVPA needed to produce health benefits.

Furthermore, depending on the amount of weekly MVPA (registered with the accelerometers), the participants were divided into two groups: 'under-threshold' (UT) for those performing less than 180 min of MVPA per week and 'above-threshold' (AT) for those performing more than 180 min per week.

Table 1 Demographic and injury-related characteristics of the 96 participants.

Characteristics	Mean (SD)
Age (years)	41.66 (10.29)
Weight (kg)	74.79 (15.07)
Height (m)	1.75 (0.09)
BMI (kg·m-2)	24.42 (3.80)
Time since injury (months)	199.15 (113.72)
HR (beats/min)	68.53 (12.16)
	n (%)
Physical Exercise	
Non-exercisers	37 (38.5)
Exercisers	59 (61.5)
Sex	
Male	83 (86.46)
Female	13 (13.54)

Data are shown as mean (standard deviation) for all 96 participants; *n* (%), number of participants in each category and the percentage of the sample in each category; BMI, Body Mass Index; non-exercisers: under 180 min of physical exercise a week (NEG); exercisers: at least 180 min of physical exercise a week (EG); HR, heart rate.

Data analysis

A specific ad-hoc function was written using Matlab R2010a. (MathWorks, Natick, USA) to reduce and remove incorrect data and to perform the calculations involving the study variables. To accurately analyze the accelerometer signal, all values were first checked to guarantee that they did not exceed the established upper limits (>5000 counts s^{-1}). To accurately report PA outcomes, the expected motionless periods (e.g. watching television, reading a book) needed to be differentiated from periods of non-wear. Data that comprised 1200 consecutive '0' counts were defined as non-wear time and were omitted from all further analyses.[40] Participants who did not wear the accelerometer for at least 9 h over 4 days were not included in the study. In order to complete missing data when the accelerometer was not worn on all seven days, the average of five or six days was taken and the values added to complete a seven-day week.[41]

To estimate the energy expenditure as measured using the accelerometer, the equation described by García-Massó *et al.* was used.[38] This equation is the result of the validation of various multiple linear models to estimate O_2 consumption (VO_2) in individuals with paraplegia. Based on their results, one multiple linear model was obtained, and an ad hoc equation was designed to record PA with the least possible error in this population.

The intensity levels of PA were subdivided into light, moderate-to-vigorous and sedentary behavior[42] depending on the MET. Therefore, values <1.5 METs were considered sedentary activities, values between 1.5 and 2.99 METs were considered light activities, values between 3 and above were considered moderate-to-vigorous activities. Thus, we obtained the number of minutes per week that the participants spent performing PA at each intensity level (dependent variables).

Statistics

Statistical analysis of the data was performed with SPSS v.24 (SPSS Inc., Chicago, USA). First, we described the data. Standard statistical methods were used to obtain the mean, standard deviation of the mean, standard error and 95% confidence intervals.

An independent t-test was performed to explore the differences between groups (i.e. exercisers and non-exercisers) on the dependent variables, namely, minutes per week of PA, intensity levels and sedentary behavior. We evaluated the assumption of homoscedasticity using a Levene test and a Hartley F_{Max} test. When this assumption was violated, we used the Satterthwaite approximation to adjust the degrees of freedom for the t-test.

We used a Pearson chi-square test to analyze the categorical variables and to establish the relationship between the PE performed (i.e. exercisers and non-exercisers) and the achievement of the PA threshold (i.e. UT and AT). Further, the Odds ratio was computed. All tests of hypotheses were conducted at the alpha = 0.05 level (Type I error of 5%).

Results

Demographics and clinical profile: sample characteristics

A high degree of compliance was achieved. Eighty-one participants wore the accelerometer seven days a week, and 15 wore the accelerometer for six days.

The descriptive demographic data and the injury-related profiles are shown in Table 1.

Weekly levels of physical activity

For all participants, 5,341.70 (966.41) minutes per week were spent engaged in sedentary behavior, 2,188.99 (723.94) minutes per week were spent engaged in light activity, and 206.24 (180.03) minutes per week were spent engaged in MVPA.

