Energy expenditure during sitting, standing, wheelchair propulsion and walking in stroke survivors

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“ONDERGETEKENDE

Femke de Haan,

bevestigt hierbij dat de onderhavige verhandeling mag worden geraadpleegd en vrij mag worden gefotokopieerd. Bij het citeren moet steeds de titel en de auteur van de verhandeling worden vermeld.”

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SAMENVATTING

Doelstelling

Het doel van deze studie is het energieverbruik van mensen met een beroerte tijdens zitten, staan, voortbewegen in een rolstoel en lopen te vergelijken met het energieverbruik van ≤1.5 Metabolic Equivalent of Task (MET) genoemd in de definitie van sedentair gedrag voor gezonde volwassenen.

Methode

Het energieverbruik van mensen met een beroerte is gemeten door middel van indirecte warmtemeting (Metamax II) tijdens liggen, gesteund en ongesteund zitten, staan, voortbewegen in een rolstoel en lopen. De berekeningen zijn zowel uitgevoerd voor zowel de totale groep als voor de verschillende niveaus van de Functional Ambulation Categories (FAC).

Resultaten

Gesteund en ongesteund zitten gaven een lagere MET-waarde dan 1.5 voor de totale groep en FAC-niveaus. Voor de activiteit staan liet alleen de FAC 0 groep een hogere waarde zien (1.60 METs). Zowel de totale groep (n=27) als de groepen gedifferentieerd naar verschillende FAC niveaus lieten hogere MET-waardes zien dan 1.5 tijdens het voortbewegen met een rolstoel en lopen.

Conclusie

Het energieverbruik voor mensen met een beroerte tijdens zitten is niet hoog genoeg om als niet-sedentair te worden geclassificeerd. Ook voor staan is er geen evidentie dat het een niet-sedentaire activiteit is, uitgezonderd voor de FAC 0 groep. De definitie van sedentair gedrag voor gezonde volwassen is slechts gedeeltelijk toepasbaar op mensen met en beroerte omdat de activiteit staan niet deel uitmaakt van de definitie.

Klinische relevantie

Deze studie geeft inzicht in het energieverbruik van mensen met een beroerte tijdens houdingen en activiteiten. Dit kan leiden tot op maat gemaakte zorg en adviezen ten aanzien van sedentair gedrag en lichte activiteiten. Een belangrijke implicatie voor de praktijk is dat zelfstandig voortbewegen in een rolstoel een lichte activiteit is voor mensen met een beroerte. Deze bevinding kan gebruikt worden om mensen met een beroerte aan te moedigen om actiever te zijn door zichzelf te verplaatsen in de rolstoel.

ABSTRACT

Aim

The aim of this study is to compare the amount of energy expenditure during lying, sitting, standing, wheelchair propulsion and walking of stroke survivors with the energy expenditure of ≤1.5 Metabolic Equivalent of Task (MET) within the definition of sedentary behavior used in healthy adults.

Methods

Energy expenditure of stroke survivors was measured by indirect calorimetry (Metamax II) during lying, supported and unsupported sitting, standing, wheelchair propulsion and walking. Measurements were performed with aids used in daily life. Calculations were done for the total group as well as categorised by the Functional Ambulation Categories (FAC).

Results

Supported and unsupported sitting showed a lower MET value than 1.5 for the total group and all FAC levels. Only the group FAC 0 showed a higher MET value during standing (i.e. 1.60 METs). The total group (n=27) showed higher levels than 1.5 METs when propelling a wheelchair and walking, respectively 1.91 and 2.55. These increases were also the case when differentiated by ambulation level.

Conclusion

The energy expenditure for individuals with stroke to maintain their balance while sitting is not high enough to classify as non-sedentary. Moreover, also for standing, except for individuals classified at FAC 0, there is currently no evidence that qualifies standing as true non-sedentary time. Because standing is not a part of the definition of sedentary behavior for healthy adults, the definition seems only partly applicable to stroke survivors.

Clinical Relevance

This study gives insight concerning the amount of energy expenditure of stroke survivors during postures and activities, which may lead to better tailored care and advises during and after rehabilitation in terms of sedentary behavior and low intensity activities. Independent wheelchair propulsion seems to be a light activity which can be used in the clinical practise to encourage stroke survivors to be more active.

