Q J Med 2004; **97**:463–475
doi:10.1093/qjmed/hch084

Review

QJM

Quantification of walking mobility in neurological disorders

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Introduction

Difficulty in walking is a major feature of neurological disease, and loss of mobility is the activity of daily living on which patients place the most value.[1] Consequently, how to measure and assess this is of importance to any member of the inter-disciplinary team. In clinical practice, the World Health Organization international classification of functioning (ICF)[2] is often adopted as the underlying framework for the assessment of mobility, which is an individual's ability to move about effectively in their environment.[2] The ICF also introduces the constructs of performance (what an individual does in his environment) and capacity (ability to execute a task or action). This has a clear impact on the current methodology for the assessment of mobility.

Different pathologies and impairments culminate in abnormal or reduced walking. For instance, in multiple sclerosis (MS), impairments such as weakness and spasticity from pyramidal tract lesions, loss of proprioception and co-ordination from dorsal column and cerebellar lesions, vestibular and visual dysfunction, cognitive and mood disturbance and pain may all contribute (Figure 1). In primary muscle disease, mobility is determined by weakness but secondary factors such as weight gain, contractures, fatigue and breathlessness may have important impacts. The degree of impairment has a non-linear relationship with activity and participation. For example leg strength and walking speed are poorly correlated,[3] while many personal and environmental factors may influence the impact of similar degrees of loss of walking on mobility.

Impaired walking can be a marker of both disability and disease progression, and is therefore an important outcome measure in the treatment and rehabilitation of diseases such as MS and Parkinson's disease (PD). In some cases, measurement of mobility may have a direct influence on access to treatment. For example in MS, eligibility for disease-modifying drugs is in part determined by the maximum walking distance.[4]

Current practice in mobility measurement

Clinicians regularly observe gait for diagnostic purposes and commonly form opinions, often aided by the impression of the patient and/or carer, as to whether walking is 'better' or 'worse' in the context of progression of disease or response (or lack of it) to treatment. In the context of monitoring, it is clearly preferable to measure walking objectively.

As yet, there is no 'gold standard' assessment that provides a direct measure of mobility in a community setting,[5] i.e. performance. Current assessment of mobility (Table 1) usually involves subjective or observer-rated instruments that range from direct clinical observation to asking the patient, sometimes aided by questionnaires or diaries. Most indices provide a measure related to a specific point in time and a particular setting, and are characterized by brevity, a non-familiar environment, the need for direct observation, dependence on

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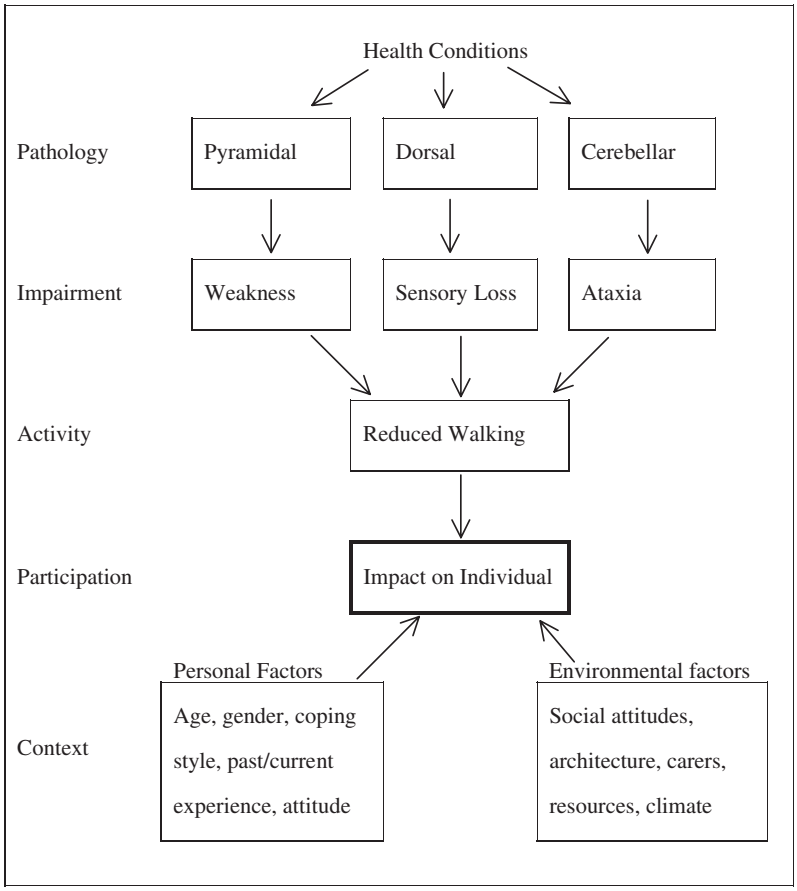