Comparison between PA levels of exercisers and non-exercisers

Table 2 shows the difference in the PA levels between groups (i.e. EG and NEG).

When comparing the different levels of intensity of PA (i.e. light and moderate-to-vigorous) and sedentary behavior in the NEG and the EG, significant differences were obtained for sedentary behavior [t (94) = 2.50, $P < 0.05$, $r = 0.25$], with the NEG showing a greater number of minutes per week. In contrast, the EG spent a greater number of minutes per week engaged in light PA [t (94) = - 2.16, $P < 0.05$, $r = 0.22$] and in MVPA [t (89.11) = - 4.55, $P < 0.01$, $r = 0.42$].

Table 2 Comparison of the physical activity levels between exercisers and non-exercisers.

	NEG $n = 37$ (38.5%)	EG $n = 59$ (61.5%)	$N = 96$
Sedentary Behavior	5,644.6 (773.5)	5,151,7 (1,031.1)	5,341.70 (966.4)
Light PA	1,995.2 (699.9)	2,310.5 (735.4)	2,188.99 (723.9)
Moderate-to-vigorous PA	114.3 (140.8)	263.8 (178.9)	206.24 (180.0)

Data are shown as mean (standard deviation), *n* (%) is the number of participants in each category and the percentage is the proportion of the sample in each category; PA, Physical Activity; NEG, non-exercisers; EG, exercisers.

Relationship between engagement in physical exercise and MVPA threshold achievement

With regard to MVPA threshold achievement, 57.3% did not reach the required minimum number of minutes of MVPA per week to provide health benefits. The following table (Table 3) shows the participant count in both groups (EG and NEG) who either achieved or failed to achieve the MVPA threshold.

There was a significant relationship between being engaged in PE and reaching the minimum levels of MVPA recommended for health benefits x^2 (1) = 25.03, $P < 0.01$. Based on the odds ratio, the EG participants were 13.88 times more likely to achieve the MVPA recommendation than the NEG.

Discussion

This study assessed PA in a large sample of individuals with paraplegia with accelerometers using a specific equation designed for this population, which reduces the chances of measurement errors.

The mean time of sedentary behavior was 778 min/day (13 h/ day), equivalent to 54% of the 24 h in a day. These figures are higher than those found by Warms *et al.*[26] (556 min/day, approximately equivalent to 9 h/day) in their study conducted on individuals with paraplegia. However, the methodological differences between the two studies do not allow to draw valid conclusions as the latter authors used the PAR (Physical Activity Record) questionnaire;[43] this establishes the average activity intensity for each 15-minute period of the day in order to determine the average amount of time spent on a daily basis engaged in activity with varying intensities. On the other hand, our figures for sedentary behavior are relatively low compared to the 1,092 min/day (approximately 18 h/day), achieved in Parkinson's disease population using accelerometers.[44] Likewise, upon comparison with previous studies conducted in other population samples, our sample showed lower values of sedentary behavior than amputees (932 min/day or its equivalent 15 h and 30 min/day), assessed through a questionnaire, and multiple

Table 3 Relationship between physical exercise and MVPA threshold achievement.

	Above threshold	Below threshold
EG	37 (62.7)	22 (37.3)
NEG	4 (10.8)	33 (89.2)
Total	41 (42.7)	55 (57.3)

Data show the frequencies (and percentages) of the participants in each category. Threshold is set at 180 min of MVPA per week; EG, exercisers; NEG, non-exercisers.

sclerosis subjects (1,152 min/day or its approximate equivalent of 19 h/day), assessed using a pedometer.[45,46] Therefore, despite the mobility problems in persons with paraplegia, these patients appear to have more active lifestyles compared to people with other illnesses or disabilities. When our results on sedentary behavior were compared against the data obtained in a similar study conducted on a healthy sample,[47] paraplegic study participants spent 16% more time on sedentary behavior than healthy people, i.e. 653 min/day (approximately 11 h/day). This could be due to the fact there is still much to be done in terms of the existing social barriers such as employability, leisure time or community participation, factors that have a direct impact on promoting active lifestyles.[48–50] Therefore, the removal of barriers coupled with the promotion of facilitating factors would be important to reduce sedentary behavior in SCI population.

