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WALKING IN POSTPOLIOMYELITIS SYNDROME: THE RELATIONSHIPS BETWEEN TIME-SCORED TESTS, WALKING IN DAILY LIFE AND PERCEIVED MOBILITY PROBLEMS

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Objective: **To compare walking test results with walking in daily life, and to investigate the relationships between walking tests, walking activity in daily life, and perceived mobility problems in patients with post-poliomyelitis syndrome.**

Subjects: **Twenty-four ambulant patients with post-poliomyelitis syndrome.**

Methods: **Walking tests were performed at self-preferred and maximal speed. Walking activity was measured with an ambulatory activity monitor. Heart rate, step cadence and walking speed in the test and in daily life were compared. Walking speed in daily life was represented by the intensity of walking. Perceived mobility problems were assessed with the Nottingham Health Profile.**

Results: **Heart rate during walking was lower in the test at self-preferred speed than in daily life (mean difference: 11.3 ± 10.4; $p = 0.001$). Self-preferred walking speed in the test and in daily life correlated significantly ($r = 0.55$; $p = 0.04$). In a sub-group with a test performance below the median value, test performance correlated significantly with walking activity. No significant correlation was found between perceived mobility problems and walking activity.**

Conclusion: **Walking in daily life may be more demanding than walking under standardized conditions. Patients with post-poliomyelitis syndrome with the lowest test performance walked less in daily life. Patients do not necessarily match their activity pattern to their perceived mobility problems.**

Key words: post-poliomyelitis syndrome, walking, exercise test, heart rate, activities of daily living, quality of life.

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INTRODUCTION

Paralytic poliomyelitis most often affects the muscles of the lower extremities. As a consequence, many individuals with late onset polio sequelae report a decline in walking ability (1, 2). Limitation in walking activity is one of the most prominent problems of patients with post-poliomyelitis syndrome (PPS) (3–5).

Walking capacity has been reported as an indicator of performance and activities of daily living in patients with PPS (4, 6–9). Frequently used methods to measure walking performance are time-scored tests at maximal or self-preferred walking speed, usually carried out in a clinical setting (4, 7, 8). These standardized performance tests measure various aspects of walking, such as speed, distance and physical effort.

Walking at comfortable speed in a clinical setting is assumed to represent walking in daily life (10, 11). However, the level of effort and the characteristics of walking, such as speed and step cadence, during walking tests under standardized conditions may differ from those of walking in daily life, when conditions are not standardized.

Therapeutic interventions for polio patients may aim at increasing their walking ability. It can be questioned whether walking ability in daily life, and changes in it, can be measured with walking tests. It seems likely that a relationship exists between walking test performance and the amount of walking in daily life (12). However, this relationship has never been investigated in patients with PPS. We hypothesized that walking test performance is an indicator of the amount of walking in daily life.

In patients with PPS, perceived physical mobility problems were found to be related to performance in walking tests (4). However, it is unknown whether perceived mobility problems also imply that there is less actual walking activity. Therefore, it is important to investigate the relationship between perceived physical mobility problems and actual walking in daily life.

Recently, we carried out a study to investigate the effects of pyridostigmine on fatigue in PPS patients (13). In that study, walking tests were performed at self-preferred and maximal speed, and the amount of walking in daily life was measured with an activity monitor (14). The activity monitor allows long-term (48 hours) continuous measurement of daily activities and physical effort with minimal influence on behaviour. Perceived physical mobility problems were also measured in this study with a validated questionnaire.

The purpose of the present study was threefold: (i) to investigate whether walking at self-preferred speed in a clinical

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setting reflects the levels of effort and characteristics of normal walking in the actual circumstances of daily life; (ii) to investigate whether the performance in walking tests is related to the amount of walking in daily life; and (iii) to investigate the relationship between perceived physical mobility problems and the amount of walking in daily life.