Figure 1. Framework of international classification of function (ICF) as illustrated by mobility in MS.

exact instructions, and an unquantifiable impact of the observer, which is likely to vary depending on the aim of the evaluation (e.g. assessment for social security payment vs. interferon prescription). Such measures may provide an index of what an individual *can* do (capacity) or *believes* they can do (in terms of walking), but the extent to which they indicate *actual* performance in the home environment is speculative.

Clinical practice increasingly demands that interventions have robust outcome data and clear benefits. Many current measurement tools used in practice have limitations[6] (see Table 2). We review some current methods of assessing mobility in terms of reliability, validity, responsiveness (identifies change that is significant to patient and clinician) and whether they can inform objectively on performance.

Quantitative or timed analysis

Timing of walking

Walking may be timed over a fixed distance or expressed as a speed (m/s). Timed walks of 10 m/25 ft have been used as an outcome measure in a variety of neurological conditions, including stroke and head injury,[7–9] form part of a recommended outcome measure for clinical trials in multiple sclerosis,[10] and have been recommended by expert opinion.[11] Among the advantages of gait speed is that it is simple, quick and inexpensive, has established face validity, and is relatively independent of distance: it is expressed as a continuous/ratio measure, allowing data to be expressed in relation to a normal range, and the degree of deviation can clearly be seen. However there is variability in methodology, for instance instructions given ('own speed' or 'fast as possible'), the environment of the test, and whether to include starting, stopping or a turn,[8] all of which may affect reliability. Furthermore, a ceiling effect is apparent at normal walking speed (1.2–1.4 m/s).[12] While reliability within tests is good, between tests this decreases[13] and there is variability of up to 20% for three repeated measures:[14] thus some investigators have suggested that a change >20% is most likely to represent reliable change.[15]

While a timed walk is simple to undertake, relatively reliable, responsive, and allows

an indication of capacity, it remains nevertheless a 'performance', the validity of which as an index of mobility within the individual's usual environment remains uncertain.

Endurance tests (2 or 6 min)[16]

The 2- or 6-min walk test is used to measure the maximum distance that a person can walk over that time interval, and is commonly used in the assessment of cardiovascular or pulmonary disease. It has been used to assess outcome and mobility in individuals with stroke, head injury[17] and Parkinson's disease[18] and has been found to be reliable.[17] While including an endurance component, other factors such as pain, mood and cardiovascular fitness can influence the outcome.[19] There is little information on the clinical relevance of this test as a predictor of community function in neurological disorders.

Quantitative movement analysis

The use of specific movement analysis techniques (both laboratory- and community-based) may provide more detailed quantification of walking. Sophisticated laboratory assessment can provide objective computerized analysis, giving accurate details of temporal measures, kinematics (limb motion assessed by the use of motion analysis systems and markers across joints), electromyography and kinetics (forces exerted by body using in-ground force plate transducers). This may inform our understanding of the components of impaired walking in an individual, but is expensive in terms of time and finance, unsuitable for large group studies, and is of uncertain relation to community mobility. Developments in digital video technology may allow home-based assessments.[20] Video-observed scoring systems[21] have also been used to assess the quality of gait and used as outcome measures, for example in a trial of physiotherapy in MS,[22,23] which facilitates evaluation of inter-rater reliability for a range of scoring systems.[23] As with gait speed, gait analysis provides objective data on capacity, but the link to mobility in the community is unclear.

