Physical Activity and Sedentary Behaviors in People With Stroke Living in the Community: A Systematic Review

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Background. Regular physical activity is vital for cardiovascular health. Time spent in sedentary behaviors (eg, sitting, lying down) also is an independent risk factor for cardiovascular disease. The pattern in which sedentary time is accumulated is important—with prolonged periods of sitting time being particularly deleterious. People with stroke are at high risk for cardiovascular disease, including recurrent stroke.

Purpose. This systematic review aimed to update current knowledge of physical activity and sedentary behaviors among people with stroke living in the community. A secondary aim was to investigate factors associated with physical activity levels.

Data Sources. The data sources used were MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Allied and Complimentary Medicine Database (AMED), EMBASE, and the Cochrane Library.

Study Selection. Studies involving people with stroke living in the community and utilizing objective measures of physical activity or sedentary behaviors were included.

Data Extraction. Data were extracted by one reviewer and checked for accuracy by a second person.

Data Synthesis. Twenty-six studies, involving 983 participants, were included. The most common measure of activity was steps per day (22 studies), which was consistently reported as less than half of age-matched normative values. Only 4 studies reported on sedentary time specifically. No studies described the pattern by which sedentary behaviors were accumulated across the day. Walking ability, balance, and degree of physical fitness were positively associated with higher levels of physical activity.

Limitations. This review included only studies of people living in the community after stroke who were able to walk, and the majority of included participants were aged between 65 and 75 years of age.

Conclusions. Little is known about the time people with stroke spend being sedentary each day or the pattern in which sedentary time is accumulated. Studies using objective, reliable, and valid measures of sedentary time are needed to further investigate the effects of sedentary time on the health of people with stroke.

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Participation in adequate physical activity is critical to optimal metabolic health and the prevention of chronic diseases, particularly type 2 diabetes and cardiovascular disease.[1] Even moderately active individuals are 20% less likely to experience a stroke than inactive adults, and this risk reduction is greater in people with high levels of physical activity.[2] Current guidelines recommend that people with stroke should accumulate at least 150 minutes a week of moderate-intensity physical activity.[3]

In the past 10 years, research in the general population about the health effects of *sedentary behavior*, defined as "activities expending ≤1.5 metabolic equivalents [METs] while in a sitting or lying posture" has increased.[4–6]

Epidemiological studies in the United Kingdom and Australia have shown a link between increased amounts of sitting time and cardiovascular disease morbidity and mortality, a link that is independent of levels of physical activity.[7–9] Studies have shown that, in addition to the total amount of sitting time accumulated in the day, the pattern in which sitting time is accumulated across the day is important, with long, uninterrupted bouts of sedentary behaviors the most detrimental to health.[10,11] Sedentary behavior research has resulted in changes to the way physical activity is recommended for the general population. The emphasis has broadened from encouraging moderate-to-vigorous intensity physical activity to now include advice to sit less and to break up sitting time with light activity (ie, moving around or standing).[12,13] Changing activity behavior is an important part of a risk reduction program for people with stroke, yet the problem of sedentary behavior, and to a lesser extent lack of physical activity, in people with stroke is poorly understood.

With current knowledge of the separate and independent health consequences of physical activity and sedentary behaviors, it is important to document current knowledge about both physical activity levels and patterns of sedentary behaviors in people living with stroke-related disability. This systematic review provides a synthesis of research about objectively measured physical activity and sedentary behavior in people with stroke and is a logical progression from an earlier systematic review that focused on the clinometric properties of accelerometers for use with people with stroke.[14] Information from this systematic review can be used to identify gaps in knowledge and to guide future research with people with stroke. The overarching aim of this systematic review is to answer the question: How active are people living in the community with a stroke-related disability? Specifically:

1. How much time per day do people with stroke spend sedentary (ie, sitting or lying down)?

2. How much time per day do people with stroke spend engaged in physical activity, and when they are active, what is the intensity level (light, moderate, vigorous) of this activity?

3. What is the pattern of accumulation of sedentary time and physical activity? and

4. What factors influence physical activity levels in people with stroke?

Materials and Methods

Study Identification

The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[15] Similar to the Consolidated Standards of Reporting Trials (CONSORT) statement,[16] the PRISMA statement aims to improve the standard of reporting of systematic reviews and meta-analyses. A comprehensive search strategy was conducted using the following databases: MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Allied and Complimentary Medicine Database (AMED), EMBASE, and the Cochrane Library. The search strategy was built in MEDLINE and adapted to the other databases. Medical Subject Headings (MeSH) terms included (but were not limited to) "stroke," "brain injuries," "motor activity," "locomotion," "walking," "energy metabolism," "physical fitness," "sedentary lifestyle," "monitoring," "ambulatory," and "actigraphy." The full search strategy is available from the lead author (C.E.). The principal searches were conducted between June 30, 2012, and July 13, 2012. On November 7, 2012, a final search for new articles published since July 2012 was conducted. Reference lists of systematic reviews and included articles were scrutinized for further eligible studies.