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Keywords:

1. Stroke
2. Sedentary behavior
3. Physical activity
4. Metabolic Equivalent of Task
5. Energy expenditure

INTRODUCTION

It is widely accepted that physical activity is fundamental for maintenance of metabolic health.[1-3] For example, a low cardio respiratory fitness level is associated with a higher risk of developing type II diabetes, types of cancer and cardiovascular diseases.[1-3] Recent research suggests risks for specific metabolic health consequences from 'non-exercise' time or sedentary behavior, like increased risk of coronary heart disease, hypertension, diabetes, obesity, and some cancers.[2,4-6] In addition, in healthy adults sedentary behavior is a risk factor for increased morbidity and mortality, independent of the amount of physical activity.[6-8] In other words, even though individuals meet the minimal public health recommendation of 30 minutes of vigorous activity per day, they still are at higher risk for increased mortality and morbidity.[6-11]

The hierarchy of the degree of physical activity has been described by means of the activity intensity continuum.[12] Sedentary behavior and light intensity activity fall in the low end of the activity intensity continuum, whereas moderate and vigorous intensity fall in the high end. The main focus of previous research on activity has been on moderate and vigorous activity, however, interest in sedentary behavior in the general population increased in the last decade.[3,13,14] In the past researchers have defined sedentary behavior as not participating in moderate to vigorous physical activity at recommended levels.[15] However, this seems to be incorrect when regarding the physiological consequences of sedentary behavior independent of the amount of moderate to vigorous activity.[6-11] The current definition of sedentary behavior in healthy adults is "any waking behavior characterized by an energy expenditure ≤ 1.5 metabolic equivalent of task (MET) while in a sitting or reclining posture".[16] It is surprising that, given the theoretical assumption that a lack of muscle activity contributes to the negative health outcomes associated with sedentary behavior, muscle (in)activity is not part of the currently accepted definition.[2] However, this has been solved by describing postures in the definition in which most of the body's largest muscles are under relaxation (i.e. sitting or reclining).[2]

Even though the above mentioned studies are conducted in healthy adults, the same findings of risk factors of sedentary behavior are most likely also apparent in stroke survivors. Currently it is still unknown during which postures and activities of daily life stroke survivors are sedentary or light active. As far as known no research has been conducted regarding this matter in stroke survivors. Recently published statement for healthcare professionals for the management of stroke survivors recommend participation in structured physical activity programs as well as reduction of sedentary behavior to improve or maintain health.[17] It is generally agreed that the majority of stroke survivors develop or return to an inactive lifestyle after rehabilitation due to the barriers to engage in physical activity.[17-20] These barriers are, among others, lack of professional support on discharge from hospital and follow-up, transport issues to structured classes/interventions, lack of control and negative affect.[19] Moreover, the effects of exercising are found to be negligible after follow-up.[15] Therefore, and based on the findings of previously mentioned studies[5-8,21], stroke survivors should not only engage in physical activity but also try to reduce or break up sedentary time to reduce the high risk for health problems like recurrence of stroke.[17,18]

Neuromuscular deficits present in stroke survivors, e.g. atypical muscle tone, impaired coordination, balance and sensory deficits, and muscle co-contraction are likely to influence energy expenditure in different postures.[22-24] Therefore it can be hypothesized that unsupported sitting requires energy demands which are high enough to define sitting as non-sedentary in stroke survivors, because of the demand of large muscles to maintain balance. In addition, in the general population, standing is defined as non-sedentary due to nondescript small movements, like shifting or fidgeting.[2] Stroke survivors often use a walking aid to maintain their posture, which may result in a lower energy expenditure whilst standing due to less nondescript small movements and less demand of the leg muscles. Therefore, standing may be sedentary for stroke survivors using a walking aid. Furthermore, there are few activities within healthy adults in which an individual is non-sedentary whilst sitting (e.g. riding a bike), due to a high enough level of energy expenditure.[12] Stroke survivors who experience severe neuromuscular deficits are often bound by a wheelchair to be independently mobile in daily life.[19] Thereby they have to perform active movement to propel the wheelchair whilst in a sitting posture, which may result in a high enough energy expenditure to be considered a light activity. In addition, given the variety of neuromuscular deficits, the patterns of energy expenditure may differ across different levels of ambulation. It can be hypothesized that the energy expenditure during postures and activities for less ambulant stroke survivors is higher compared to more ambulant stroke survivors due to the deficits mentioned above.

