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Review

Outcome measures to assess walking ability following stroke: a systematic review of the literature

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Abstract

Objectives The recovery of independent walking is an important goal in stroke rehabilitation. The objective of this systematic review was to identify all outcome measures used in the stroke research literature that included an evaluation of walking ability and evaluate the concepts contained in these measures with reference to the International Classification of Functioning, Disability and Health (ICF) framework.

Data sources Searches were conducted of MEDLINE, CINAHL, EMBASE and PsycINFO databases for the time period January 1990–December 2005 using appropriate keywords.

Review methods Studies were selected for further analysis if they used one or more standardized outcome measure incorporating an aspect of walking defined by the ICF. The outcome measure had to have published psychometric properties and specifically measure walking rather than mobility. The content of each outcome measure was classified with reference to the ICF subcategories for walking. The number of times each outcome measure was used was calculated.

Results Three hundred and fifty-seven studies met the selection criteria. Sixty-one different outcome measures were used a total of 848 times to measure walking ability. Six of the outcome measures reflected impairment and 52 reflected limitations of activity and participation. The other three outcome measures showed overlap between domains, reflecting aspects of both impairment and limitations in activity and participation. The three most frequently used measures (self-paced gait speed measured over a short distance, spatiotemporal parameters and fast gait speed) were used 350 times but only assessed one ICF subcategory. The Rivermead Mobility Index and the Adapted Patient Evaluation Conference System assessed the greatest number of ICF subcategories but were used only 19 times and once respectively.

Conclusions The most frequently used outcome measures reflect only one aspect of walking ability: walking short distances. Mobility tasks related to function in the community, like walking long distances, around obstacles and over uneven ground, and moving around outside or in buildings other then the home are not well represented by outcome measures used in most studies.

Keywords: Walking; Cerebrovascular accident; Outcome assessment (health care); Rehabilitation

Introduction

Stroke is the most common cause of severe disability in adults [1] and the third leading cause of death both in New Zealand [2] and in the United Kingdom [3]. Although persistent physical disability is reported in 50–65% of individuals who survive stroke [1,4,5], as many as 70% are able to walk independently [5]. However, it appears that only a small percentage of these individuals are able to walk functionally in the community [6,7]. This apparent discrepancy in walking ability may be attributable to the wide choice of outcome measures to assess different aspects of walking. Thus, functional abilities can be either apparent or masked, depending on the choice of outcome measure.

Selection of a suitable outcome measure is critical to accurately characterize and monitor changes in walking ability during rehabilitation interventions for adults with stroke. However, selection can pose a challenge to both researchers and clinicians as, at first sight, the range of outcome measures available in the clinical research literature appears overwhelming. The psychometric properties of outcome measures, such as reliability, validity and responsiveness to change, are commonly used as criteria for selection and are clearly important [8–10]. Two recent major reviews give guidance in this area, with critical appraisal of psychome-

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tric properties of 15 outcome measures commonly used in stroke research to capture aspects of activity and participation [9,11]. However, researchers and clinicians also need to consider what information they require from an outcome measure. The International Classification of Functioning, Disability and Health (ICF) framework can be used to systematically identify and quantify the different components of available outcome measures and therefore provide an additional basis for selection of a measure, based on comparison of content [12].

The ICF aims to provide a common language for the description of health and is becoming the generally accepted conceptual framework to describe an individual's level of function and health in rehabilitation [13]. The ICF framework can be divided into two parts. 'Functioning and disability' is the first and 'contextual factors' is the second part. Part 1, 'functioning and disability', has two components: (i) body functions and structures and (ii) activities and participation. Part 2, 'contextual factors', is divided into two components: (i) environmental and (ii) personal factors, which are described as the external and internal influences on functioning and disability respectively [14].