One person (C.E.) conducted all the searches and completed the initial screen of titles and abstracts. Two people (C.E., P.J.M.) independently reviewed the full text of all potential titles against the inclusion criteria. Any disagreements were resolved by consensus. To be included, studies had to meet the following criteria: (1) report new, original data; (2) peer-reviewed full-text article (theses and conference abstracts were excluded); (3) include adults who had experienced a stroke; (4) include at least one objective measure of free-living physical activity or exercise (eg, accelerometry); (5) the objective measurements of physical activity must have been taken in a free-living situation (ie, while undertaking their usual daily activities in the community and not in a hospital, residential care facility, or laboratory) and over at least 2 days; and (6) full text available in English.

Critical Appraisal

We selected a critical appraisal tool (the Scottish Intercollegiate Guidelines Network Methodology Checklist 4: Case-Control Studies[17]) that had been specifically designed for use in case-control observational studies and had been through a process of robust development.[18] As the studies included in this review were not all case-control studies, we adapted this tool to be appropriate for use in a wider range of research designs. All adaptations were made with reference to and in accordance with the Cochrane Collaboration guidelines for assessing risk of bias.[19] The tool, as used in this review, includes detailed instructions on scoring of each item and is available on request from the lead author (C.E.). Two independent reviewers (P.J.M., C.T.) assessed the risk of bias of each study, and any disagreements between the 2 reviewers were resolved by a third reviewer (C.E.).

Data Extraction and Analyses

Data were extracted from all included studies by one reviewer (C.E.) and checked for accuracy by a second person (P.J.M.). Where data were collected from the same participants at different time points, only data from the latest time post-stroke were included. Where data were collected before and after an intervention, only whole group baseline data were included. Every attempt was made to contact authors of included studies to obtain unreported data.

Role of the Funding Source

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Results

Study Identification

A total of 4,890 potentially relevant hits arose out of the original and updated searches, of which 61 proceeded to full-text review. The process of study selection in accordance with the PRISMA statement[15] is presented in the Figure.

A total of 26 studies (reported in 30 articles) were included, with a combined total sample of 983 participants. Studies were published between 1998 and 2012, with the majority of studies (n=19, 73%) published between 2007 and 2012. Sample sizes ranged from 8[20] to 102,[21] and the majority included participants at least 6 months after stroke who were living in the community and able to walk short distances independently. Characteristics of the included studies are shown in Table 1. Physical activity data, including measurement tools used and predictors of physical activity, are summarized in Table 2.

Methodological Quality

Table 3 presents the results of the critical appraisal for each included study. Overall, the quality was good, with all articles scoring a low risk of bias (or not applicable) on at least 5 out of the 9 criteria. In 25 of the 30 articles, inclusion and exclusion criteria were clearly stated. However, the number of potential participants who were screened for inclusion was reported in only 7 articles (23%). In the majority of studies (n=24, 80%), a valid and reliable method of measuring physical activity was used. However, only 11 studies (37%) were considered to have adequately accounted for confounding variables in their analyses, in particular by ensuring groups were matched (where applicable) and measurement of physical activity was conducted over at least 5 consecutive days.

Sedentary Time

No studies specifically aimed to measure sedentary behavior, but we were able to extract estimates of sedentary time from several articles. Four studies used a measurement protocol that enabled reporting of the time participants were not on their feet—that is, sitting or lying down. One study with a small sample size (n=8) reported that sedentary time over 24 hours was 81%, or approximately 19.5 hours.[20] Another study with a larger sample size (n=42) demonstrated people with stroke spent an average of almost 7 hours (63% of the average 10-hour monitored period) either sitting or lying down.[22] This was the only trial that reported comparisons between the sedentary time of participants with stroke and those who were healthy (controls). Participants who were healthy spent a similar time sedentary (7.5 hours) accumulated over a longer time period (13 hours), and they were recorded as having almost double the number of changes in posture (109 compared with 57).[22] Janssen et al[23] did not directly report on sedentary time, but the percentages of time in an 8-hour period spent moving from a sitting to a standing position (16.6%), standing (9.4%), and walking (8.3%) leave approximately 66% of time where participants with stroke must have been either sitting or lying down. In one study in which accelerometers were used to monitor physical activity, accelerometer counts of 0 per minute (indicating no activity) occurred for 13 hours (87%) (of a 15-hour monitoring period).[24]

