PAPER

Community walking activity in neurological disorders with leg weakness

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Background: The aims of this study were to determine walking mobility in the community in individuals with lower limb weakness and to establish the extent to which some clinic based measures predict such activity.

Methods: Five groups (n = 12–18) of independently ambulant patients with lower limb weakness due to neurological conditions and a matched healthy control group were recruited. Measures of isometric knee extension/flexion muscle strength, time to stand up (sit-to-stand, STS), gait speed, and daily step counts (recorded over 7 days) were obtained. The Rivermead Mobility Index (RMI) provided a measure of functional ability. Between group differences and associations were explored. Backward stepwise regression analysis was used to identify variables influencing daily step count in individuals with neurological impairment.

Results: Patients were significantly weaker (mean (SD) quadriceps strength 69 ± 34% *v* 102 ± 37% predicted), slower to stand up (2.9 ± 1.3 *v* 2.0 ± 0.6 s), and had slower self selected gait speed (0.74 ± 0.3 *v* 1.2 ± 0.2 m/s) than controls. Mean daily step count was also lower (3090 ± 1902 *v* 6374 ± 1819) than in controls. In neurology patients step count was correlated with RMI score ($r_s = 0.49$, $p < 0.01$) and STS ($r = -0.19$, $p < 0.05$). However, self selected gait speed was the only significant predictor in the regression analysis ($p < 0.01$) of daily mean step count.

Conclusions: Measures of muscle strength, timed STS, and RMI do not appear to closely reflect community walking activity in these patient groups. Self selected gait speed was partially predictive. Measurement of community walking activity may add a new dimension to evaluating the impact of interventions in neurological disorders.

As fuctional independence is an important goal in neurological rehabilitation, it is important to assess how individuals participate in their daily living environment. This daily activity is determined by the interaction of ability, opportunity, and need.[1]

Current assessment of mobility usually involves subjective or observer rated instruments that range from limited direct observation to questioning the patient/carer, asking them to keep a diary, and administering questionnaires.[2] Most indices derive from measures related to specific times and (often unfamiliar) settings; they are characterised by brevity, the need for direct observation, dependence on exact instructions, and an unquantifiable impact of the observer which may vary depending on the aim of the evaluation. Such indices 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 performance in the community is speculative.

Activity monitoring over a 7 day period has been found to be reliable and representative of an individual's movements on a day to day basis.[3] Long term activity monitors have been used to quantify ambulatory activity and determine functional outcomes in a range of populations[4–7]; however, such activity data is lacking as regards neurological conditions.

The present study aimed to examine the hypothesis that some commonly used outcome measures do not predict community walking activity in neurological disorders associated with lower limb weakness.

METHODS

Study design and subjects

Five groups of patients (n = 12 to n = 18) (table 1) were compared to age and sex matched control groups of healthy subjects. Groups were matched on marginal distributions of means. Power calculations (mean daily step count and gait speed) from a pilot study of patients with muscle weakness and mobility restrictions (n = 10) were used to determine the required sample size. The data suggested a mean difference between patients and healthy subjects of 3559 steps and a difference in gait speed of 0.67 m/s. A sample size of 15 in the patient groups and 15 in the matched control groups would achieve a power of 0.99 (α level 0.05).[8] In some groups, lower numbers of patients were recruited, that is n = 12, with a reduction of power to 80%. Power increases were obtained by using unequal allocation of patients and controls.[9]

Seventy four neurology patients (mean (SD) age 56.0 (13.2) years, height 170.6 (9.3) cm, weight 77.0 (17.1) kg, and BMI 26.3, 43 male) were recruited from neurology clinics at University Hospital Wales, Cardiff, UK. Inclusion criteria for patients were: (a) diagnosis by a specialist neurologist as having lower limb weakness with a clear indication as to cause, and (b) ability to stand and walk at least 10 m either independently or with a walking aid.

Thirty two healthy volunteers (mean (SD) age 57.8 (13.8) years, height 170 (10.2) cm, weight 69.7 (11.9) kg, and BMI 24.1, 14 male) were recruited from local volunteer, charity, and social groups. The volunteers had no mobility restrictions or general health problems and none participated in elite sports activities. The study was approved by the local research ethical committee. Subjects were required to provide informed written consent.