Body functions are defined as the physiological functions of body systems, and body structures are the anatomical parts of the body. A deficit in this area is termed impairment, signifying a significant loss or deviation of either a body structure or function. Activity is defined as the execution of a task or action by an individual and the negative aspect is denoted an activity limitation. Participation describes involvement in a life situation in the actual context in which an individual lives; environmental factors are implicit by definition. The corresponding negative impact is participation restriction. Following stroke, for example, weakness would be classified as impairment, difficulty walking over uneven ground would be described as activity limitation, and inability to resume work would be defined as participation restriction.

Recovery of walking ability following stroke is rated highly by patients [7] and a large percentage of therapy time is spent retraining walking [15]. The inclusion of the ICF category of walking (d450) in both the brief and comprehensive core sets for stroke was also unanimously agreed on by 36 experts involved in the consensus process for the development of ICF core sets [16]. Within the ICF framework, the category of walking is included in the mobility domain (d4). Four categories can be related to aspects of ambulation: d450 walking, d455 moving around (other than walking), d460 moving around in different locations and d465 moving around using equipment. A recent review of outcome measures used in a random sample of 160 studies in stroke research has highlighted that the most frequently used ICF category was d450 walking [12]. However, the authors did not further evaluate those measures with respect to the next level of classification available in the ICF framework.

The objective of this systematic review was therefore to identify and quantify the concepts contained in outcome measures used in the stroke research literature that included an evaluation of walking ability, using the ICF as the reference tool. The specific aims were to (i) determine the range of outcome measures currently used in stroke research that include an assessment of an aspect of walking ability, (ii) estimate the researcher acceptance of different measures by calculating the frequency of use in the published literature over the last 15 years, and (iii) determine the breadth of content of walking assessment with respect to the ICF subclassifications.

Search strategy

Searches were conducted of MEDLINE, CINAHL, EMBASE and PsycINFO databases for the time period January 1990–December 2005. This time frame was chosen to reflect current usage. The searches were designed to identify which outcome measures used in the published literature following adult stroke evaluate an aspect of walking ability. Medical subject headings (MeSH) used in the search were as follows: cerebrovascular accident, walking, locomotion, gait, ambulation and gait disorders, neurologic.

Selection criteria

The title of the study was initially used to determine inclusion, with the abstract used for clarification if the title was inconclusive. Studies were included that had an experimental design from case series to randomized controlled studies. Case studies were excluded. Studies were also excluded if there were subjects with other diagnoses besides stroke. Studies were only included if English versions of both the study and the outcome measure were available. Any form of original research pertaining to outcome measures for stroke that met the inclusion criteria was included, ranging from development of a measure and/or property testing, use as a dependent variable or use as inclusion or exclusion criteria. One author (SM) was responsible for the selection of studies and data extraction.

A study was selected for analysis if it used one or more standardized outcome measures that incorporated an aspect of walking as defined by the ICF: *walking along a surface on foot, step by step, so that one foot is always on the ground, such as strolling, sauntering, walking forwards, backwards or sideways* [14]. The ICF subcategories were drawn from the section 'walking and moving' and were selected only if it were possible for them to relate to walking. For example d4550 crawling and d4554 swimming clearly have no association with walking. If items were stated to be 'indoors' without further clarification, they were classified as d4600 'within home'. This decision was guided by the literature, which suggests that only a small proportion of individuals walk regularly in the community following stroke [6].

The outcome measure had to have published psychometric properties and specifically measure walking rather than mobility. This was determined for every outcome measure identified in this search by checking the reference list of the study and searching the MEDLINE and CINAHL databases for the outcome measure.

The content of each outcome measure was classified with reference to the ICF subcategories for walking. If the outcome measure identified impairment(s), this was shown in the body structure and function category. The activity and participation descriptors for mobility (d450–465) were used to further categorize different aspects of walking tested by each outcome measure. The mode of administration of the outcome measure was also classified. Other information extracted from each study was the type of research design, chronicity of stroke of the subjects and the way in which the outcome measure was used.

The number of times each outcome measure was used was calculated. Outcome measures were also classified as clinical if it were possible for the test to be carried out in a clinical setting, and laboratory if the test was exclusively used in a laboratory setting.