Regarding the varying levels of PA intensity, we obtained a mean time of 5.2 h daily of light-intensity activity. Unfortunately, research that directly measures this type of PA is scarce, especially in people with disabilities; therefore, the comparison of results is difficult. When the results are compared with those obtained for people without disabilities we found a similar pattern, since healthy individuals spend 3.5–5.5 h per day carrying out light-intensity activities.[47] This is a positive result since research findings suggest that when light-intensity activity is increased, detrimental sedentary time is reduced.[51]

The MVPA obtained for the participants was 206.24 min (an average of 29 min/day), which is a very positive result in terms of achieving body-related health benefits, since the minimum value recommended has been set at 180 min of MVPA.[9,11,12] These data can only be compared with the study conducted by Warms *et al.,*[26] this being the only one of the 10 existing studies that have assessed PA in people with SCI. This study obtained a daily mean of 17 min/day, which is lower than that obtained in our study. However, the heterogeneity of the diseases and injuries of the participants in said study must be accounted for, as only 25 of the 50 manual wheelchair users had SCI. There is another study on people with SCI[28] that measured PA with accelerometers and obtained an average of 49 min of dynamic activities; however, it did not report MVPA values, yet an elaborated concept of dynamic activities, which, beside MVPA, included walking and general movement. Therefore, the results are not comparable.

Although, in general, the MVPA values obtained in our study exceed the established threshold, we also aimed to compare our result on MVPA with that obtained for healthy people. The sample in our study spent on average 10 min/day less performing MVPA than healthy people.[47] This is a substantial difference that should be addressed. Since it has been suggested that activities of daily living may account for up to 50% of MVPA in people with SCI,[51] it would therefore be particularly advisable for SCI population to have active lifestyles.

Even though the sample reached the MVPA threshold, this was only achieved by 42.7% of the participants. This suggests that factors other than injury may affect the weekly MVPA results. When we split the participants into EG and NEG based on the self-reported time spent engaged in PE, the results revealed that EG achieved an average of 260 min of MVPA per week, thus reaching the minimum MVPA recommended while the NEG obtained an average of 102 min per week of MVPA, failing to reach the recommended value. Therefore, engagement in PE is a factor that helps to achieve the desired levels of MVPA. Indeed, the NEG offered a low percentage of subjects reaching the threshold (27.3%), while this was attained by 62.7% of the EG participants. Nevertheless, although most of the EG participants achieved the recommended MVPA, 37.3% presented values below this threshold. This implies that not all kind of PE, even when practiced for more than three hours per week, help to reach the target level of MVPA. It would therefore be interesting for future studies to determine which PE activities more usually performed by people with paraplegia (i.e. basketball, hand bike, gym, racket sports) might help them to reach such level of MVPA.

The EG spent more than twice the amount of time performing MVPA as compared to the NEG. This supports the importance of being physically active and potentially considering adaptive sports as it has been suggested that people with SCI who participate in sports tend to work at higher intensities and for longer durations than those who merely exercise.[6] This result differs from that reported by Warms *et al.* (2008)[26] with manual wheelchair users according to which no differences were found in the levels of MVPA between those who usually performed PE of those who did not. This disparity in the outcome might be due to the way in which they classified active and non-active participants. While our study quantified the exact time of PE performed by the participants, their study used a classification based on the duration of exercise behavior in participants, considering the time they had been regularly doing PE.

Besides, the EG showed a higher level of light PA and a lower amount of sedentary behavior than NEG. Engagement in PE is related with psychological well-

being and improve physical abilities, as shown by previous studies.[6,7,52] This could in turn increase the vitality and willingness to have a more active lifestyle in terms of daily life activities, such as going out with friends, going shopping, doing housework, etc.

This could lead to an increased amount of energy and a tendency to increase the amount of daily living activity, ultimately, leading a more active lifestyle.