Summarizing, it is unclear whether the definition of sedentary behavior for healthy adults is applicable to stroke survivors since we do not know if stroke survivors show the same level of muscle activity, and thus energy expenditure, during maintaining postures like sitting and standing. Therefore, the aim of this study is to compare the amount of energy expenditure during lying, sitting, standing, wheelchair propulsion and walking of stroke survivors with the energy expenditure of ≤1.5 METs within the definition of sedentary behavior used in healthy adults.

METHODS

Design and subjects

The current study is a cross-sectional multicenter study. The Medical Ethics Research Committee (MERC) of the University Medical Centre (UMC) Utrecht confirmed that the Medical Research Involving Human Subjects Act (WMO) did not apply to this study.
Two healthcare institutions from the Stroke Service UMC Utrecht participated in this study; Rehabilitation Centre De Hoogstraat and nursing home Albert van Koningsbruggen. The inclusion of the subjects and data collection were performed between November 2013 and March 2014.

The population consisted of people who were stroke survivors and were rehabilitating in the participating centers. Subjects were considered eligible when they were diagnosed with stroke (ischemic or hemorrhagic), the onset of stroke was ≥ 6 weeks ago, able to understand and perform simple tasks, ≥ 18 years old, and able to understand and speak Dutch. A potential subject was excluded when the pre-morbid Barthel Index (BI) was ≤ 19 points. The subjects received an informational letter and written informed consent was obtained.

The aim was to include 25 subjects by convenience sampling. A sample size calculation could not be performed due to unknown effect size. Because the aim was to compare the energy expenditure of all stroke survivors to the definition in healthy adults, e.g. not categorized by ambulation categories, a sample of 25 stroke survivors seemed to be sufficiently to gain insight in the spread of METs.[25] In addition, to be able to compare the energy expenditure between the groups of ambulation levels the aim was to include 2 to 4 subjects per level.

Measures

The collected subject characteristics included gender, age, length, weight, lesion type, side of stroke, weeks since diagnosis, and use of cardiac medication. Stroke severity was assessed using the BI[26] and the Utrecht Scale for Evaluation of Rehabilitation (USER) domain physical functioning[27], both valid and reliable for measuring stroke severity.

The ambulation levels of the subjects were scored with the Functional Ambulation Categories (FAC).[28,29] This is an observational list which is validated for people with stroke. It is an ordinal scale which distinguishes 6 levels of walking ability on the basis of the amount of physical support required.[28,29] Level 0 indicates no walking ability or walking between parallel bars or with support of two persons. Level 5 indicates independent walking ability on all surfaces.[28,29]

The main study parameter was the Metabolic Equivalent of Task (MET) during lying, supported and unsupported sitting, standing, wheelchair propulsion and walking measured by indirect calorimetry. It is based on the indirect measure of the heat expended by nutrients oxidation, which is estimated by monitoring oxygen consumption (O_2) and carbon dioxide production (CO_2) for a certain period of time. The mobile gas analysis system MetaMax II (CORTEX Biophysik GmbH, Leipzig, Germany) consisted of a facemask, a transmitting unit (containing different oxygen and carbon dioxide gas analyzers), and a receiving unit. The transmitting unit with facemask and tubing (total weight 0.57 kg) was attached to the subjects with a harness. The receiving unit was connected to a laptop computer located within 5 meter of the transmitting unit. Metabolic stress test software (Metasoft, Version 2.6) was used to measure oxygen uptake (VO_2) every 10 seconds. The MetaMax II is a reliable and valid instrument to measure respiratory parameters.[30,31] Moreover, the heart rate was measured during the activities with the Polar T31 (Polar Electro, Kempele, Finland) heart rate transmitter, which is a reliable and valid instrument to measure heart rate.[32]

Procedures

The subjects were scheduled for testing between 10 and 12 o'clock and 14 and 17 o'clock to prevent a higher metabolism due to the digesting of a meal. The duration of the measurements was one hour per subject.

Measurement of energy expenditure for each posture started when the energy expenditure was stable for 30 seconds (i.e. maximum difference of 2 ml/kg/min VO_2). The VO_2 intake in rest was determined during lying down in a relaxed supine position for 5 minutes. After these 5 minutes the subjects were asked to sit supported and unsupported, and stand for maximum 5 minutes. After that the subjects were asked to propel their wheelchair for 6 minutes conform the instructions of the six-minute walk test (6 MWT).[33,34] This was performed indoors, along a long, flat, straight, enclosed corridor with a hard surface which was seldom travelled. The course was 25 meters in length. The length of the corridor was marked every 2.5 meter. The turnaround points were marked with a cone. The distance covered and the way it was performed by the subject were recorded. Furthermore, the subjects were asked to perform the 6 MWT. If the subject could not complete the 6 MWT, the total minutes walked were recorded.