Results

Out of 881 studies initially identified, 357 studies met the selection criteria and were included in the analysis. Of these, 65 were randomized controlled trials, 65 were prospective cohort studies, six were retrospective studies, 109 were articles that either further evaluated psychometric properties of existing scales (predominantly concurrent validity or test–retest reliability) or reported initial development and evaluation of the outcome measure, and 112 were other experimental designs.

There were 59 studies with subjects with acute stroke (less than 1 month), 23 with subjects between 1 and 6 months, 59 with subjects between 0 and 6 months, 116 with subjects with chronic stroke (more than 6 months), 54 with subjects greater than 1 month following stroke and 46 with either mixed time since stroke or unknown time since stroke.

From these studies, 61 different outcome measures were identified that included an assessment of some aspect of walking. These outcome measures were used a total of 848 times, with outcome measures being used as inclusion or exclusion criteria three times, as descriptors 11 times and as dependent variable 834 times. There was no variable that was used exclusively as inclusion/exclusion criteria or as a descriptor.

Range of outcome measures

Tables 1 and 2 present the range of measures, ranked by their frequency of use and categorized according to the ICF subcategories of walking. A representative reference is given for each measure. Of the 61 measures, three were exclusively laboratory-based (kinematics, kinetics, electromyography) and all measured aspects of impairment. Of the other 58 clinic-based measures, three measured impairment exclusively (spatiotemporal parameters, Hemiplegic Gait Analysis Form, Lateropulsion Scale) and 52 reflected limitations of activity and participation. Three other tests showed overlap between domains, including aspects of both impairment and limitations in activity and participation (Tinetti Gait and Balance Scale, Rivermead Visual Gait Analysis, Wisconsin Gait Scale). Forty-one measures used direct observation and the remaining 20 used self-report methods, often in the form of a questionnaire.

Frequency of use

Outcome measures that were used in 10 or more studies are shown in Table 1. Those used in less than 10 studies are shown in Table 2. Seventeen outcome measures were used more than 10 times: 13 clinical outcome measures and four laboratory-based measures. Overall, these 17 measures were used 731 times and made up 86% of the total usage. The most frequently used clinical outcome measure was self-paced gait speed over a short distance (10 m or less), which was used in 180 of the 357 studies (50%). Gait speed at a fast or maximal pace was the second most frequently used clinical outcome measure, being used in 74 studies (21%). The most commonly used laboratory measure was spatiotemporal parameters, which included parameters such as cadence, step length, stance duration, swing duration and double support time. Spatiotemporal parameters were used in 96 of the 357 studies (27%).

The frequency of use of an outcome measure depended on the chronicity of stroke. Over half the usages of the Barthel Index (63%), the Functional Ambulation Categories (64%) and the Rivermead Mobility Index (52%) were in studies where the subjects were acute or subacute (less than 6 months following stroke). Over half the usages of self-paced gait speed (62%), spatiotemporal variables (54%), fast gait speed (55%), kinematics (78%), kinetics (84%), 6 minute walk test (80%), Timed Up and Go (61%), Electromyography (71%), Motor Assessment Scale (50%) and Rivermead Motor Assessment (60%) were in studies where the subjects were chronic (greater than 6 months) or chronic mixed with subacute.

Breadth of content

Thirty-two of the 61 outcome measures assessed walking over a short distance, 25 by direct measurement or observation and seven through patient self-report. Only five outcome measures considered walking over a longer distance, defined by the ICF as greater than 1 km [14]. Other aspects of mobility commonly encountered in real life situations were also included. Twenty-six of the outcome measures assessed climbing (stairs or curbs) and 12 evaluated walking on different surfaces. However, only three measures assessed obstacle negotiation.