Abbreviations: RMI, Rivermead Mobility Index; STS, sit-to-stand

Table 1 Specific categories together with illustrative diagnoses for each category

Category	Illustrative specific diagnoses
Extra-pyramidal	Parkinsonism (PD)
Pyramidal (UMN lesions)	Hereditary spastic paraplegia
	Motor neuron disease with clinical UMN signs only
LMN disorder with no or minor sensory loss	Motor neuropathy
	Motor neuron disease with clinical LMN signs only
	Spinal muscular atrophy
Peripheral nerve disorder with sensory loss	Guillain-Barré syndrome
	Chronic inflammatory demyelinating polyneuropathy or sensory/motor neuropathy
	Other sensory/motor polyneuropathy
Primary muscle or neuromuscular junction disorder	Muscular dystrophy
	Polymyositis
	Myasthenic syndrome
	Acid-maltase deficiency
	Familial periodic paralysis

LMN, lower motor neuron; UMN, upper motor neuron.

Measures of isometric muscle strength

Quadriceps and hamstrings muscle strength was tested using a KINCOM dynamometer (KINCOM 125E plus; Chattecx, Oxfordshire, UK). A seat belt was used to secure the subject in the sitting position (hips and knees flexed to 90°); a stabilisation strap was placed across the femur of the leg being tested. The subjects were requested not to use their hands to hold onto the chair during execution of the muscle contraction and to produce their maximal possible standardised muscle contraction. The moment arm distance was recorded. Four isometric contractions for quadriceps and hamstrings were completed with a 1 min resting period between each repetition. As most patients did not have major asymmetrical patterns of muscle weakness (such as occurs in individuals following stroke), strength testing was restricted to the right leg. The mean value was used for all analyses. To allow for the effect of gender, age, height, and weight, the mean absolute quadriceps and hamstring muscle strengths were expressed as a percentage of the mean predicted muscle strength.[10]

Measures related to mobility

Measures of functional ability, sit-to-stand (STS) represented by time to stand up, self-selected gait speed, and long term activity monitoring were obtained. The Rivermead Mobility index (RMI) provided a measure of reported mobility.[11]

Time to stand up (time taken to achieve full extension from the point of movement initiation) was defined by means of kinematic measurement using the VICON 512 system and reflective markers attached to the lower limbs of the subject being tested (VICON Motion Systems, Oxford, UK). MATLAB 6.0 software (MathWorks, Natick, MA) was used to execute automatic algorithms to identify the times of all STS phases.[12] Chair height was set individually to correspond to 100% of knee joint height from the floor.[13–15] Subjects stood up at a self-selected pace with a self-selected foot position using their arms for assistance only if necessary. Self selected gait speed was calculated using stride length and time taken to walk along a 10 m walkway.[16]

Activity level by total mean step count was recorded using the StepWatch Step Activity Monitor (SAM; Cymatech, Seattle, WA, USA) attached to the right ankle. All subjects wore the device each day for seven consecutive 24 h periods and only removed it for bathing.

Activity indices extracted were total number of right steps/day, the mean daily (24 h) step count (recorded for 7 days), sustained activity measures (for example, maximum average steps/min during any continuous 60 min), and percentage of time involved in low, medium, and high activity. Time (in hours) spent participating in low level activities (defined as less than 15 steps/min), medium level activities (15–40 steps/min), and high level activities (more than 40 steps/min) were also obtained.[17] To facilitate comparison with the literature, the percentage of time spent inactive and at low, medium, or high levels of activity was converted into time in hours. This allowed for the creation of a 24 h activity profile.

Table 2 Muscle strength (predicted) and STS for each group

Diagnostic group	Quadriceps strength (%)†	Hamstrings strength (%)†	STS (s)†
Extra-pyramidal (n = 15)	81.3 (36.4), −48.8 to 11.6	65.7 (30.6),* 13.9 to 57.0	2.5 (0.9),* 0.1 to 1.1‡
Pyramidal (n = 12)	67.2 (30.7),** 12.1 to 65.4	55.9 (33.5),** 19.4 to 67.1	2.9 (1.2),** 0.2 to 1.7‡
LMN (sensory intact) (n = 12)	53.4 (38.0),** 21.5 to 78.3	55.6 (20.5),* 30.2 to 70.5	2.9 (0.9),* −2.1 to 0.6‡
LMN (sensory loss) (n = 18)	87.4 (27.5), −45.3 to 0.6	61.4 (22.4),** 31.4 to 66.2	2.8 (1.7),* −0.1 to 1.2‡
Muscle disease (n = 17)	50.6 (30.1),** 36.9 to 88.7	55.9 (42.7),** 32.7 to 85.4	3.3 (1.6),** 0.4 to 2.2‡
Grouped neurology subjects (n = 74)	68.9 (34.9)	59.2 (30.7)	2.9 (1.3)
Control subjects (n = 32)	102.4 (37.0)	103.2 (30.1)	2.0 (0.59)