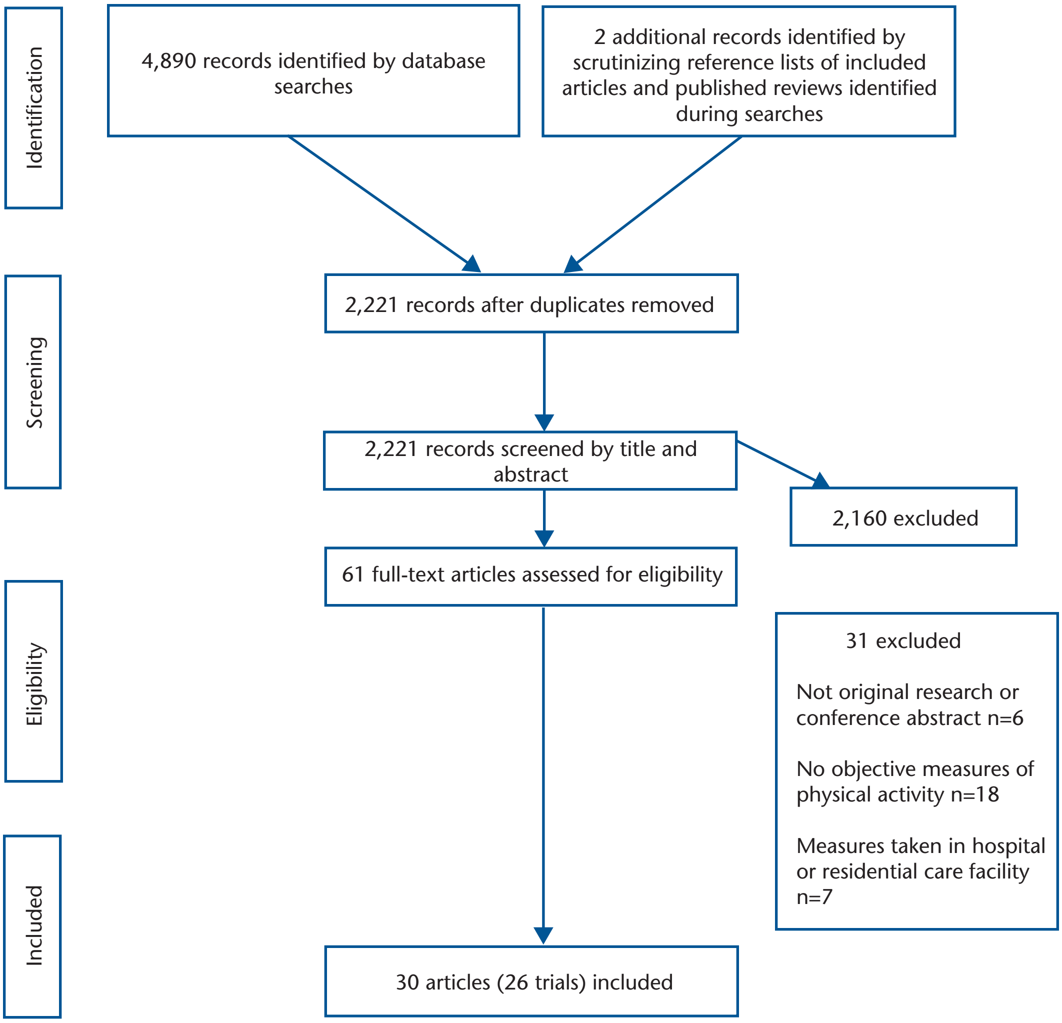

Figure.
Flow chart of study inclusion.

Time Spent in Light-Intensity Activity (Standing and Walking)

In 22 studies, steps per day were reported; in 15 of these studies, the StepWatch Activity Monitor (Orthocare Innovations, Oklahoma City, Oklahoma) was used, which is the most accurate monitor for measurements of steps, particularly in people who walk slowly or with uneven gait patterns.[25,26] Of those studies in which the StepWatch Activity Monitor was used, average daily step counts for survivors of stroke was between 1,389 (SD=797)[27] and 7,379 (SD=3,107).[28] In 4 studies,[28–31] the average daily step counts of age-matched controls who were healthy (also measured using the StepWatch Activity Monitor) were reported as between 6,294 (SD=1,768)[29] and 14,730 (SD=4,522)[28] steps per day.

Time on feet or time spent walking was reported in 5 studies. Estimates of time on feet ranged from 2.7 to 4.5 hours per day.[20,22,23] In 2 studies, average time spent walking (excluding standing time) was reported as 3.8 (SD=1.1) hours per day[32] and 1 hour per day (SD not available).[30]

The intensity of walking activity based on step cadence was reported in 2 studies. In these studies, 45%[27] and 69%[32] of all walking activity was at light intensity—that is, less than 30 steps per minute. Finally, using heart rate estimations of intensity of activity normalized to individual participants, Baert et al[33] estimated that participants spent an average of 2.5 hours or 13% of monitored time in light-intensity activity.