The subjects had to perform the voluntary activities for at least 1 minute to determine a stable MET. When a subject could not perform the activity for at least 1 minute, the measurement was not included in the analysis. During the measurements the patients were asked not to speak and move as less as possible other than the performed activity. The activities were measured under the same circumstances the subjects performed them in daily life. This means, if the participant would stand with a walking aid in daily life, then the measurement of standing was conducted the same way. It was also possible that someone needed an ankle foot orthosis or facilitation during walking. All used aids were recorded for the different activities performed.

Data analysis

The mean (±SD) and the confidence interval of the VO_2 (ml/kg/min) and heart rate measured during lying, supported and unsupported sitting, standing, wheelchair propulsion and walking were calculated by descriptive statistics. The mean energy expenditure (represented in METs) for every activity was determined by dividing the mean VO_2-value of each activity with the mean VO_2-value during rest (lying). METs were calculated for the total group as well as FAC levels.

Non-parametric test procedures with the raw data were used due to small sample sizes for each FAC level. Differences between FAC levels in metabolic demand for the activities were analyzed using the Kruskal-Wallis test. Differences in metabolic demand for the activities compared to rest values were analyzed using the non-parametric Wilcoxon signed-rank test. The energy expenditure of subjects during rest was set as 1.0. These analyses were performed for the total group and all FAC levels separately.

Statistical analysis was conducted using SPSS version 19.0. Missing values were handled according to the principles of available case analysis. For all statistical tests, an alpha-value of less than .05 was considered statistically significant.

RESULTS

Subject characteristics

A number of 31 possible subjects were asked to participate within this study. Informed consent was provided by 29 of them. One person could not participate because he was not able to attend at the measuring dates. Furthermore, one person was excluded due to the problem that there was no possibility to measure the rest metabolism during lying.
Table 1 presents the descriptive statistics of the total sample and groups divided by the levels of the FAC. No subjects with FAC 1 participated in the study. The mean age of the total sample is 61.0 years and 77.8 percent of the subjects suffered an ischemic stroke. The amount of weeks passed after stroke was divers and ranged from 6 to 286.5 weeks. There were no significant differences on subject characteristics between the groups.

Outcome data

Table 2 presents the descriptive statistics of the oxygen uptake and the heart rate for the total sample and divided by the levels of the FAC. One subject with FAC 0 was not able to perform the standing activity. Moreover, two subjects did not perform the supported sitting activity due to not pursuing the protocol. The subjects who did not perform the wheelchair propulsion activity were complete ambulant (n=9) or the activity was to straining (n=2). Therefore, the number of subjects which carried out the wheelchair propulsion activity (n=16) is different from the other activities. Two subjects were not able to walk at all, and 20 subjects completed the 6 MWT.

Table 3 shows the MET values of the FAC levels. The total sample mean METs for sitting supported, sitting unsupported, standing, wheelchair propulsion and walking are respectively 1.04, 1.09, 1.31, 1.91 and 2.55.
There are no significant differences found in metabolic demands during the activities between the FAC levels. The mean MET values of all groups during wheelchair propulsion and walking are higher than 1.5 MET. Moreover, the mean value during standing for the subjects with FAC 0 is also higher than 1.5 MET.
Furthermore, table 3 shows whether the METs during sitting, standing, wheelchair propulsion and walking are significant different than the METs in rest. All activities are significantly different compared to rest for the total group. Supported and unsupported sitting, standing and walking are significantly different compared to rest in the group FAC 4. In addition, standing and walking are significantly different compared to rest in the group FAC 5.

Table 1. Subject characteristics (n=27).