Energy expenditure

The measurement of energy cost during walking has been used as a measure of the efficiency of walking activity. The methods are either direct or indirect calorific assessments. Direct assessment takes place in specialized chambers that allow analysis of everyday tasks; clearly not appropriate for own-environment assessment. Indirect methods may use the consumption of oxygen, heart rate monitoring or metabolism of isotope labelled water.[24–26] While these methods have been used to assess the benefit of orthotics or surgery to improve gait in cerebral palsy[24] and are of interest in epidemiological studies, they have many drawbacks, including financial cost, feasibility and interference with activity, and may be influenced by physical fitness and non-ambulatory exertion. As such, they are not practical as measures of real-life mobility.

Functional scales

The lack of a 'gold standard' for measuring the impact of disease on mobility has led to a proliferation of functional scales, some of which are considered below. The majority are ordinal, i.e. represent an order in which one value is better or worse than another, although the interval between values is not equal (interval scale). This type of scale uses data either from observed activity (and thus has the same limitations in principle as a timed walk) or from patient or carer questionnaires: the latter may provide accurate qualitative information about mobility but has severe quantitative limitations. Use of aids, e.g. a stick may define scores over and above absolute mobility, e.g. the Kurtzke expanded disability scale (EDSS). Whether new psychometric methods such as Rasch analysis or item response theory as statistical techniques to convert ordinal scales into interval measures will make such scales more useful and rigorous outcome measures, needs to be determined.[27]

Specific mobility scales

Rivermead Mobility Index (RMI)[28]

The RMI is an ordinal scale based on asked questions about mobility derived disability and an observation of standing. It has good psychometric properties (Table 3), and is more sensitive to change than the ambulation index and gait speed in MS.[14] It has been used as an outcome measure in many studies and RCTs, including physiotherapy in MS.[22] The relation to real-life mobility is unknown.

Ambulation Index (AI)[9]

This semi-quantitative ordinal scale is scored 0–10, based on ambulation-related disability, use of an aid and the time taken to walk 25 ft. It was originally designed for use in immunosuppression treatment trials in MS. It has moderate inter-rater agreement, and is weakly responsive.[29] It is again influenced by the use of an aid, which can be dependant on

Table 1 Summary of some methods of assessing walking mobility

Type	Name	What is measured?	Use
Direct observation			
Clinical examination	Simple observation of walking	Clinical impression	Many neurological disorders
	Kurtzke Expanded Disability Severity Scale (EDSS)[31]	Clinical examination rating impairment and disability detected, followed by assessment of maximum walking distance and aids required. Scored 0 – 10	MS
Timed walk	10 m	Gait speed	MS, stroke, PD, head injury
	25 ft		
	2 or 6 min walk	Measures distance covered over time	PD, respiratory/heart disease
Quantitative movement analysis	Kinetic gait analysis	Laboratory-based computerized analysis of gait giving information about velocities, angles and moments	
	Video evaluation	Video-based scoring system on quality of gait[21,23]	Physiotherapy trials
Energy consumption	Physiological Cost Index	Walking and other activities given a score according to difference between resting and active heart rate, an indirect measure of energy consumption	Epidemiological studies of activity
Self-report or questionnaire			
Specific mobility-based scales	Rivermead Mobility Index (RMI) [28]	Based on mobility-derived disability, ranging from ability to turn in bed to running, and an observation of standing without aid	Stroke, MS
	Ambulation Index [9]	Semi-quantitative scale (0–10) based on time to walk 25 feet and use of aids.	MS
	Multiple Sclerosis Walking Scale (MSWS-12) [42]	Patient-based measure using twelve questions with 5 responses regarding limitations of mobility. (Limited your ability to walk, run, climb stairs, use support)	MS