The ICF distinguishes between the locations in which mobility occurs, as shown by columns d4600 to d4602 of

Table 1
Most frequently used outcome measures classified according to the ICF

Outcome measure and representative reference	Frequency of use	Aspect of walking measured—ICF												
		Body structure and function	Activities and participation											
			d450 walking					d455 moving around (other than walking)			d460 moving around in different locations			d465 moving around using equipment
			d4500 walking short distances	d4501 walking long distances	d4502 walking on different surfaces	d4503 walking around obstacles	d4509 walking, unspeci-fied	d4551 climbing (stairs, steps, curbs)	d4552 running	d4553 jumping (hopping, skipping)	d4600 moving around within the home	d4601 moving around within other buildings	d4602 moving around outside home & other buildings	
Gait speed (self-paced) [35]	180		♦											
Spatiotemporal parameters [49]	96	♦												
Gait speed (fast) [35]	74		♦											
Barthel Index [50]	73		♦					♦						
Kinematics [51]	59	♦												
Functional Ambulation Categories [36]	36		♦		♦			♦						
Kinetics [52]	31	♦												
6 minute walk test [53]	30		♦											
Timed Up and Go [54]	28		♦											
Electromyography [55]	24	♦												
Motor Assessment Scale [56]	22		♦					♦						♦
Rivermead Mobility Index [50]	19		♦		♦			♦	♦		♦		♦	
Rivermead Motor Assessment [36]	15		♦					♦	♦	♦			♦	
36 Item Short Form Health Survey (SF-36) [57]	12		♦	♦				♦	♦					
Frenchay Activities Index [50]	11			♦									♦	
Scandinavian Stroke Scale [58]	11		♦											♦
Nottingham Extended Activities of Daily Living Index [50]	10				♦								♦	
Total	731	4	11	2	3	0	0	6	3	1	1	0	4	2

Table 2
Least frequently used outcome measures classified according to the ICF

Outcome measure and representative reference	Frequency of use	Aspect of walking measured—ICF												
		Body structure and function	Activities and participation											
			d450 walking					d455 moving around (other than walking)			d460 moving around in different locations			d465 moving around using equipment
			d4500 walking short distances	d4501 walking long distances	d4502 walking on different surfaces	d4503 walking around obstacles	d4509 walking, unspecified	d4551 climbing (stairs, steps, curbs)	d4552 running	d4553 jumping (hopping, skipping)	d4600 moving around within the home	d4601 moving around within other buildings	d4602 moving around outside home & other buildings	
Nottingham Health Profile [59]	9						♦	♦			♦		♦	
Sickness Impact Profile [60]	8		♦		♦			♦						
2 minute walk test [61]	7		♦											
Stroke Rehabilitation Assessment of Movement [62]	6		♦					♦						
Chedoke-McMaster Stroke Assessment [63]	5		♦		♦			♦			♦		♦	
Falls Efficacy Scale [64]	5							♦					♦	
Functional Walking Category (Perry) [65]	5				♦			♦			♦		♦	♦
Tinetti Gait & Balance Test [66]	5	♦	♦											♦
Lindmark Motor Capacity Assessment [67]	4						♦							♦
Mobility Milestones [68]	4		♦											
StepWatch Activity Monitor [43]	4						♦							
12 minute walk test [61]	3		♦	♦										
5 minute walk test [69]	3		♦											
Hemiplegic Stroke Scale [70]	3					♦								
Modified Emory Functional Ambulation Profile [32]	3		♦		♦	♦		♦						
Physical Activity Scale for the Elderly [71]	3						♦							
Rankin Handicap Scale [72]	3						♦							
Stroke Impact Scale [44]	3		♦					♦						
3 minute walk test [73]	2		♦											
Activities-Specific Balance Confidence Scale [74]	2				♦	♦		♦			♦		♦	
Functional Ambulation Classification of the Hospital of Segunto [75]	2										♦		♦	
Human Activity Profile [76]	2		♦	♦	♦			♦	♦					
Mobility Scale for Acute Stroke Patients [77]	2		♦											

Table 2 (*Continued*)