Time Spent in Moderate-to-Vigorous Physical Activity

Fewer studies reported on time spent specifically engaged in more vigorous physical activity. In 2 studies, moderate or vigorous activity was defined in terms of step

Table 1.
Characteristics of Included Studies[a]

Study	Design	Sample Size n (% Male)	Age (y) $\bar{X}$ (SD or Range)	Inclusion Criteria	Time Since Stroke (y) $\bar{X}$ (SD or Range)	Physical Activity Outcome Measure	Time Frame of Measurement	Monitored Period (per Day)
Alzahrani and colleagues, 2009[38]/2011[22]/2012[50]	Cross-sectional	42 (69%)	70 (10)	Able to walk independently	2.8 (1.4)	IDEEA	2 d	10.8 h
Baert et al, 2012[33]	Cross-sectional	16 (75%)	61.9 (11.9)	Age <75 y	1	Pedometer Heart rate monitor	5 d	Waking hours
Bowden et al, 2008[35]	Cross-sectional	59 (81%)	61.9 (10.8)	Able to walk independently	4.0 (3.7)	SAM	5 d	Waking hours
Fulk et al, 2010[29]	Cross-sectional	19 (53%)	65.7 (11.9)	Able to walk independently at ≥0.4 m/s	3.5 (3.0)	SAM	7 d	Waking hours
Hachisuka et al, 1998[21]	Cross-sectional	102 (67%)	64.6 (5.0)	Living at home	7.0 (4.6)	Pedometer	7 d	Waking hours
Haeuber et al, 2004[51]	Cross-sectional	17 (47%)	65 (6)	Able to walk independently	3.4 (0.75–10)	SAM Accelerometer	4 d	Waking hours
Hale et al, 2008[52]	Cross-sectional	20[b] (50%)	72 (7.1)	Living at home, able to walk independently	Not reported	Accelerometer	7 d	11 h
Janssen et al, 2010[23]	Longitudinal	41 (73%)	61 (13)	≤4 d of stroke	0.9[c]	Accelerometer	1 d	8 h
Katoh et al, 2002[41]	Cross-sectional	20 (80%)	64 (9)	Able to walk independently	1.8 (1.0)	Accelerometer	12 d (SD=4)	14 h
Manns and colleagues, 2009[28]/2010[34]	Cross-sectional	10 (40%)	54.3 (10)	Able to walk independently	7.5 (8.3)	SAM	4 d	Waking hours
Manns and Baldwin, 2009[32]	Longitudinal	10 (60%)	66 (15)	Able to walk independently	0.3[d]	SAM	3 d	Waking hours
Michael et al, 2005[36]	Cross-sectional	50 (56%)	65 (45–84)	Able to walk independently	0.86 (0.5–13.8)	SAM	2 d	Waking hours
Michael et al, 2006[39]	Cross-sectional	53 (59%)	66 (45–84)	Able to walk independently	0.86 (0.5–13.8)	SAM	2 d	Waking hours
Michael and Macko, 2007[27]	Cross-sectional	79 (53%)	65 (45–84)	Able to walk independently	0.86 (0.5–13.8)	SAM	2 d	Waking hours
Michael et al, 2009[53]	Preintervention-postintervention	10 (70%)	71 (61–79)	Able to walk independently	7.5 (4–22)	SAM	5 d	24 h
Moore et al, 2010[54]	Randomized crossover trial	14 (70%)	50 (9.6)	Able to walk independently ≤0.9 m/s	1.1 (0.7)	SAM	5 d	Waking hours
Mudge et al, 2009[55]	Randomized controlled trial	58 (55%)	71.5 (39–89)	Able to walk independently	3.9 (0.5–18.7)	SAM	3 d	Waking hours
Rand and colleagues, 2009[56]/2010[24]	Cross-sectional	40 (33%)	66.5 (9.6)	Able to walk independently	2.9 (2.4)	Accelerometer	3 d	15 h
Resnick et al, 2008[40]	Randomized controlled trial	87 (59%)	63.7 (12.3)	Able to walk independently	Not reported	SAM Self-report	2 d	24 h
Robinson et al, 2011[42]	Cross-sectional	50 (54%)	65 (8.4)	Able to walk independently	7.1 (7.5)	Pedometer	7 d	Not specified
Roos et al, 2012[30]	Cross-sectional	51 (not reported)	63.7 (10.4)	Able to walk independently	3.4 (3.1)	SAM	3 d	24 h
Sakamoto et al, 2008[20]	Cross-sectional	8 (50%)	63.4 (7.3)	Able to walk independently	3.4 (1.4)	IDEEA	24 h	24 h
Shaughnessy et al, 2005[57]	Cross-sectional	19 (53%)	68 (13)	Living at home	0.25[e]	SAM	48 h	24 h
Tiedemann et al, 2012[37]	Randomized controlled trial	76 (50%)	66.7 (14.3)	Able to walk independently	6.7 (6.7)	Pedometer	7 d	Waking hours
Touillet et al, 2010[58]	Preintervention-postintervention	9 (78%)	46 (7.2)	Able to walk independently	0.6 (0.4)	activPAL[f]	7 d	Not specified
Zalewski and Dvorak, 2011[31]	Cross-sectional	17 (82%)	71.3 (9.5)	Self-described as mobile in the community	2.2 (0.7–7.2)	SAM Self-report	1	24 h