Disease-specific measures of activity	UK Neurological Disability Scale (UKNDS) [37]	Patient-based questionnaire composed of twelve subsections including mobility, scored 0–5 based on use of aids.	MS, CIDP
	Unified Parkinson's Disease Rating Scale[58]	Multi-component rating scale that includes self-report of activity (Falls, walking and freezing) and observation (Arising from chair, gait and postural stability)	PD
Generic measures of activity (ADL)	Functional Independence Measure (FIM)[59]	Scale comprising 18 items with four levels of response, includes mobility (transfers from bed/chair, toilet and bath) and locomotion (distance walked and ability to climb stairs)	Various neurological conditions
	Barthel Index[60] OPCS Disability Scales Nottingham EADL[61]	Designed to cover range of activity/participation with mobility subsections based on use of aids and ability to walk a distance or climb stairs	Stroke, MS
Quality of life measures	SF-36[62]	Questionnaire consisting of eight domains including Physical Functioning (sports, lifting, walking 100 yards, dressing) Role Physical (work/other activities)	MS, stroke, MND, PD, epilepsy
	Multiple Sclerosis Impact Scale[40]	29 questions (20 physical) scored 1–5 about limitations in carrying, balance, moving indoors	MS
Physical activity	Diaries Recall questionnaires	Based on keeping a diary of all physical activities or relying on recall after 7 days, results are often converted into energy expenditure.	Epidemiological studies of activity
Ambulatory activity monitoring			
Motion sensors	Pedometers Accelerometers	Devices that are worn at the ankle or waist. Allow long-term monitoring of activity, measure total steps or displacement counts	MS, trials of exercise
	Microprocessor-based accelerometers	Device which is worn at the ankle and allows long-term monitoring, activity expressed as steps per minute	Stroke

Table 2 Some psychometric properties of mobility measures

Scale	Reliability (Intra-rater/Intra-class correlation coefficient)	Validity (Pearson's correlation)		Responsiveness (effect size)
Timed walk	Variability: 20 ± 8%[14] Intra-rater: ICC 0.96–0.99[8,17]	Max walk rho = –0.79 [30] 2 min walk rho = –0.61[17]	RMI r = –0.80[14]	
RMI[28]	Intra-rater: ICC 0.96[17]	10 m walk r = –0.80 to 0.82[14,28] AI r = –0.96 [14]	EDSS –0.96[14] 6 min walk 0.63[28]	
AI[9]	Inter-rater: κ = 0.73, ICC 0.96[29] Intra-rater: κ = 0.59,[29] ICC 0.93[29]	8 m walk r = 0.91[30] EDSS r = 0.68[14] RMI r = –0.96[14]	FIM r = –0.73[29] SF-36 PF r = –0.87[29]	0.2[29]
MSWS[42]	Intra-rater: ICC 0.94 [63]	25 ft walk r = 0.46 EDSS r = 0.65 SF36 PF r = –0.77 [42]	GNDS-LL 0.52 MSIS-phys 0.79[63]	0.93[42] SRM = 0.9[42]
EDSS[31]	Inter-rater: κ = 0.32–0.76,[29,64] ICC 0.78 [65] Intra-rater: κ = 0.7,[29] ICC 0.61–0.94 [65]	8 m walk r = –0.86[30] FIM r = –0.84 to 0.87[29,65] BI r = –0.74 to 0.89[29,65,66]	AI r = 0.68 [29] SF-36 PF r = –0.82[29] RMI r = –0.96[14]	0.11[29] 0.10[65]
GNDS (UK)[37]	Inter-rater: ICC 0.98 [37] Intra-rater: ICC 0.96–0.97[37,66]	EDSS r = 0.64–0.75[37,66,67] FIM r = –0.81 SF-36 PF r = –0.81[37]	GNDS-LL vs. RMI r = –0.91[66] EDSS r = 0.88[66] 25 ft walk r = 0.83[67]	
UPDRS[58]	Intra-rater: ICC 0.92[68]			
FIM[59]	Inter-rater: ICC 0.99[29] Intra-rater: ICC 0.94–0.98[29,69]	EDSS r = –0.87 AI r = –0.73 [29]	BI r = 0.88 SF-36 PF r = 0.88[29]	0.46[29] 0.27[65] SRM = 0.48[69]
BI[60]	Intra-rater: κ = 0.75 ICC 0.98 [29]	OPCS r = 0.84	SF-36 PCS r = 0.3[69]	0.24–0.39[29,65] SRM = 0.56[69]
SF-36[62]	Cronbach's α = 0.94[70]	PF vs. EDSS r = –0.86 RP vs. EDSS r = –0.33[70]		