Outcome measure and representative reference	Frequency of use	Aspect of walking measured—ICF												
		Body structure and function	Activities and participation											
			d450 walking					d455 moving around (other than walking)			d460 moving around in different locations			d465 moving around using equipment
			d4500 walking short distances	d4501 walking long distances	d4502 walking on different surfaces	d4503 walking around obstacles	d4509 walking, unspeci-fied	d4551 climbing (stairs, steps, curbs)	d4552 running	d4553 jumping (hopping, skipping)	d4600 moving around within the home	d4601 moving around within other buildings	d4602 moving around outside home & other buildings	
Orpington Prognostic Scale [78]	2		♦											
Pedometer [45]	2						♦							
Rehabilitation Activities Profile [79]	2						♦	♦			♦		♦	
Activity Index [80]	1						♦							
Adapted Patient Evaluation Conference System [81]	1		♦		♦			♦			♦		♦	♦
Advanced Mobility and Balance Scale [82]	1		♦		♦		♦							
Brunel Balance Assessment [83]	1		♦											
Clinical Outcome Variables Scale [84]	1		♦		♦			♦						♦
Community Rehabilitation Program Mobility Index [85]	1						♦	♦						
Duke Health Profile [86]	1							♦	♦					
EuroQol [60]	1						♦							
Ewart's Self Efficacy Scale [87]	1		♦	♦				♦	♦					
Functional Autonomy Measurement System [88]	1							♦			♦		♦	
Hemiplegic Gait Analysis Form [89]	1	♦												
Kenny Self-Care Evaluation Index [90]	1						♦	♦						
Lateropulsion Scale [91]	1	♦												
Modified Rivermead Mobility Index [92]	1		♦					♦						
Nottingham Leisure Questionnaire [93]	1						♦							
Rivermead Visual Gait Assessment [94]	1	♦	♦											♦
Sødring Motor Evaluation of Stroke Patients [95]	1						♦	♦						♦
Wisconsin Gait Scale [96]	1	♦												♦
Total	117	5	21	3	9	3	14	20	3	0	8	0	9	8