[a] IDEEA=Intelligent Device for Energy Expenditure and Activity, SAM=StepWatch Activity Monitor.
[b] n=20 survivors of stroke out of total sample of N=47.
[c] All participants measured at 48 weeks poststroke.
[d] Measured 6 wk after hospital discharge, about 17 wk poststroke.
[e] Measured 3 mo after discharge from rehabilitation.
[f] Manufactured by PAL Technologies Ltd, Glasgow, United Kingdom.

Table 2.
Physical Activity Data[a]

Study	Steps per Day, Measurement Tool $\bar{X}$ (SD)	Other Physical Activity Data $\bar{X}$ (SD)	Age-Matched Control Data	Significant Predictors of Physical Activity	Factors Not Predictive of Physical Activity
Alzahrani and colleagues, 2009[38]/2011[22]/2012[50]	5,475 (3,999), IDEEA	Time on feet: 230 (115) min/d Time not on feet: 418 (101) min/d Transitions: 57 (43)	Time on feet: 309 (103) min/d Time not on feet: 454 (96) min/d Transitions: 109 (91) Steps: 10,964 (3,804)	Mobility (gait speed, 6MWT, timed stair climb)	
Baert et al, 2012[33]	6,428 (4,117), pedometer	HR derived: —Moderate-intensity activity: 44 (39) m/d —Light-intensity activity: 149 (107) min/d		Mobility (RMA, gait speed) Fitness ($\dot{V}O_2$peak) Mood (Beck Depression Inventory) Participation (SIS)	Age, sex, daylight hours
Bowden et al, 2008[35]	2,777 (1,483), SAM			Gait speed categories	
Fulk et al, 2010[29]	3,838 (1,963), SAM		Steps: 6,294 (1,768)	Mobility (6MWT)	Mobility (gait speed) Impairment (FMA-LE, BBS) Participation (SIS) Age
Hachisuka et al, 1998[21]	3,315 (1,930), pedometer				
Haeuber et al, 2004[51]	3,035 (1,951), SAM	Accelerometer-derived energy expenditure: 321 (187) kcal/d		Energy expenditure and steps per day	
Hale et al, 2008[52]		Accelerometer-derived "activity units"/d: 673,920 (379,495)			Mobility (RMI)
Janssen et al, 2010[23]		% 8-h period performing sit-to-stand maneuver: 16.6 (13.6) % 8-h period standing: 9.4 (8.8) % 8-h period walking: 8.3 (9.5)			
Katoh et al, 2002[41]	4,346 (2,993), uniaxial accelerometer	Accelerometer-derived energy expenditure: 112 (82) kcal/d		Fitness ($\dot{V}O_2$peak workload on kinetics [-ve correlation])[b]	
Manns and colleagues, 2009[28]/2010[34]	7,379 (3,107), SAM	No. of activity bouts: 64 (19)/d Duration of activity bouts[c]: 4.1 (0.7) min	No. of activity bouts: 74 (10)/d Duration of activity bouts[c]: 4.1 (0.7) min, 5.6 (1.6) min Steps: 14,730 (4,522)		Fitness (O_2 kinetics and bouts of activity approached significance) Impairment (CMSA limb scores) Functional ability (CS-PFP10)
Manns and Baldwin, 2009[32]	6,795 (2,068), SAM	Any activity: 229 (65) min/d No. of activity bouts: 61.5 (17.9) —% active time light intensity (<15 strides/min): 68.5 (8.4) —% active time moderate intensity (15–39 strides/min): 26.2 (5.4) —% active time high intensity (≥40 strides/min): 5.4 (5.8)			
Michael et al, 2005[36]	2,837 (1,503), SAM			Mobility (gait speed) Impairment (BBS)	Fitness ($\dot{V}O_2$peak, economy of gait)
Michael et al, 2006[39]	2,821 (1,527), SAM			Impairment (BBS)	Fatigue (FSS)

(Continued)