Future research should measure PA levels during the performance of different sports and PE programs and additionally consider the use of a water-resistant accelerometer in order to allow the analysis of PA intensity levels in aquatic physical activities. We consider that this is an important limitation of our study because swimming is a highly widespread PA among spinal cord injury population. Another limitation is that the wheelchair characteristics of the participants were not examined, and these are likely to significantly affect energy expenditure and PA participation in manual wheelchair users.[53] The results of this study should be taken with caution because, although the accelerometer was small and portable, participants may have changed their usual behavior in response to study participation.

Conclusions

In summary, our study highlights that MVPA levels are low in manual wheelchair users who are not regular exercisers, but most of those who self-reported being regular exercisers reach the minimum levels recommended for health benefits. Sedentary behavior is also a concern in this population. Participation in PE additionally leads to better results in light PA levels.

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Conflicts of interest Authors have no conflict of interests to declare.

References

1 Tasiemski T, Kennedy P, Gardner BP, Blaikley RA. Athletic Identity and sports participation in people with sprinal cord injury. Adapt Phys Act Q. 2004;21(4):364–378.
2 Lee M, Myers J, Hayes A, Madan S, Froelicher VF, Perkash I, *et al*. C-reactive protein, metabolic syndrome, and insulin resistance in individuals with spinal cord injury. J Spinal Cord Med. 2005;28(1):20–25.
3 Maruyama Y, Mizuguchi M, Yaginuma T, Kusaka M, Yoshida H, Yokoyama K, *et al*. Serum leptin, abdominal obesity and the metabolic syndrome in individuals with chronic spinal cord injury. Spinal Cord. 2008;46(7):494–499.
4 Garshick E, Kelley A, Cohen SA, Garrison A, Tun CG, Gagnon D, *et al*. A prospective assessment of mortality in chronic spinal cord injury. Spinal Cord. 2005;43(7):408–416.
5 Whiteneck GG, Charlifue SW, Frankel HL, Fraser MH, Gardner BP, Gerhart KA, *et al*. Mortality, morbidity, and psychosocial outcomes of persons spinal cord injured more than 20 years ago. Spinal Cord, 1992;30(9):617–630.
6 Ginis KM, Jetha A, Mack DE, Hetz S. Physical activity and subjective well-being among people with spinal cord injury: a meta-analysis. Spinal Cord. 2010;48(1):65–72.
7 Hicks AL, Martin KA, Ditor DS, Latimer AE, Craven C, Bugaresti J, *et al*. Long-term exercise training in persons with spinal cord injury: effects on strength, arm ergometry performance and psychological well-being. Spinal Cord Off J Int Med Soc Paraplegia. 2003;41(1):34–43.
8 Dietz V. Spinal cord lesion: effects of and perspectives for treatment. Neural Plast. 2001;8(1-2):83–90.