ICC = intra-class correlation; RMI = Rivermead Mobility Index; EDSS = Expanded Disability Severity Scale; max walk = maximum walking distance; 2 min walk = distance walked in 2 min; AI = Ambulation Index; FIM = Functional Independence Measure; SF36-PF = Physical Function component of SF-36; SF-36 RP = Physical Role component of SF-36; MSWS = MS Walking Scale; GNDS (UK) = Guys/UK Neurological Disability scale; GNDS (LL) = Mobility sub-section of GNDS; MSIS-phys = Physical component of MS Impact Scale; UPDRS = Unified Parkinson's Disease Rating Scale; BI = Barthel Index; FIM = Functional Independence Measure; OPCS = Office Population Censuses Surveys.

psychosocial factors such as vanity and fear of falling, rather than actual performed mobility.[30]

Impairment/disability scales

Kurtzke Expanded Disability Severity Scale (EDSS)[31]

The EDSS is designed as an observed examination scored on an ordinal scale, and was the first to be widely adopted as an outcome measure in multiple sclerosis. While an advance when first proposed, and still widely used, its flaws are now well-known. These include the fact that it measures impairment at its lower end and disability at the upper, with the middle entirely dependent upon mobility. It has rather low sensitivity,[32] and can have poor intra-rater and inter-rater reliability.[33] This may be because maximum walking distance can vary day to day,[34] some assessors may ask for maximum walking distance rather than observe it (or give variable instructions) and some clinicians and patients are inaccurate at estimating distance.[35,36]

UK (Guy's) Neurological Disability Scale (UKNDS)[37]

The UKNDS was developed as a patient-oriented, questionnaire-based measure of disability in MS, with a mobility component, that has satisfactory psychometric properties and appears reliable and responsive with good validity.[38] Walking is considered 'not affected' or affected but independent (no assistance) for scores of 0 and 1, respectively, while scores 2–5 represent increasing degrees of support (aids, person, wheelchair). Such a scale probably provides useful information, but gives virtually no indication about the amount of walking undertaken with the possible exception of grade 5 ('restricted to wheelchair'). As with the EDSS and AI, the mobility section is dominated by the use of aids or assistance, without being able to clarify amount of walking.

Global ability and participation measures

Activities of daily living questionnaires (e.g. Barthel Index) and measures of quality of life (e.g. SF-36) have mobility subsections. These are directed toward functional abilities and dependency and are therefore limited as direct outcome measures of mobility.

Patient-oriented measures

There has been increasing interest in health status and health-related quality of life (HR-QOL), which have been defined as patient-oriented outcomes as opposed to objective measures (physician-oriented). These measures incorporate to varying degrees the patient's viewpoint, and have been described as the 'optimum outcome measure'.[39] An example of such a patient-oriented measure is the Multiple Sclerosis Impact Scale (MSIS-29).[40] This is a patient-based outcome measure consisting of 29 questions, each scored out of 5. It was developed using psychometric methods and it has high test/re-test reliability. Validity and responsiveness has been demonstrated in a number of MS populations.[40,41] Another promising new patient self-report scale is the MS walking scale (MSWS-12).[42] Developed using psychometric principles, it consists of 12 items, each scored out of 5. The authors report excellent reliability and validity, but it has yet to be independently assessed.

Questionnaire-based scales may give a better idea of perceived performance rather than capacity, but are limited by their indirect and non-verifiable nature.[11] Ordinal scales are poorly responsive, as a threshold must be crossed before change is recorded. Perception and recall, in a population where cognitive impairment and affective disorder is common, may be further limitations (e.g. impaired autobiographical memory is present in up to 60% in some MS populations, and is associated with impaired ability to make comparative judgements[43]). The patient's perception of their own mobility and in particular, of change in mobility clearly changes over time. Initially, at the onset of a disorder, large changes in absolute mobility dominate perceptions, e.g. the difference between walking only half a mile versus a 10-mile hike. Later, and with increased disability, the difference between being able to cross a room or not assumes major relevance, whereas a 10-mile hike is a remote memory. Such disjunctions between patient perception and absolute levels of mobility are of major importance, and emphasize the need to combine relative and absolute measures of outcome.