Table 2.
Continued

Study	Steps per Day, Measurement Tool $\bar{X}$ (SD)	Other Physical Activity Data $\bar{X}$ (SD)	Age-Matched Control Data	Significant Predictors of Physical Activity	Factors Not Predictive of Physical Activity
Michael and Macko, 2007[27]	1,389 (797), SAM	SAM cadence derived: 45% all stepping activity was at low intensity, 46% at moderate intensity and 6% at high intensity		Fitness ($\dot{V}o_2$peak)	Fatigue
Michael et al, 2009[53]	2,608 (1,563), SAM				
Moore et al, 2010[54]	3,846 (2,932), SAM[d]				
Mudge et al, 2009[55]	5,719 (3,431), SAM	% waking hours inactive: 83 (8)			
Rand and colleagues, 2009[56] and 2010[24]		Triaxial accelerometer counts: 53,075 (83,476) Accelerometer-derived energy expenditure: 156 (141) kcal/d 87% of waking hours inactive		Self-report activity EE (PASIPD) Mobility (6MWT) Impairment (BBS, CMSA lower limb score) HRQOL (SF-36)	
Resnick et al, 2008[40]	4,055 (2,401), SAM			Fitness ($\dot{V}o_2$peak)	
Robinson et al, 2011[42]	2,540 (2,176), pedometer			Fatigue (FSS) Depression (CES-D)	Age Falls and balance self-efficacy (ABC and FES) Perceived difficulty walking Satisfaction with level of participation
Roos et al, 2012[30]	3,000 (slow walkers) to 6,000 (fast walkers), SAM	1[e] (slow walkers) to 1.5 (fast walkers) h/d walking; 150 bouts[f] of walking per day	10,000, SAM, 250 bouts[f] of walking per day	Mobility (gait speed)	
Sakamoto et al, 2008[20]	5,689 (3,833), IDEEA	31% day (24 h) lying, 50% sitting, 11% standing, 8% walking	10,246 (2,486) steps, 22% standing, 29% lying		
Shaughnessy et al, 2005[57]	2,765 (1,677), SAM				
Tiedemann et al, 2012[37]	4,365 (3,350), pedometer			Mobility (gait speed, 6MWT) Impairment (choice reaction stepping time, postural sway, balance range) HRQOL (SF-36)	
Touillet et al, 2010[58]	6,973 (2,439), activPAL	63.3 (52.9) min/wk in walking of bouts at least 15-min duration[g]			
Zalewski and Dvorak, 2011[31]	2,990 (2,488), SAM		Steps: 6,378 (2,149)	Mobility (gait speed, 6MWT)	

[a] IDEEA=Intelligent Device for Energy Expenditure and Activity; 6MWT=Six-Minute Walk Test; RMA=Rivermead Motor Assessment; SIS=Stroke Impact Scale; HR=heart rate; SAM=StepWatch Activity Monitor; FMA-LE=Fugl-Meyer Assessment, lower extremity score; BBS=Berg Balance Scale; RMI=Rivermead Mobility Index; CMSA=Chedoke-McMaster Stroke Assessment; CS-PFP10=10-item Continuous Scale Physical Functional Performance test; PASIPD=Physical Activity Scale for Individuals With Physical Disabilities; HRQOL=health-related quality of life; $\dot{V}o_2$peak=peak oxygen uptake; FSS=Fatigue Severity Scale; CES-D=Centre for Epidemiology Studies, depression scale; ABC=Activity-specific Balance Confidence scale; FES=Falls Efficacy Scale; SF-36=36-Item Short-Form Health Survey (specific outcome measures are denoted by blue type).
[b] "on kinetics (-ve correlation)" indicates impaired delivery of oxygen to skeletal muscle and is related to lower levels of physical activity.
[c] A *bout* was defined as any minute with a stride count >1.
[d] Whole group baseline data (from second baseline assessment).
[e] Estimated from graphs. No response from authors to request for raw data.
[f] Bout=3 strides in ≥15 s and end of bout ≥10 s with no strides.
[g] Calculated as session duration multiplied by session frequency as measured by the activPAL.

Table 3.
Critical Appraisal Scores[a]