Characteristics (units or maximum score)						
Subjects (n)	**Total (27)**	**FAC 0 (4)**	**FAC 2 (5)**	**FAC 3 (5)**	**FAC 4 (7)**	**FAC 5 (6)**
Age	61.0 ± 11.7 (36-80)	68.5 ± 9.9 (56-80)	56.4 ± 11.6 (38-68)	69.0 ± 6.6 (63-80)	52.6 ±12.5 (36-73)	63.0 ± 9.2 (49-76)
Sex, n (%)						
Male	16 (59.3)	2 (50.0)	3 (60.0)	3 (60.0)	3 (42.9)	5 (83.3)
Female	11 (40.7)	2 (50.0)	2 (40.0)	2 (40.0)	4 (57.1)	1 (16.7)
Length (m)	173.7 ± 9.7 (152-195)	175.3 ± 8.6 (165-168)	173.2 ± 7.6 (162-182)	171.2 ± 11.3 (152-180)	175.9 ± 14.1 (160-195)	172.7 ± 6.4 (161-178)
Weight (kg)	80.2 ± 15.9 (51.0-119.6)	87.5 ± 28.2 (58.8-119.6)	80.5 ± 11.0 (66.0-96.0)	86.0 ± 11.2 (75.0-103.0)	75.9 ± 18.8 (51.0-107.0)	75.5 ± 8.9 (68.0-91.0)
Type of stroke, n (%)						
Ischemic	21 (77.8)	4 (100.0)	4 (80.0)	4 (80.0)	5 (71.4)	4 (66.7)
Hemorrhagic	6 (22.2)	0 (0.0)	1 (20.0)	1 (20.0)	2 (28.6)	2 (33.3)
Hemiparetic side, n (%)						
Right	10 (37.0)	3 (75.0)	4 (80.0)	2 (40.0)	4 (57.1)	4 (66.7)
Left	17 (63.0)	1 (25.0)	1 (20.0)	3 (60.0)	3 (42.9)	2 (33.3)
Weeks poststroke	25.9 ± 53.0 (6.0-286.5)	80.0 ± 137.7 (6.0-286.5)	18.6 ± 14.4 (6.0-42.0)	12.8 ± 8.0 (7.5-27.0)	22.0 ±11.1 (6.5-34.0)	11.4 ± 4.8 (7.0-19.0)
Cardiac medication, n (%)						
No	11 (40.7)	0 (0.0)	2 (40.0)	2 (40.0)	3 (42.9)	4 (66.7)
Yes	15 (55.6)	4 (100.0)	2 (40.0)	3 (60.0)	4 (57.1)	2 (33.3)
Unknown	1 (3.7)	0 (0.0)	1 (20.0)	0 (0.0)	0 (0.0)	0 (0.0)
Barthel Index (20)	11 ± 6 (2-19)	6 ± 4 (2-10)	11	12 ± 7 (6-19)	18	-
USER-mobility (70)	37 ± 17 (4-66)	11 ± 7 (4-18)	30 ± 13 (9-41)	30 ± 11 (18-44)	42 ± 7 (31-51)	56 ± 9 (43-66)
Walking aid Functional Ambulation Categories, n (%)						
Parallel bars and 1 person	4 (14.8)	4 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Anterior walker	3 (11.1)	0 (0.0)	0 (0.0)	3 (60.0)	0 (0.0)	0 (0.0)
4-point cane and knee ankle foot orthosis	1 (3.7)	0 (0.0)	1 (20.0)	0 (0.0)	0 (0.0)	0 (0.0)
4-point cane and ankle foot orthosis	7 (25.9)	0 (0.0)	2 (40.0)	2 (40.0)	3 (42.9)	0 (0.0)
1-point cane and ankle foot ohosis	4 (14.8)	0 (0.0)	1 (20.0)	0 (0.0)	2 (28.6)	1 (16.7)
Ankle foot orthosis	3 (11.1)	0 (0.0)	1 (20.0)	0 (0.0)	0 (0.0)	2 (33.3)
None	5 (18.5)	0 (0.0)	0 (0.0)	0 (0.0)	2 (28.6)	3 (50.0)

*Values are mean ± SD (range) unless otherwise indicated.