Because of a lack of a gold standard for assessing mobility, validating such questionnaire-based outcome measures is performed using construct validity (comparison with current scales used) rather than criterion validity.[6] Although these measures allow some representation of a patient's walking capacity, they remain surrogate markers of absolute mobility in the community.

Physical activity questionnaires

These questionnaires were initially used to study the epidemiology of physical activity,[44,45] and rely on either diary or recall, and subsequent conversion of

Table 3 Length of sampling time and limitations of assessment methods

Measure	Venue	Sample time	Limitations
Observed mobility			
Quantitative movement analysis	Gait laboratory	Seconds/minutes	Costly in time and finance, not practical for large groups
Timed walk (gait analysis)	Clinic, home	Seconds/minutes	Only allows us to understand how fast an individual walks, not their level of activity. Limited sample time.
Distance covered/time	Gym, lab	e.g. 2, 6 min	Influenced by many other factors such as mood, pain, motivation. Capacity rather than performance
Scaled by aids (EDSS, AI)	Clinic, home	Minutes	The use of aids is not only dependent on an individual's physical state but also on psychosocial factors.
Asked measures (observer- or self-assessed)			
Mobility scales/components	Home, post, telephone	Days/weeks	Limited by inherent nature of ordinal scales and reliance on patients' estimation and perception of abilities.
Diaries	Home, post, telephone	Days/weeks	Time consuming for the subject, diaries influence behaviour and rely on patient compliance
Physical activity questionnaires	Home, post, telephone	Days/weeks	Converts activities into METs (metabolic equivalents): relation to ambulatory activity unclear
QOL mobility	Home, post, telephone	Days/weeks	Reliance on patients' perceptions of their abilities
Activity monitoring			
Stepwatch Activity Monitor	Own environment	Hours/days/weeks	The optimum length of recording is unknown, patient compliance is needed

activity into energy expenditure. Questionnaires are easy to use and inexpensive, but are retrospective and rely on a recall, perception and estimation of physical activity, which may be more or less than actual activity.[46] Diaries require a high level of adherence, and may interfere with or influence physical activity (Hawthorne effect).[47] When physical activity questionnaires are compared to activity monitoring, they underestimate distance walked/ energy expenditure,[46] and are less sensitive to differences between inactive populations (MS and sedentary volunteers).[48]

Ambulatory activity monitors

The use of motion sensors, such as pedometers, has been advocated for comprehensive quantification of mobility.[49] Through computerization, activity can be measured over many days unobtrusively and without interfering excessively with normal pattern of life. Such direct measurement methods in principle provide more precise information regarding what an individual actually does in everyday life and, potentially, how this changes over time.

Accelerometers

Accelerometers provide information on frequency and intensity of movement over continuous time intervals,[50] and have been used in multiple sclerosis.[48] Three-dimensional accelerometers may have limitations in accuracy and reliability.[51] Most commercially available accelerometers are worn at the waist, and are sensitive to vertical movement. The position, mode of attachment, the movement style and walking speed of the individual being monitored will therefore affect the response. The accuracy of a waist-attached pedometer was compared to that of a two-dimensional accelerometer worn at the ankle, and the latter had less error, particularly in obese subjects and those with gait asymmetry.[52]

Microprocessor-based 2D accelerometers (e.g. the Step Activity Monitor, SAM) were developed to overcome limitations of waist-attached devices.[51,52] The SAM, for example, is worn at the ankle and measures cadence (right steps per minute) on a minute-by-minute basis, allowing recording of activity for up to 21 days in an unobtrusive manner. Other advantages include that is easily worn, allowing the elderly and the increasingly disabled to be assessed, and can be programmed according to a subject's height, cadence and gait speed. A range of data outputs are possible, including total number of steps/day or week, the average 24 h step count over a week, sustained activity measures (e.g. maximum number of steps achieved during any continuous interval e.g. 1, 10, 60 min), peak activity indices (highest mean step rate during any 30×1 min intervals) and percentage of time spent in inactivity (no steps/min). The sustained activity measure gives an estimate of endurance while the peak indices give an estimate of best performance. If the total step count/ 24 h is combined with a measure of stride length, an estimate of total distance walked can be made.