	Selection of Participants				Assessment			Confounding/Analyses	
Study	Comparable Groups	Eligibility Criteria	Numbers Screened and Recruited	Dropouts Reported	Clear Primary Outcome and Valid Assessment Tool	Blind Assessment of Prognostic Factors	Clearly Defined Prognostic Factors	Confounders Considered	Selective Reporting
Alzahrani et al, 2009[38]	-	√	X	√	√	√	√	X	√
Alzahrani et al, 2011[22]	X	√	X	√	√	-	-	X	√
Alzahrani et al, 2012[50]	-	√	X	√	√	√	√	X	√
Baert et al, 2012[33]	-	X	X	√	X	X	√	√	√
Bowden et al, 2008[35]	-	√	X	√	√	X	√	√	√
Fulk et al, 2010[29]	X	√	X	√	√	√	√	√	√
Hachisuka et al, 1998[21]	√	√	X	√	X	√	X	√	√
Haeuber et al, 2004[51]	-	√	X	√	√	√	√	X	√
Hale et al, 2008[52]	X	√	X	√	√	√	X	X	√
Janssen et al, 2010[23]	-	X	√	√	X	√	√	X	√
Katoh et al, 2002[41]	-	X	X	√	X	X	√	√	√
Manns et al, 2010[34]	√	√	X	√	√	√	√	X	√
Manns et al, 2009[28]	-	√	X	√	√	√	√	X	√
Manns and Baldwin, 2009[32]	-	√	X	√	√	√	√	X	√
Michael et al, 2005[36]	-	√	√	√	√	√	√	X	√
Michael et al, 2006[39]	-	√	√	√	√	√	√	X	√
Michael and Macko, 2007[27]	-	√	X	√	√	√	√	X	√
Michael et al, 2009[53]	-	√	X	√	√	√	√	√	√
Moore et al, 2010[54]	-	√	√	√	√	-	-	√	√
Mudge et al, 2009[55]	√	√	√	√	√	√	√	X	√
Rand et al, 2010[24]	-	√	X	√	√	√	√	X	√
Rand et al, 2009[56]	-	√	X	√	√	√	√	X	√
Resnick et al, 2008[40]	-	√	X	X	√	√	√	X	√
Robinson et al, 2011[42]	-	√	√	√	X	√	√	√	√
Roos et al, 2012[30]	X	√	√	√	√	-	-	X	√
Sakamoto et al, 2008[20]	X	√	X	X	√	√	-	X	√
Shaughnessy et al, 2005[57]	-	X	X	√	√	√	√	X	X
Tiedemann et al, 2012[37]	-	√	√	√	X	√	√	√	√
Touillet et al, 2010[58]	-	√	X	√	X	X	√	√	X
Zalewski and Dvorak, 2011[31]	X	X	X	√	√	√	√	X	√

[a] X=criteria not met, high risk of bias; √=criteria met, low risk of bias; -=not applicable. Highlighting serves to make clear the criteria for which a low risk of bias was determined.

cadence. Between 32% (SD=11.2%)[32] and 52% (SD not available)[27] of walking time was estimated to involve a step cadence of ≥30 steps per minute, classified as at least moderate-intensity activity. Using heart rate estimates, participants in one study[33] spent an average of 44 minutes (7% of a 10-hour day) in at least moderate-intensity activity.

Patterns of Activity and Inactivity

In 3 studies, patterns of activity (bouts of stepping) across the day were reported.[30,32,34] In 2 studies, bouts were defined as any minute with ≥1 strides, and people with stroke were reported as accumulating averages of 62 (SD=18)[32] and 64 (SD=19)[34] stepping bouts per day. Roos et al[30] used a different definition of a stepping bout. In their study, a stepping bout began when a participant took ≥3 strides in a 15-second interval and ended when the participant spent ≥10 seconds standing still. By this definition, people with stroke accumulated around 150 stepping bouts per day. In the 2 studies in which daily stepping bouts of participants with stroke were compared with those of control participants, controls accumulated significantly more bouts of stepping per day ($\bar{X}$=64 [SD=19] versus 74 [SD=10][34] and $\bar{X}$=150 versus 250[30]). In 1 study, mean numbers of transitions (between sitting and standing) were reported as 57 per day (SD=43) for participants with stroke and 109 per day (SD=91) for controls.[22] No studies specifically examined the pattern in which sitting time was accumulated across the day or the average duration of bouts of sitting.

Factors Influencing Free-Living Physical Activity

In 9 studies, the influence of walking ability on free-living physical activity was examined.[24,29–31,33,35–38] In 7 studies, walking speed (measured over 5 or 10 m) was significantly associated with either steps per day[30,31,33,35–37] or accelerometer-derived activity counts.[38] One trial showed no association between walking speed and daily step counts.[29] In 5 studies, walking capacity (as measured by the Six-Minute Walk Test) was reported as being significantly correlated with either steps per day[29,31,37,38] or accelerometer-derived activity counts.[24] In 6 studies, the influence of balance on free-living physical activity was examined. Significant associations between Berg Balance Scale scores and either steps per day[36,39] or accelerometer-derived activity counts[24] were reported in 3 studies; however, in another study, no signficiant association between Berg Balance Scale scores and steps per day was found.[29] Tiedemann et al[37] found a positive association between choice reaction stepping time and measures of postural sway with the number of steps per day taken by participants. For physical fitness, positive associations with peak oxygen uptake and steps per day were reported in 5 studies,[27,33,34,40,41] and only 1 study reported no association between peak oxygen uptake and steps per day.[36] Depression[33,42] and poorer quality of life[37] were negatively associated with the average daily step count and accelerometer-derived activity counts.[24]

Participants' age and sex were investigated as potential predictive factors in all studies, but no significant correlations with physical activity levels were found.[29,33,42] Table 2 summarizes the predictive factors and physical activity.