Table 2. Oxygen uptake and heart rate values

Activities	V'O2/kg			HR		
	n	mean ± sd	CI	n	mean ± sd	CI
Lying						
Total	**27**	**4.38 ± .84**	**4.05 ; 4.72**	**23**	**71.16 ± 10.71**	**66.53 ; 75.79**
FAC 0	4	4.21 ± 1.62	1.64 ; 6.79	4	68.02 ± 10.57	51.20 ; 84.85
FAC 2	5	4.36 ± .57	3.65 ; 5.07	2	63.11 ± 7.96	-8.43 ; 134.65
FAC 3	5	4.67 ± .56	3.97 ; 5.36	5	82.87 ± 11.13	69.05 ; 96.69
FAC 4	7	3.79 ± .46	3.36 ; 4.21	6	67.79 ± 8.30	59.08 ; 76.50
FAC 5	6	4.98 ± .51	4.45 ; 5.52	6	69.56 ± 8.30	60.85 ; 78.27
Supported sitting						
Total	**25**	**4.47 ± .75**	**4.16 ; 4.78**	**24**	**74.78 ± 10.58**	**70.31 ; 79.24**
FAC 0	3	3.90 ± 1.24	.82 ; 6.99	3	66.17 ± 12.88	34.17 ; 98.17
FAC 2	5	4.45 ± .80	3.46 ; 5.44	4	76.88 ± 9.26	62.15 ; 91.61
FAC 3	4	4.58 ± .43	3.90 ; 5.26	4	88.87 ± 7.54	76.87 ; 100.87
FAC 4	7	4.28 ± .72	3.62 ; 4.94	7	72.17 ± 8.31	64.49 ; 79.85
FAC 5	6	4.94 ± .59	4.32 ; 5.56	6	71.33 ± 7.03	63.95 ; 78.70
Unsupported sitting						
Total	**27**	**4.77 ± 1.15**	**4.32 ; 5.23**	**25**	**76.93 ± 11.18**	**72.31 ; 81.55**
FAC 0	4	4.62 ± 1.54	2.17 ; 7.07	4	70.34 ± 11.42	52.18 ; 88.51
FAC 2	5	4.59 ± .96	3.41 ; 5.78	3	74.35 ± 9.64	50.41 ; 98.30
FAC 3	5	4.78 ± .59	4.06 ; 5.51	5	88.61 ± 12.12	73.56 ; 103.66
FAC 4	7	4.43 ± .94	3.56 ; 5.31	7	73.30 ± 7.66	66.21 ; 80.39
FAC 5	6	5.41 ± 1.64	3.68 ; 7.13	6	77.11 ± 10.16	66.44 ; 87.77
Standing						
Total	**26**	**5.66 ± 1.48**	**5.06 ; 6.26**	**25**	**87.16 ± 12.47**	**82.19 ; 92.34**
FAC 0	3	5.85 ± 1.94	1.03 ; 10.68	3	73.16 ± 10.39	47.36 ; 98.96
FAC 2	5	5.49 ± .80	4.50 ; 6.48	4	94.25 ± 7.78	81.87 ; 106.63
FAC 3	5	5.97 ± .86	4.90 ; 7.04	5	97.03 ± 10.41	84.11 ; 109.96
FAC 4	7	5.14 ± 1.27	3.97 ; 6.31	7	83.75 ± 10.47	74.07 ; 93.43
FAC 5	6	6.07 ± 2.40	3.55 ; 8.59	6	85.32 ± 13.16	71.51 ; 99.12

Wheelchair propulsion						
Total	**16**	**8.06 ± 1.84**	**7.08 ; 9.04**	**16**	**86.17 ± 11.37**	**80.12 ; 92.23**
FAC 0	2	5.56 ± 2.27	-14.84 ; 25.95	2	68.24 ± 2.29	47.66 ; 88.82
FAC 2	5	7.40 ± 1.15	5.98 ; 8.83	5	87.84 ± 12.33	72.54 ; 103.15
FAC 3	4	7.77 ± .91	6.32 ; 9.22	4	95.48 ± 7.53	83.49 ; 107.46
FAC 4	4	10.05 ± 1.23	8.10 ; 12.01	4	82.41 ± 4.72	74.90 ; 89.92
FAC 5	1	9.59	-	1	91.54	-
Walking						
Total	**25**	**10.95 ± 2.74**	**9.80 ; 12.11**	**24**	**99.79 ± 16.18**	**92.95 ; 106.62**
FAC 0	3	8.42 ± 2.90	1.21 ; 15.62	3	83.09 ± 15.65	44.22 ; 121.96
FAC 2	5	9.92 ± 1.99	7.44 ; 12.39	4	109.33 ± 15.95	83.95 ; 134.71
FAC 3	4	9.63 ± 1.61	7.06 ; 12.19	4	105.35 ±12.40	85.61 ; 125.08
FAC 4	7	10.68 ± 2.16	8.68 ; 12.68	7	91.67 ± 11.09	81.42 ; 101.93
FAC 5	6	13.54 ± 3.22	10.16 ; 16.91	6	107.53 ± 16.89	89.80 ; 125.25