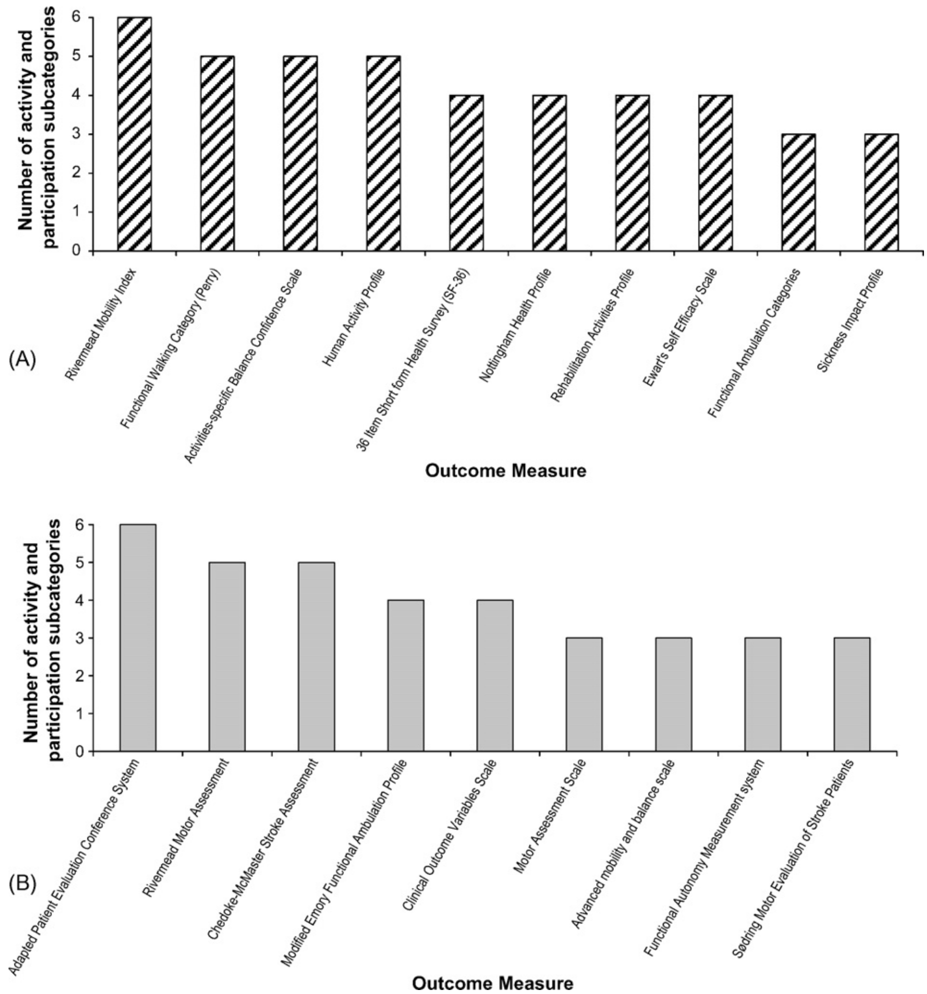

Fig. 1. Bar histograms showing the measures with the greatest number of ICF subcategories to assess walking (out of a possible maximum of 12). (A) Measures that use self-report are shown with diagonal striping; (B) measures that are directly observed are shown in grey.

Tables 1 and 2. Nine scales measured walking around the home, while 13 measures reported on walking outside the home. Of note, there were no scales that directly assessed walking in buildings other than the home.

Category 465 indicates moving around using equipment. In the scope of this review, walking is the method of moving around and therefore equipment reflected use of an assistive device. Ten outcome measures specifically scored walking based on presence or type of assistive device.

Table 1 shows that seven of the 12 activities and participation subcategories are assessed by less than three of the 17 most frequently used measures. The under-represented categories are walking long distances, walking around obstacles, unspecified walking, jumping, moving around within the home or other buildings and moving around with equipment.

By comparison, Fig. 1 presents the outcome measures that had the greatest breadth of content in terms of walking ability. This was determined by identifying outcome measures that had the highest number of ICF activity and participation subcategories related to walking. In total, only 19 outcome measures assessed three or more subcategories out of a possible maximum of 12. Ten of these measures used self-report and nine used direct testing or observation. The highest number of subcategories assessed by an outcome measure was six. The Rivermead Mobility Index and the Adapted Patient Evaluation Conference System were the two outcome measures that each measured six subcategories of walking. Walking long distances, around obstacles, running, jumping or moving around within other buildings were measured in fewer than seven of the measures shown in Fig. 1.

Discussion

The goal of this review was to identify and quantify concepts contained in existing outcome measures used in stroke research literature that included an evaluation of walking ability, using the ICF framework as the reference tool. This review has confirmed that the current clinical research literature incorporates a wide range of available outcome measures that measure aspects of walking ability, similar to previous research in stroke and other diagnosis groups [17–19]. While some measures record very specific aspects of walking, others include aspects of walking ability as part of a more global assessment of functional ability. It was common for researchers to select more than one measure to assess walking; however this did not necessarily mean that all aspects of walking ability were covered.

This review selected studies for analysis only if they included standardized outcome measures with known psychometric properties. There were multiple studies that devised their own assessment procedures and did not report on psychometric properties, for example over-ground gait endurance [20–24] or gait speed calculated over 2 minutes [22]. Some researchers modified standardized tests [25] or used parts of tests previously not validated to stand alone [26]; however it appears that this practice is less prevalent than has been reported elsewhere [19]. It is possible this difference may be due to the wider range of measures now available for use in subjects with stroke in contrast to other groups such as traumatic brain injury. It is also possible this difference could be attributed to more stringent review requirements for both funding and publication. A number of commonly used outcome measures were also excluded from the analysis as they did not measure walking specifically. For example, the Functional Independence Measure does not distinguish between the use of a wheelchair and walking [27].