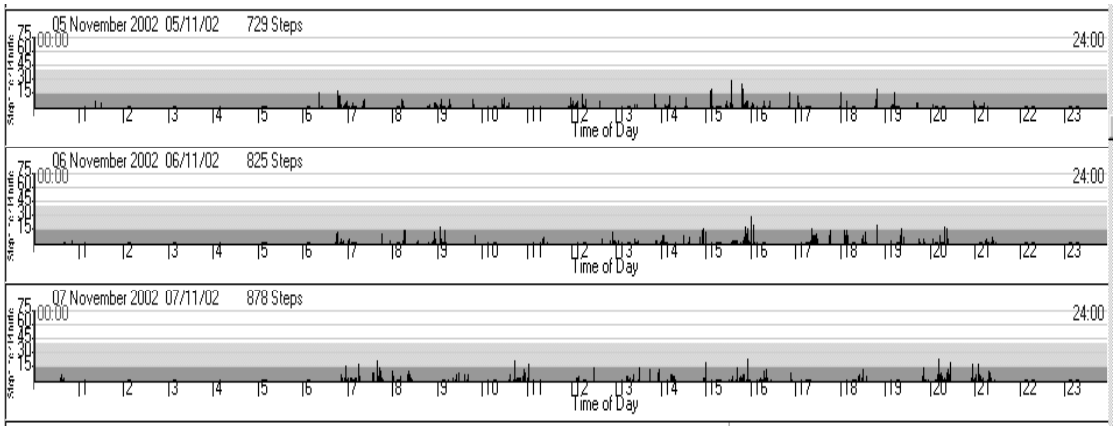
Such devices have been used successfully in populations with notable gait asymmetry, particularly amputee subjects and individuals following a stroke.[53] The accuracy and reliability of the SAM in stroke patients has been investigated, and found to offer good potential to quantify home- or community-based activity levels.[53,54] The monitor was found to be reliable in MS, PD and neuromuscular disease,[55,56] and reference ranges are quoted in Table 4. However, this method is dependent on patient adherence (wearing the monitor). It is limited to walking mobility, and cannot assess mobility associated with wheelchair use or other transport. The use of such a device can be supplemented by a debriefing session at the conclusion of monitoring. Step counts or distances/time generate interval or ratio measures over sufficiently long periods of everyday life to have strong face validity as measures of mobility

Table 4 Illustrative normal and MS patient Stepwatch activity indices

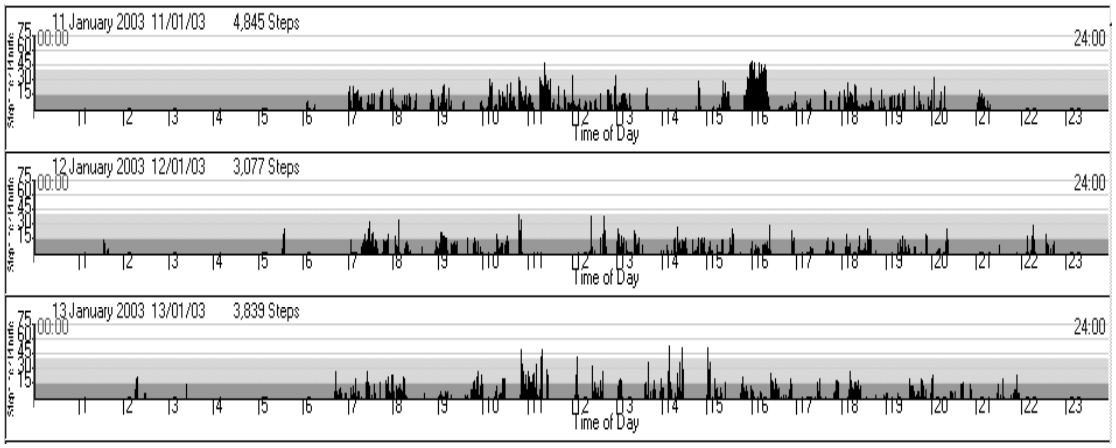
Stepwatch indices	Healthy subjects ($n = 25$)	Multiple sclerosis ($n = 25$)
Total steps/7 days	38391 (19672–68464)	21179 (2000–38764)
Mean steps/24 h over 7 days	5484 (2810–9780)	3025 (285–5537)
Peak activity index (steps/min)	49.2 (37.3–62.7)	29.6 (5.7–44.5)
Sustained activity index 60 min	22.2 (14.2–50.3)	10.6 (1.2–23.2)
1 min	60.8 (50.4–71.4)	43.3 (10.4–7.4)
Inactivity (%) (over 24 h)	74.6% (68.0–85.7%)	79.5% (66.5–93.1%)