Abbreviations: n, number of subjects; sd, standard deviation; CI, 95% Confidence Interval for mean; FAC, Functional Ambulation Categories; V’O2/kg, oxygen uptake; HR, heart rate

Table 3. METs during activities

FAC levels	METs					
	Lying	*Supported sitting*	*Unsupported sitting*	*Standing*	*Wheelchair propulsion*	*Walking*
Total	1.00	1.04 ± .11	1.09 ± .15*	1.31 ± .25*	1.91 ± .42*	2.52 ± 0.55*
FAC 0	1.00	1.07 ± .12	1.13 ± .13	1.60 ± .22	1.93 ± .51	2.32 ± .60
FAC 2	1.00	1.01 ± .08	1.05 ± .11	1.26 ± .08	1.70 ± .18	2.26 ± .32
FAC 3	1.00	.96 ± .11	1.03 ± .18	1.28 ± .23	1.64 ± .37	2.13 ± .56
FAC 4	1.00	1.13 ± .09*	1.16 ± .14*	1.35 ± .24*	2.43 ± .29	2.84 ± .60*
FAC 5	1.00	.99 ± .07	1.07 ± .20	1.20 ± .32*	1.89	2.71 ± .46*

Values are mean ± sd**.** Abbreviations: FAC, Functional Ambulation Categories; MET, Metabolic Equivalant of Task
*significant p-value ($p < .05$) calculated with Wilconxon signed-rank Test

DISCUSSION

The aim of this explorative study was to compare the amount of energy expenditure during lying, sitting, standing, wheelchair propulsion and walking of stroke survivors with the energy expenditure of ≤ 1.5 METs within the definition of sedentary behavior in healthy adults. The total group showed higher levels than 1.5 METs when propelling a wheelchair and walking, respectively 1.91 and 2.55 METs. These increases were also observed when differentiated by FAC level. However, supported and unsupported sitting showed a lower MET value than 1.5 for the total group and all FAC levels. Only the group FAC 0 showed a higher MET value during standing (i.e. 1.60 METs).

No previous research has been conducted to measure the energy expenditure during sitting in stroke survivors. We hypothesized that unsupported sitting would be non-sedentary for stroke survivors who are less ambulant. The results of this study do not provide evidence for that. The differences between supported sitting and unsupported sitting were small and not significant. The results of this study indicate that stroke survivors are sedentary during sitting.

Previous research is ambiguous concerning standing to be a sedentary behavior or light activity in healthy adults.[12,35,36] The theory behind the assumption of standing costing more energy is that of the need of muscle contraction to maintain the upright posture.[2,37] Due to the lack of demand for recruitment of larger muscle groups, activities that require ≤1.5 METs are considered to be sedentary behaviors.[15] Most research in sedentary behavior has not evaluated muscle activity. As discussed by Verschuren et al. (2014), it is an important component to understand**.**[38] Since the mechanisms underlying the negative health consequences of prolonged sedentary time may be directly due to muscle inactivity, it is important to establish how much muscle activity is sufficient to attenuate these consequences. The contribution of non-exercise activity thermogenesis, which includes fidgeting, spontaneous muscle contraction, and maintaining posture, may represent a greater proportion of daily energy expenditure among stroke survivors, than for healthy adults.[39] The compendium of physical activities, published by Ainsworth et al. (2011), shows two types of standing, e.g. standing quietly (1.3 MET) and standing fidgeting (1.8 MET).[12] The difference between these types of standing could be the reason for the ambiguous thoughts about standing being sedentary or not. Houdijk et al. (2010) conducted a study which reveals that standing in stroke survivors is more energy demanding than in healthy adults.[37] However, raw data have not been mentioned, therefore a comparison with the current study cannot be made. For the total sample standing seems to be a sedentary behavior because the energy expenditure did not exceed the 1.5 MET within the definition. For individuals classified at FAC 0, energy expenditure, that represent muscle activity was >1.5 METs. This finding suggests that standing for individuals with this level of involvement is a challenging task. Another important issue is that standing in this study was measured using the walking aids the subjects used in daily life. Because of the use of walking aids it might be possible that the energy expenditure during standing is lower compared to standing without a walking aid due to less use of the big leg muscles and less shifting and fidgeting.