The ICF defines a short distance as less than 1 km. The majority of outcome measures fell into this category as few directly observed or questioned the ability to walk distances greater than 1 km. Exceptions included the 12 minute walk test, in which it is feasible for subjects to walk more than 1 km, and four self-report measures (SF-36, Frenchay Activities Index, Human Activity Profile and Ewart's Efficacy Scale) that include questions about walking over 1 km. Only two of these measures (SF-36 and Frenchay Activities Index) were used with any frequency, suggesting that the majority of the stroke research literature does not assess this dimension of walking ability. It is likely that many individuals following stroke would not be able to walk 1 km as levels of fitness are often poor following stroke [28] and few individuals access the community [6,7]. However, it may be relevant to measure and rehabilitate longer distances more frequently than is currently practiced, if successful community walking is to be achieved [29,30].

It is encouraging to report that walking under different conditions is tested or surveyed, albeit sparingly, reflecting an attempt to measure the influence of environmental factors. Twelve outcome measures assessed walking over different surfaces and 26 measured ability to negotiate stairs or curbs. However, only three infrequently used measures included walking around obstacles. These three ICF subcategories are dimensions included in a recently proposed theoretical construct of community mobility [30,31]. The modified Emory Functional Ambulation Profile is the only outcome measure in this review that assesses these three ICF subcategories. Despite promising psychometric testing [32–34] and breadth of content, this outcome measure has only a low frequency of use in the published literature.

It is useful to consider which aspects of walking are assessed most frequently in the research literature. The three most frequently used tests of walking ability measured only one ICF subcategory of walking (d4500 walking short distances) and were used across all stroke populations. While self-selected gait speed was the most commonly used measure, fast gait speed and spatiotemporal parameters were also used frequently. The implementation of these tests varied slightly between researchers, with both self-selected gait speed and fast gait speed being most commonly measured over a distance of 5–10 m. The high frequency of use of these tests probably reflects their extensive testing in neurological populations, which has shown robust psychometric properties and ease of use [35–38].

In comparison, measures that had the greatest breadth of content were less frequently used, with the Rivermead Mobility Index, SF-36, Functional Ambulation Categories, Rivermead Motor Assessment and Motor Assessment Scale being taken up to any extent in the literature. Moreover, the 19 measures identified with the greatest breadth of content are used 146 times, making up only 17% of the total outcome measure usage. Thus, breadth of content does not appear to be a primary factor in the selection of an outcome measure for clinical research.

The ICF qualifies activities and participation with the words capacity and performance [14]. Capacity indicates the highest probable level of functioning that a person may reach in a given domain at a given moment and is usually measured in a standardized environment. In contrast, performance reflects daily function in an individual's usual environment. Essentially, capacity and performance are distinguished by what a person *can* do and what they *actually* do. This review did not specifically address the issue of measurement of capacity versus performance. However, two-thirds of the measures were direct tests administered in either a clinical or laboratory setting, suggesting that they are more likely to measure capacity rather than performance. The remaining one-third of outcome measures used a self-reporting technique in an attempt to capture the patient's perception of their ability. However, these self-report measures were used in less than 20% of all occurrences of measuring walking ability. So not only do fewer measures potentially reflect performance, but they are used less frequently in the stroke research literature.

The preference for use of direct testing or observation rather than self-reporting techniques may reflect acknowledgement of the difficulties associated with the use of questionnaires, in so much as they rely on each individual's ability to accurately recall and report various activities [8]. In particular, self-report measures are known to suffer from a lack of reliability associated with under- or over-reporting [39]. Despite these disadvantages, questionnaires remain one of the few ways to date to gain an insight into performance in the community.

Study limitations

The assessment of frequency of use as a measure of researcher acceptance of different outcome measures has some limitations. In this study, we included only articles from 1990 onwards. We did this to represent the outcome measures used most frequently in the current clinical research literature. Thus data on the 'frequency of use' reflect not only the uptake of the measure in the literature but also how much time has elapsed since introduction of the measure into the clinical research literature.