Data are means (ranges). Data from Pearson 2004, personal communication.

MS Relapse: 3 days of activity monitoring following right hemiparetic relapse. Average stepcount per 24 h= 836.



Reassessed eight weeks later following corticosteroids and physiotherapy. Average stepcount per 24 h= 4015.



Each of the three tracks represents 24 hours with the y-axis representing number of steps per minute. The x-axis represents the 24 h clock, running from 00.00 to 23.59.

Figure 2. Illustration of graphical data downloaded from a period of activity monitoring in a MS patient undergoing relapse and subsequent recovery.

in the community. Observation of neurological patients recovering from clinical events shows much greater changes recorded using step counts, compared to conventional mobility scores; such difference can approach an order of magnitude (Figure 2).

A new gold standard

In principle, the gold standard for walking activity should measure performance, the total ambulation over a representative period of time. As activity varies markedly during the day and may vary cyclically over longer periods, e.g. a week, the sample length needs to be long enough to be representative, but not so long as to be impractical. Total ambulation could be measured in terms of distance walked, and/or paces taken in a given period. While estimates of distance walked could be made by using mean stride length, the fact that this varies with speed is an issue. Accurate distance walked may require new technologies, such as advanced global positioning systems.

The ideal measure of walking activity would also be reliable, accurate in measuring mobility (valid), clinically practical and economical. Furthermore, it should generate interval or ratio scale data for increased sensitivity, and comparison with a normal range. Unfortunately none of the measures discussed above can meet this standard; the strengths of some are the weakness of others. Most measures are either attempting to derive mobility from brief observations, or assessing what level of mobility is perceived, rather than assessing what individuals actually do in real life.

Continuous long-term home monitoring using accelerometry is the technique that currently allows many of the above aims to be achieved. Many questions remain to be answered regarding activity monitoring, including the most appropriate period of monitoring that reflects the individual's activity (7 days has been suggested),[57] and the optimum measure (e.g. 24 h step count, maximum cadence achieved, duration of inactivity, total distance walked). In particular, the relationships between such outputs and measures of activity, participation and quality of life, require exploration.

Conclusion

We propose that the gold standard for measuring ambulatory mobility in neurological disorders should be the total ambulatory activity undertaken by an individual in their usual environment in performing their usual range of daily activities.

Ambulatory activity monitoring allows such activity to be expressed as steps and distance over time, placed into context by patient self-report of usual events. Adoption of such a standard will necessitate a review of the validity of measures that only sample (by observation or questioning) brief periods of activity in an artificial environment (capacity), and of the relationship between mobility, participation and quality of life.

Acknowledgements

ORP is supported by Cardiff and Vale NHS Trust; MEB is supported by the Wales Office for Research and Development (DTA 00_2_008). The authors would like to acknowledge Kim Coleman of Cymatech Step Watch, makers of the Step Activity Monitor (SAM), and staff in the Department of Neurology, University Hospital Wales and the Research Centre for Clinical Kinaesiology, University of Wales College of Medicine, Cardiff.

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