9 Jacobs PL, Nash MS. Exercise recommendations for individuals with spinal cord injury. Sports Med. 2004;34(11):727–751.
10 Biddle SJ, Fox K, Boutcher S. Physical activity and psychological well-being. New York: Routledge; 2003.
11 Myers J, Nieman D. ACSM's Resources for clinical exercise physiology. 2nd ed. Baltimore: Wolters Luwer/Lippincott Williams & Wilkins; 2010.
12 Myslinski MJ. Evidence-based exercise Prescription for individuals with spinal cord injury. J Neurol Phys Ther. 2005;29(2):104–106.
13 Abel T, Platen P, Vega SR, Schneider S, Strüder HK. Energy expenditure in ball games for wheelchair users. Spinal Cord. 2008;46(12):785–790.
14 Abel T, Kröner M, Rojas VS, Peters C, Klose C, Platen P. Energy expenditure in wheelchair racing and handbiking-a basis for prevention of cardiovascular diseases in those with disabilities. Eur J Cardiovasc Prev Rehabil. 2003;10(5):371–376.
15 Price M. Energy expenditure and metabolism during exercise in persons with a spinal cord injury. Sports Med. 2010;40(8):681–696.
16 de Groot S, van der Woude LHV, Niezen A, Smit CAJ, Post MWM. Evaluation of the physical activity scale for individuals with physical disabilities in people with spinal cord injury. Spinal Cord. 2010;48(7):542–547.
17 Martin Ginis KA, Phang SH, Latimer AE, Arbour-Nicitopoulos KP. Reliability and validity tests of the leisure time physical activity questionnaire for people with spinal cord injury. Arch Phys Med Rehabil. 2012;93(4):677–682.
18 Ginis K, Latimer A, Hicks A, Craven B. Development and evaluation of an activity measure for people with spinal cord injury. Med Sci Sports Exerc. 2005;37(7):1099–1111.
19 Latimer AE, Ginis KA, Craven BC, Hicks AL. The physical activity recall assessment for people with spinal cord injury: validity. Med Sci Sports Exerc. 2006;38(2):208–216.
20 Gutierrez DD, Thompson L, Kemp B, Mulroy SJ. The relationship of shoulder pain intensity to quality of life, physical activity, and community participation in persons with paraplegia. J Spinal Cord Med. 2007;30(3):251–255.
21 Zemper ED, Tate DG, Roller S, Forchheimer M, Chiodo A, Nelson VS, *et al*. Assessment of a holistic wellness program for persons with spinal cord injury. Am J Phys Med Rehabil. 2003;82(12):957–968.
22 Rauch A, Fekete C, Oberhauser C, Marti A, Cieza A. Participation in sport in persons with spinal cord injury in Switzerland. Spinal Cord. 2014;52:706–711.
23 Dyrstad SM, Hansen BH, Holme IM, Anderssen SA. Comparison of self-reported versus accelerometer-measured physical activity. Med Sci Sports Exerc. 2014;46(1):99–106.
24 van den Berg-Emons RJ, Bussmann JB, Haisma JA, Sluis TA, van der Woude LH, Bergen MP, *et al*. A prospective study on physical activity levels after spinal cord injury during inpatient rehabilitation and the year after discharge. Arch Phys Med Rehabil. 2008;89(11):2094–2101.
25 Warms CA, Belza BL. Actigraphy as a measure of physical activity for wheelchair users with spinal cord injury. Nurs Res. 2004;53(2):136–143.