The frequency of use of different outcome measures will also have been affected by the relative proportions of studies with subjects with acute or chronic stroke. Subjects with acute stroke may not have the endurance for some longer tests of walking (e.g. 6 minute walk test) or for testing that can be time-consuming (e.g. kinematics, electromyography). Thus it is not surprising that usage of the Barthel Index, the Functional Ambulation Categories and the Rivermead Mobility Index was higher in studies of subjects with acute stroke. These are all quick tests and largely rely on self- or therapist-report, so are more practical in an acute setting. The Barthel Index has also been shown to have predictive validity [40,41], which is useful in acute care. Conversely the use of the Barthel Index in subjects with chronic stroke has been more limited, possibly due to its known ceiling effects [42] and its poor responsiveness to change [9].

Another limitation was that only one author was responsible for study selection and data extraction. One person may be less reliable than two individuals who are able to compare and resolve discrepancies. We attempted to minimize this limitation by cross-checking the data a second time and discussing issues that were unclear. Likewise, our interpretation of the ICF framework and the content and use of the outcome measures may not concur with the interpretation of others.

Issues for future research

Measurement of walking ability following stroke requires outcome measures that reflect the breadth and range of activities inherent in the term 'walking ability'. The use of the ICF as a model for selection of an appropriate measure confirms that the commonly used measures were most likely to assess only one or sometimes two aspects of walking, usually the ability to walk a short distance and negotiate stairs. Of note, more complex but commonly encountered mobility tasks such as walking around obstacles and walking on uneven surfaces were frequently not evaluated. As well, information on walking in buildings other than the home and over long distances was not captured. Thus, community activities relevant to the patient such as ability to walk around a shopping mall or a supermarket [7], walking on an uneven pavement or in a crowded street are poorly represented in these measures.

Even measures such as the Rivermead Mobility Index that spanned the widest range of ICF walking activities and had robust psychometric properties [9] did not cover the entire range of walking dimensions. This highlights the need for further debate between clinicians and researchers to define the most useful concepts and facilitate the development of walking scales that can more accurately reflect the range of walking ability poststroke.

Several studies identified by this review used the StepWatch™ Activity Monitor to measure walking ability [43–46]. Previous methods of activity monitoring have included use of heart rate monitors, pedometers, energy expenditure equipment and video cameras, which have been used with variable success (for reviews see [47,48]). Although accelerometers have been used for about 30 years to monitor movement, recent advances in technology have made them smaller and more cost-effective, leading to an upsurge in their use to monitor activity. However, full interpretation of activity monitor output is enhanced by the use of additional self-report information, for example an activity diary to describe the types or location of activities. Further research is required to determine whether the combination of self-report and activity monitor output can minimize some of the known problems with self-report questionnaires.

Conclusions

The clinical research literature has a wide range of outcome measures to assess one or more aspects of walking ability following stroke. However, the most frequently used measures of walking ability, self-paced gait speed, spatiotemporal parameters and fast gait speed, only measure one aspect of walking ability. The Rivermead Mobility Index and the Adapted Patient Evaluation Conference System span the greatest range of walking subcategories, but are used much less frequently, highlighting that breadth of content does not appear to be a primary factor in the selection of an outcome measure for clinical research. In particular mobility tasks related to function in the community are not well represented by the majority of outcome measures. There is a need to develop outcome measures that can capture a greater range of walking ability, particularly in the community.

Key messages

- A wide range of outcome measures is available for the assessment of walking ability. Self-paced gait speed, spatiotemporal parameters and fast gait speed are the most frequently used measures in the research literature, but represent only one aspect of walking ability.
- The Rivermead Mobility Index and the Adapted Patient Evaluation Conference System had the greatest breadth of content to assess walking ability, but are used relatively infrequently.

- Mobility tasks related to function in the community, like walking long distances, around obstacles and over uneven ground, and moving around outside or in buildings other than the home were not well represented by outcome measures used in most studies.

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