METHODS

The data were derived from the measurements of 24 patients with PPS (4 men and 20 women) consecutively included in the pyridostigmine trial, who underwent ambulatory monitoring of their daily life activities (13). The mean age of these patients was 54.5 (SD 8.9) years. PPS symptoms had existed for an average of 10.9 (SD 7.7) years, and all patients had new muscle weakness in at least 1 leg. All patients were able to walk for at least 2 minutes at self-preferred speed. Walking aids and orthopaedic devices were used in the walking tests in the same way in which they were used when walking outdoors. Nine patients used some type of walking aid (canes, crutches, orthosis).

Outcome measures

Walking tests. Two tests were performed on a closed, marked 65-metre indoor, oval-shaped track. The patients first walked for 2 minutes at self-preferred speed and the distance was measured. They then walked 75 metres at maximal speed (without running) and the time was recorded. Each test was started after the patient had rested for 5 minutes, sitting on a chair. For each test, the mean walking speed was calculated from the distance and the time. When walking at self-preferred speed, the patient's heart rate was measured every 5 seconds with a Polar Sporttester (Polar Vantage NV with Advantage Interface System; Polar Electro Nederland BV, Almere, The Netherlands). Mean steady state heart rate was calculated from the recording period between 70 and 90 seconds after the patient had started walking.

When walking at self-preferred speed, a unilateral surface electromyography (EMG) of the patient's quadriceps muscles was recorded with a portable ME300 Muscle Tester (ME300 Muscle Tester, 2-channel; Mega Electronics Ltd., Kuopio, Finland). Disposable surface electrodes (Medi-Trace Pellet, self-adhesive Ag/AgCl ECG electrodes; surface: 1 cm^2, centre-to-centre distance: 31 mm) were placed over the vastus lateralis. Over the same period that was used to calculate the mean heart rate, the step cadence was determined from the peak amplitudes in the EMG signal (15).

Walking in daily life. The activity monitor, described in detail by Bussmann et al. (14), is based on long-term accelerometry. Signals from piezo-resistive accelerometers attached to the thighs and trunk were continuously measured and stored (32 Hz) on a portable data-recorder. Data from ECG were recorded simultaneously. The patients' data were recorded for a period of 48 hours in their regular daily life environment. After downloading the stored data onto a computer, several body postures and motions (walking included) were automatically detected from the accelerometer signals (Vitagraph, Temec Instruments BV, Kerkrade, The Netherlands). The duration of walking was calculated as the percentage of time that a patient demonstrated walking activity (defined as walking for at least 5 seconds) in the 48-hour recording period. In addition, "longer walking" was determined as the duration of walking continuously for at least 30 seconds, and was expressed as a percentage of the 48 hours.

Four walking periods of at least 120 seconds were selected to determine steady state heart rate, step cadence and motility (which is an indicator of walking speed). Patients had not performed strenuous activities in the 60 seconds before the start of these walking periods. The time-span between 2 periods was a minimum of 60 minutes. Values were calculated from the recording interval between 70 and 90 seconds after the onset of walking, and were averaged over the 4 walking periods. Heart rate was extracted from electrocardiographic data (16), and cadence was extracted from the pattern of the accelerometry data recorded from the thighs. Motility expresses the intensity of the accelerometry data. Its value depends on the variability of the accelerometer signal around the mean, i.e. the amplitudes of the peaks and the frequency of occurrence of these peaks (14). It has been shown that a strong relationship exists between motility and walking speed, and that this relationship is independent of the efficiency of walking (16, 17).

Perceived physical mobility problems. Perceived mobility problems were assessed with the Physical Mobility category of a validated Dutch version of the Nottingham Health Profile (NHP^{PM}) (18). The NHP^{PM} score was calculated as the percentage of the 8 items answered with "yes" (a perceived problem).

The walking tests were performed and the NHP was administered during the second pre-medication study visit to the hospital (13). Within 7 days after the hospital visit, walking in daily life was measured with the activity monitor.

Statistics

Walking test results and walking in daily life were compared with respect to heart rate, cadence and walking speed, by means of *t*–tests or Pearson's correlation coefficient. The within-subject variability of heart rate, cadence and motility during walking in daily life over the 4 periods was determined with the coefficient of variation (19), calculated as: $\left[\sum_{subject=i...n} \frac{\sigma(p_i)}{\bar{p}_i} \cdot 100\right] \Big/ n$, with $\sigma(p_i)$ as the standard deviation and $\bar{p}_i$ as the mean of the 4 periods of subject i, and n as the total number of subjects.