26 Warms CA, Whitney JD, Belza B. Measurement and description of physical activity in adult manual wheelchair users. Disabil Health J. 2008;1(4):236–244.
27 Myers J, Gopalan R, Shahoumian T, Kiratli J. Effects of customized risk reduction program on cardiovascular risk in males with spinal cord injury. J Rehabil Res Dev. 2012;49(9):1355–1364.
28 van den Berg-Emons RJ, Bussmann JB, Stam HJ. Accelerometry-based activity spectrum in persons with chronic physical conditions. Arch Phys Med Rehabil. 2010;91(12):1856–1861.
29 Tanhoffer RA, Tanhoffer AI, Raymond J, Hills AP, Davis GM. Comparison of methods to assess energy expenditure and physical activity in people with spinal cord injury. J Spinal Cord Med. 2012; 35(1):35–45.
30 Munakata M, Kameyama J, Kanazawa M, Nunokawa T, Moriai N, Yoshinaga K. Circadian blood pressure rhythm in patients with higher and lower spinal cord injury: simultaneous evaluation of autonomic nervous activity and physical activity. J Hypertens. 1997;15(12):1745–1749.
31 Dearwater SR, LaPorte RE, Cauley JA, Brenes G. Assessment of physical activity in inactive populations. Med Sci Sports Exerc. 1985;17(6):651–655.
32 Nooijen CF, de Groot S, Postma K, Bergen MP, Stam HJ, Bussmann JBJ, *et al*. A more active lifestyle in persons with a recent spinal cord injury benefits physical fitness and health. Spinal Cord. 2012;50(4):320–323.
33 Hiremath SV, Ding D, Farringdon J, Vyas N, Cooper RA. Physical activity classification utilizing SenseWear activity monitor in manual wheelchair users with spinal cord injury. Spinal Cord. 2013;51(9):705–709.
34 Postma K, Berg-Emons van den HJG, Bussmann JBJ, Sluis TAR, Bergen MP, Stam HJ. Validity of the detection of wheelchair propulsion as measured with an activity monitor in patients with spinal cord injury. Spinal Cord. 2005;43(9):550–557.
35 Hulley SB, Cummings SR, Browner WS, Grady DG, Newman TB. Designing clinical research. Philadelphia: Lippincott Williams & Wilkins; 2013.
36 Eng J. Sample size estimation: how many individuals should be studied? Radiology, 2003;227(2):309–313.
37 NCCIH Clinical Research Toolbox [Internet]. NCCIH; 2013.
38 García-Massó X, Serra-Añó P, García-Raffi LM, Sánchez-Pérez EA, López-Pascual J, Gonzalez LM. Validation of the use of Actigraph GT3X accelerometers to estimate energy expenditure in full time manual wheelchair users with spinal cord injury. Spinal Cord. 2013;51(12):898–903.
39 Medicine AC of S, others. ACSM's guidelines for exercise testing and prescription. Philadelphia: Lippincott Williams & Wilkins; 2013.
40 Esliger DW, Copeland JL, Barnes JD, Tremblay MS. Standardizing and optimizing the use of accelerometer data for free-living physical activity monitoring. J Phys Act Health. 2005;2:366–383.
41 Catellier DJ, Hannan PJ, Murray DM, Addy CL, Conway TL, Yang S, *et al*. Imputation of missing data when Measuring physical activity by accelerometry. Med Sci Sports Exerc. 2005;37(11 Suppl):S555–S562.
42 Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. Med Sci Sports Exerc. 1998;30(5):777–781.
43 Bouchard CE, Shephard RJ, Stephens TE. Physical activity, fitness, and health: International proceedings and consensus statement. International Consensus Symposium on Physical Activity, Fitness, and Health, 2nd, May, 1992, Toronto, ON, Canada. 1994
44 Chastin SF, Baker K, Jones D, Burn D, Granat MH, Rochester L. The pattern of habitual sedentary behavior is different in advanced Parkinson's disease. Mov Disord. 2010;25(13):2114–2120.
45 da Silva R, Rizzo JG, Gutierres Filho PJB, Ramos V, Deans S. Physical activity and quality of life of amputees in southern Brazil. Prosthet Orthot Int. 2011;35(4):432–438.
46 Cavanaugh JT, Coleman KL, Gaines JM, Laing L, Morey MC. Using Step activity Monitoring to Characterize Ambulatory activity in community-Dwelling Older Adults. J Am Geriatr Soc. 2007;55(1):120–124.
47 Silva P, Aires L, Santos RM, Vale S, Welk G, Mota J. Lifespan snapshot of physical activity assessed by accelerometry in Porto. J Phys Act Health. 2011;8(3):352–360.
48 Fekete C, Rauch A. Correlates and determinants of physical activity in persons with spinal cord injury: A review using the International classification of Functioning, Disability and health as reference framework. Disabil Health J. 2012;5(3):140–150.
49 Warms CA, Belza BL, Whitney JD, Mitchell PH, Stiens SA. Lifestyle physical activity for individuals with spinal cord injury: a pilot study. Am J Health Promot. 2004;18(4):288–291.
50 Kehn M, Kroll T. Staying physically active after spinal cord injury: a qualitative exploration of barriers and facilitators to exercise participation. BMC Public Health. 2009;9(1):168–179.
51 Janssen TW, van Oers CA, van der Woude LH, Hollander AP. Physical strain in daily life of wheelchair users with spinal cord injuries. Med Sci Sports Exerc. 1994;26(6):661–670.
52 Edwards DJ, Edwards SD, Basson CJ. Psychological well-being and physical self-esteem in sport and exercise. Int J Ment Health Promot. 2004;6(1):25–32.
53 Van der Woude LH, de Groot S, Janssen TW. Manual wheelchairs: research and innovation in sports and daily life. Sci Sports. 2006;21 (4):226–235.