LMN, lower motor neuron.
†Values are mean (SD), 95% CI difference; ‡non-parametric comparisons between groups were used (approximate confidence intervals presented).
*$p \leqslant 0.05$;**$p \leqslant 0.01$ when compared to a separately matched control group.

Statistical analysis

Descriptive analysis and inferential testing were completed using SPSS version 11 (SPSS, Chicago, IL). Independent *t* tests or Mann-Witney U tests were used to compare between two unrelated groups (patients to healthy controls for each diagnostic group). Mean step count data were compared across diagnostic groups using a one way ANOVA. In order to explore relationships between muscle strength and function (independent of pathology), patient data were combined. Backward stepwise regression analysis was used to identify the variables influential in determining activity levels in neurology patients.

RESULTS

All neurology patient groups were weaker and slower to stand up than their healthy control group (table 2). Mean gait speed in the neurology groups was reduced and ranged from 0.59 to 0.96 m/s, while that in control subjects was 1.2 m/s (table 3). RMI scores ranged from 4 to 15 across the diagnostic groups (table 3).

Neurology patients were substantially less active. They took on average 48% of the mean daily steps of healthy controls and had sustained (60 min) activity levels on average that were 43.5% of those of controls (table 3). The mean daily step counts between groups were not significantly different ($F = 0.99$, $p = 0.42$).

Daily activity profiles calculated from the % activity levels over a 24 h day are presented in table 4. Patients spent more time inactive than healthy controls (18–20 h per 24 h compared to 17 in controls) with less time participating in both medium and high level activities than healthy subjects. Time spent participating in low level activities was mostly less than in controls. Neurology subjects demonstrated lower sustained activity levels, indicative of a reduced ability to

Table 3 Mobility measures for each group

Diagnostic group	Perceived mobility: RMI†	Gait speed (m/s)‡	Daily step count (recorded over 7 days)‡	Steps/min involved in sustained activity (60 min)‡
Extra-pyramidal (n = 15)	14 (9 to 15)	0.96 (0.2)** 0.08 to 0.39	3600 (1282)** 2087 to 4551	26.3 (10.4)** 15.7 to 32.5
Pyramidal (n = 12)	11.5 (7 to 14)	0.59 (0.3)** 0.46 to 0.84¶	3291 (3269)** 790 to 5085	19.5 (15.1)** 15.3 to 36.2
LMN (sensory intact) (n = 12)	12 (4 to 15)	0.67 (0.3)** 0.35 to 0.73¶	2728 (1599)** 2446 to 4904	12.6 (7.4)** 25.9 to 41.9
LMN (sensory loss) (n = 18)	11.5 (4 to 15)	0.67 (0.3)** 0.38 to 0.75	2480 (1565)** 3131 to 5344	17.1 (9.9)** 19.4 to 34.3
Muscle disease (n = 17)	12 (9 to 15)	0.8 (0.2)** 0.27 to 0.56	3401 (1574)** 2269 to 4652	19.2 (10.7)** 17.6 to 34.3
Grouped neurology subjects (n = 74)	12 (4–15)	0.74 (0.3)	3090 (1902)	19.1 (11.4)
Control subjects (n = 32)	15	1.2 (0.16)	6374 (1819)	44.2 (12.9)

†Values are median (range); ‡values are mean (SD), 95% CI difference; ¶non-parametric comparisons between groups were used (approximate confidence intervals presented).
*$p \leqslant 0.05$; **$p \leqslant 0.01$ when compared to a separately matched control group.

maintain activity levels for a longer period of time and were inactive for significantly more of the time.