The relationships between walking speed in the walking tests and the duration of walking and the duration of longer walking in daily life were analysed by calculating Pearson's correlation coefficients. Relationships were studied for all patients, and for sub-groups, based on the median value of the walking test results, i.e. patients with a walking performance below the group median value and patients with a walking performance above the group median value.

Relationships between perceived physical mobility problems and walking in daily life and walking test results were analysed by calculating Spearman's correlation coefficients. The significance level was set at alpha < 0.05. Statistical analysis was performed with the SPSS 10.0.5 software package (SPSS Inc., Chicago, Illinois, USA).

RESULTS

For the test at self-preferred speed, the mean walking speed was 1.02 (SD 0.17) metres/second, which was significantly lower ($p < 0.01$) than the walking speed of 1.32 (SD 0.24) metres/second in the maximal test (mean difference: 0.31 (SD 0.16); 95%CI: 0.24–0.37). Walking at self-preferred and maximal speed correlated significantly ($r = 0.75$, $p < 0.01$). For walking in daily life, the correlation between the duration of walking (6.6%) and the duration of longer walking (2.9%) was $r = 0.89$ ($p < 0.01$).

Only 14 patients had walked at least 4 periods with a minimal duration of 120 seconds. The coefficient of variation (SD) over these 4 periods was 5.1% (2.0) for heart rate, 3.0% (1.9) for cadence and 7.8% (2.5) for motility.

Characteristics of walking in the test at self-preferred speed compared with walking in daily life

The mean heart rate in the walking test at self-preferred speed was significantly lower than when walking in daily life ($p < 0.01$) (Table I). There was no difference between the cadence in the walking test and the cadence when walking in daily life. The correlation between cadence in the test and in daily life was $r = 0.46$ (n.s.). The correlation between walking

Table I. *Results of the walking test at self-preferred speed and walking in daily life. The means (SD) are given for the outcome measures*

	Walking test at self-preferred speed	Walking in daily life	Mean difference	95% CI; *p*-value
Speed (metres/second) ($n = 24$)	1.02 (0.17)			
Duration of walking (% time)		6.6 (2.7)		
Duration of walking >30 seconds (% time)		2.9 (1.7)		
Heart rate (beats/minute) ($n = 14$)	98.6 (9.2)	110.0 (14.0)	11.3 (10.4)	5.4–17.3; $p < 0.01$
Cadence (steps/minute)	107.6 (10.0)	109.1 (6.6)	1.5 (9.1)	−3.8–6.8; $p = 0.55$
Speed (metres/second)	1.08 (0.14)			
Motility (g)		0.23 (0.03)		

1 g is 9.8 ms^{-2}.

speed in the test and motility of walking in daily life was $r = 0.55$ ($p = 0.04$).

Relationship between walking test performance and the duration of walking in daily life

Both self-preferred and maximal speed in the walking tests correlated significantly with the duration of walking and longer walking in daily life (Table II). The strongest correlation was found between self-preferred speed and walking duration ($r = 0.52$, $p < 0.01$).

For the sub-group with walking test results below the median value of the total group, significant correlations were found between walking test performance and walking activity in daily life. No significant correlations between walking test performance and walking activity in daily life were found for the sub-group with the better test performance results.

Relationship between perceived physical mobility problems and walking activity in daily life

The median (25–75 percentile) score on the NHP^{PM} was 25 (16–50). The NHP^{PM} correlated with the walking test performance for both self-preferred and maximal speed (Table III). The NHP^{PM} did not correlate with the duration of walking or with longer walking in daily life.