Discussion

This review synthesizes current information about sedentary behaviors and physical activity levels of people with stroke living in the community. No studies were found that specifically aimed to measure sedentary behavior, inactivity, or sitting time in people with stroke. Given the emerging evidence of the importance of sedentary behavior to health and well-being, it is imperative that we begin developing high-quality research in stroke in this field. Two studies estimated the amount of time people with stroke were sedentary each day (calculated as the total time monitored, minus any time spent active) and reported it as being 63%[22] and 90%[30] of waking hours.

Estimates of the amount of time people with stroke spent standing or walking were in the order of 1 to 2 hours per day,[22,23,30,32] which, according to 1 study, was similar to that of age-matched controls who were healthy. However, the vast majority of studies included in this review quantified physical activity in terms of step counts rather than time. Although step counts is an important and easily understandable measure that can be readily compared with age-matched norms, it misses 2 key pieces of information. First, step counts alone provide little information about the relative intensity of activity. The same number of steps at a comfortable walking pace will expend less energy than if accumulated at a fast pace. Second, step counts do not provide information about how long people with stroke spend inactive or sedentary each day. The same number of steps per day can be accumulated in 1 long bout, or in several smaller bouts. How fast a person with stroke can walk directly affects daily step counts, as someone who walks slowly will take longer to accumulate the same number of steps as someone who walks faster.[30]

When people with stroke are active, what is the intensity of this activity? This review highlights that we know very little about the intensity of free-living physical activity in community-dwelling people with stroke—and in particular the amount of time they spend engaged in activity of an intensity sufficient to induce a cardiovascular training effect. Although 3 studies used objective measures—either heart rate[33] or step cadence[27,32]—to quantify time spent in moderate-intensity physical activity, the validity of step cadence as a measure of intensity of exercise in people with stroke has not been validated. Step cadence has been validated as a measure of intensity of activity in adults who were healthy.[43] In this case, at least 100 steps per minute is considered the threshold for moderate-intensity physical activity,[43] which is more than 3 times the cadence considered to be moderate-intensity activity among people with stroke.[27,32] Furthermore, these studies provide little knowledge about whether moderate-to-vigorous physical activity was accumulated in bouts long enough to induce a training effect.

Patterns of activity accumulation warrant further discussion, as recent research highlights the importance of how both sedentary and moderate-to-vigorous physical activity are accumulated and their relation to health risk factors. Three studies reported that people with stroke had fewer bouts of walking each day compared with controls,[22,30,32] as well as fewer transitions between positions,[22] which suggests that these individuals accumulate their walking time in fewer separate bouts each day. The inverse also is likely true; that is, people with stroke may be accumulating sitting time in longer bouts each day compared with age-matched controls.

Although the issues of profound cardiovascular deconditioning after stroke are undoubtedly important and efforts to encourage people with stroke to meet the recommended guidelines of 150 minutes of at least moderate-intensity physical activity per week are vital, the barriers to these efforts are substantial.[44,45] In addition to the important research efforts aimed at increasing physical fitness levels of people with stroke, a parallel research effort should address the issue of sedentary time in these individuals. A whole-day approach to activity programming that includes recommendations to reduce sedentary time and increase physical activity may be especially appropriate for this population. They, like other populations that tend to be particularly inactive, may have more success changing behavior, at least initially, by striving to become less sedentary, as opposed to more active.[46] Research efforts are needed to investigate whether it is possible to reduce prolonged sedentary time in this group and whether this reduced sedentary time leads to improved health and ultimately to reduced risk of future stroke.

The results of this review suggest that little is known about the total amount and pattern of accumulation of sedentary time and, at the opposite end of the spectrum, that little is known about the amount of time people with stroke spend engaged in moderate-to-vigorous activity. This review also highlights the challenges associated with synthesizing activity data because activity intensity across the continuum from sedentary to vigorous activity was defined in several different ways. Future research using objective measurement techniques should clearly define and provide a rationale for these definitions of activity intensity.

Limitations

The majority of participants in the included studies were aged between 65 and 75 years. Further research about the physical activity levels of people with stroke over 75 years of age is needed. This review included only studies that measured physical activity levels of people with stroke who were living in the community and who were able to walk. Few details were provided as to whether people were engaged in formal rehabilitation programs at the time of measurement. The studies were conducted in a variety of countries, which also may have influenced the results. Although we know from other work that people with stroke in the hospital are very inactive,[47] very little is known about physical activity levels of people with stroke living at home who are unable to walk. This review highlights, and is limited by, the different definitions researchers used to classify activity intensity. More work is needed in this area, perhaps in particular to better understand what defines "light activity" for someone with stroke. The health benefits of light activity are increasingly recognized,[48,49] but further work on defining light-intensity activity for people with stroke is needed before clear recommendations can be made.

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