To our knowledge this is the first study in which the actual energy expenditure during wheelchair propulsion is measured. Much research on physical activity and energy expenditure has been done with activity monitors. For example, the amount of wheelchair propulsion has been investigated several times in people with spinal cord injury. All of these studies used an activity monitor to record the degree of physical activity by means of duration of wheelchair propulsion, number of wheel revolutions and accelerometer counts. However, none of them actually measured how much energy expenditure there is during wheelchair propulsion by means of indirect calorimetry. Furthermore, there have been two studies published about wheelchair propulsion in stroke survivors.[42,43] They compared the energy expenditure during propulsion of different wheelchairs. However, no raw data were shown and the participants had to fulfill the task as soon as possible[42], or the driving course was made more difficult using obstacles[43]. Of course, these circumstances result in a higher energy expenditure than propulsion at comfortable speed in a straight corridor. Therefore, it was still unknown what kind of activity wheelchair propulsion at comfortable speed was regarding the activity continuum. Within the current study it could be stated that wheelchair propulsion for stroke survivors is a light activity.

Energy expenditure during walking in stroke survivors has been measured several times in the past.[24,44,45] Danielsson et al. (2007) compared stroke survivors with healthy adults walking on a treadmill.[45] They have said that walking on a treadmill costs more energy in stroke survivors than healthy adults walking the same distance. However, walking on a treadmill has been stated to be different than walking on a flat surface because someone has to make his own speed.[45] Platts et al. (2006) performed a comparable execution of their research about energy expenditure during walking with this current study.[44] Subjects (n=13) were walking a flat elliptical course for 5 minutes at their comfortable walking speed. The oxygen uptake of the subjects with stroke was 11.12 mL·kg^{-1} (± 3.1 mL·kg^{-1}), which is comparable to the oxygen uptake in this current study of 10.95 mL·kg^{-1} (± 2.74 mL·kg^{-1}). In addition, the difference in energy expenditure during walking might be caused by a lower mean age (61.0 vs. 40.7 years), lower mean weight (80,2 vs. 69.2 kg) and a higher level of ambulation (able to walk independently for at least 5 minutes with a stick or without an aid) of the sample used by Platts et al..[44] Moreover, a different indirect calorimetry device was used and they did not consider dietary intake. In this current study there could be said that walking at comfortable speed is a light activity for stroke survivors since the MET value is 2.55. This falls within light activity which had been stated to range from 1.6 to 2.9 METs.[12]

There were no significant differences distinguished between the FAC levels within the activities. However, within the FAC 4 group the oxygen consumption in all activities accept wheelchair propulsion were significantly different from lying. The FAC 4 group had a respectively lower oxygen consumption in rest compared to the other groups which might explain the significant outcomes on the Wilcoxon signed-rank Test for this group. Furthermore, the FAC 5 group showed significant differences on standing and walking. The energy consumption of this group during walking was 13.54 V'O2/kg compared to 8.42 V'O2/kg of FAC 0. This indicates that walking for ambulant stroke survivors is more energy demanding then stroke survivors who are only able to walk with support of parallel bars or two persons. An explanation for that would be that the body's larger muscles are not appealed, and most likely not able, to be active.

This study has some limitations. At first, conclusions about the differences between FAC levels should be taken with caution due to the small groups. However, the number of subjects in the total group is fair and the lower end of the activity continuum has been well described by the results of the current study. Second, the sample did not include all levels of the FAC. The absence of a FAC 1 group could be caused by the difficulty to differentiate between FAC 0 en 1, and FAC 1 and 2. Another explanation could be a lack on stroke survivors with a score of 1 on the FAC at the moment of inclusion.

For future research it would be interesting to investigate the relationship between heart rate and oxygen uptake. This could give therapists an easier tool for assessing energy expenditure during treatment. Another recommendation for future research is to repeat this study differentiating the stroke survivors by the walking aids they use in daily life instead of using the FAC. In that way there might be more homogeneous groups in relation to energy consumption during standing and walking.

CONCLUSION

The energy expenditure for individuals with stroke to maintain their balance while sitting is not high enough to classify as non-sedentary. Moreover, also for standing, except for individuals classified at FAC 0, there is currently no evidence that qualifies standing as true non-sedentary time. Because standing is not a part of the definition of sedentary behavior for healthy adults, the definition seems only partly applicable to stroke survivors.
This study provides insight concerning the amount of energy expenditure of stroke survivors during postures and activities, which may lead to tailored care and advises during and after rehabilitation in terms of sedentary behavior and low intensity activities.

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