In univariate analysis, daily mean step counts were significantly correlated with the score on RMI ($r_s = 0.49$, $p<0.01$), time to stand up ($r = -0.19$, $p<0.05$), and self-selected gait speed ($r = 0.58$, $p<0.01$), but not with muscle strength. Self selected gait speed was, however, the only significant predictor in the regression analysis ($p<0.01$) of daily mean step count, accounting for 34% (adjusted R^2) of the variance in neurology subjects. Variables excluded from the model by the regression analysis were: age in years, gender, diagnosis, RMI score, hamstrings and quadriceps muscle strength, and time to stand up.

DISCUSSION

Many causes contribute to functional loss in individuals with neurological impairment.[18–20] This study shows that ambulatory mobility is restricted in neurology patients in the community. All neurology patients had significantly weaker knee extensors and/or flexors compared to a matched control group. The patients were also slower to stand up and walked less than matched healthy controls: self selected gait speed was the only clinical measure that (partially) predicted community activity.

The neurology subjects tested were recruited on the basis of a clear diagnosis and lower limb muscle weakness. Clearly, the distribution of weakness as well as the level of impairment and the presence of other impairments related to the underlying pathology varied. Despite this variability, no significant differences were identified between groups for mean daily step count and self-selected gait speed. Gait speed was the only significant predictor of actual walking mobility in the neurology patients tested in this study and accounted for 34% of the variance in actual step count.

The concept that gait speed is an important predictor of clinical outcome is not new. Walking has complex movement requirements and provides a useful measure of clinical outcome. Analysis of gait has been suggested to provide a better understanding of ''relations between primary disturbance and compensating postural reactions''.[21] Gait speed, as well as the phases of the gait cycle, are correlated with common clinical rating scales and influenced by medication in individuals with Parkinson's disease.[22 23] Muscle strength is important for adequate gait performance in individuals with muscle weakness.[24] Factors influencing selection of gait speed include muscle strength, balance, and aerobic capacity as well as general walking confidence, the external environment, and self efficacy. Gait adjustments noted in older individuals, as well as those with neurological impairment, include adoption of a more cautious walking style, shorter step lengths, and slower speeds,[25–27] which are all influenced by the particular activity being performed as well as the subject's confidence to perform the task in question.[25] Self-selected gait speed has been related to community mobility in the literature although this study explicitly makes the link to a direct objective measure of community mobility in neurological patients.[28–31] Our data support the view that self selected gait speed is partially predictive of what an individual is able to do in the community. Heterogeneity in activity levels, independent of significant change in gait speed, has been shown in recovering stroke patients.[32] Factors such as motivation and self efficacy may contribute to this and may potentially explain the partial predictions seen.

Our data do not explain why neurology patients spend more time inactive than healthy subjects over 24 h, but issues of fatigue, opportunity, and environmental restrictions might be considered.[33] Socio-economic status was not assessed in

Table 4 Daily activity profiles for each group (calculations based on a 24 h day)

Diagnostic group	Hours inactive	Hours low activity	Hours medium activity	Hours high activity
Extra-pyramidal (n = 15)	18.7 (1.7)	4.0 (1.5)	1.1 (0.5)	0.2 (0.2)
Pyramidal and para-pyramidal (n = 12)	19.2 (2.9)	3.6 (1.9)	0.9 (0.8)	0.3 (0.5)
LMN (sensory intact) (n = 12)	19.2 (2.0)	3.8 (1.5)	0.9 (0.6)	0.05 (0.1)
LMN (sensory loss) (n = 18)	20.1 (1.6)	2.9 (1.1)	0.8 (0.5)	0.1 (0.2)
Muscle disease (n = 17)	18.6 (1.7)	4.2 (1.1)	1.1 (0.7)	0.1 (0.2)
Control subjects (n = 32)	17.4 (1.1)	4.2 (0.8)	1.5 (0.5)	0.8 (0.5)

Values are mean (SD).

this study and the contribution of related factors to overall variance in activity levels is currently uncertain.

Step data recorded during continuous activity monitoring of neurology patients over a 7 day period provides an objective basis against which to judge activity and participation requiring ambulation, but even with the ability to count steps, the specific content of the walking activity remains unknown. Further research is needed to classify the content of community based walking activity as measured by mean step count. However, direct measures of community ambulatory activity may complement and illuminate self and carer assessments and quality of life measures related to intervention studies in neurological disorders.

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