Table II. *Relationship between walking test performance and the duration of walking in daily life. For further information see Methods.*

	Walking in daily life	
Walking test performance	Walking duration	Walking duration >30 s
Self-preferred speed ($n = 24$)	0.52**	0.50*
sub-group low speed	0.65*	0.59*
sub-group high speed	−0.27	−0.24
Maximal speed ($n = 24$)	0.42*	0.46*
sub-group low speed	0.73**	0.81**
sub-group high speed	0.27	0.60*

Pearson's correlation coefficients are presented. Sub-groups were formed, based on the median value of the walking test results. Median values for self-preferred speed and maximal speed were 1.05 metres/second and 1.29 metres/second, respectively. *$p < 0.05$; **$p < 0.01$.

DISCUSSION

The aim of the present study was to investigate the relationships between clinical walking tests, walking in daily life and perceived physical mobility problems in patients with PPS. Specifically patients with PPS were studied because they demonstrate an increase in neuromuscular symptoms and perceive a decline in walking ability (4, 10).

It appeared that walking in daily life differed from walking under standardized conditions: the heart rate was significantly higher in daily life than in a test at self-selected speed. This may be due to the less straining conditions during the walking test: the walking surface is flat and level, no additional tasks have to be performed, and there are no weather influences. This is in contrast with a study in patients with chronic obstructive pulmonary disease, in which no difference was found in walking speed and heart rate between an indoor and outdoor 6-minute walking test (20). However, the outdoor test in that study was performed under optimal conditions (a flat sidewalk in a quiet neighbourhood) and no additional tasks were carried out.

The higher heart rate in daily life in the present study may also be due to carry-over effects from previous activities. Although the walking periods from which the heart rate was determined with the activity monitor were all preceded by a period of relative rest, the walking tests were always preceded by a standardized period of absolute rest (5 minutes of sitting on a chair).

In contrast with heart rate, no systematic difference was found between cadence in the walking test at self-preferred speed and cadence when walking in daily life. However, the large standard deviation of the mean difference and the lack of correlation

Table III. *Relationship between perceived physical mobility problems, and duration of walking in daily life and walking test performance (n = 24). For further information see Methods.*

	NHP^{PM}
Walking in daily life	
Walking duration	−0.29
Walking duration >30 seconds	−0.15
Walking test performance	
Self-preferred speed	−0.70**
Maximal speed	−0.69**

Spearman's correlation coefficients are presented. NHP^{PM} = Nottingham Health Profile, category Physical Mobility. *$p < 0.05$; **$p < 0.01$.

between the cadence in the walking test and in daily life indicate large within-subject variability between the 2 conditions. The small coefficient of variation (3%) for cadence in daily life suggests that this is not due to large within-subject variability of walking in daily life. It seems that the individual cadence when walking in the test differs from cadence when walking in daily life, but in different directions among patients. The cause of this remains speculative.

Both self-preferred walking speed and maximal walking speed were comparable to what has been found in an earlier study focusing on patients with PPS (21). The walking speed of patients with PPS is noticeably lower than that of healthy subjects (22). The percentage of walking activity in daily life of patients with PPS (6.6%) has also been found to be less than that of healthy subjects (9.1%), but higher than that of patients with chronic congestive heart failure (3.4%) (23).

In the present study, significant relationships were found between walking test performance and the amount of walking in daily life. However, walking performance at self-preferred speed explained only 27% ($r^2 = 0.52^2$; Table II) of the variance in duration of walking in daily life. This illustrates that actual walking in daily life is not only determined by walking ability. It is likely that daily life behaviour is largely determined by social behaviour, personal lifestyle, working conditions and living circumstances, such as the localization of shops, etc.

Interestingly, much stronger relationships between walking test performance and walking in daily life were found for those patients with PPS with lower walking ability in the tests. Apparently, actual walking behaviour in these patients is mainly determined by their reduced walking ability. This is best illustrated by the variance in longer walking duration (>30 seconds) that is explained for 66% ($r^2 = 0.81^2$; Table II) by the performance in the maximal walking test. Maximal walking speed is apparently a better indicator of capacity than self-preferred walking speed for prolonged walking.

One limitation of measuring behaviour is the day-to-day variability in daily life activities (23). Single-day measurements are probably not representative for a "general" level of daily activities. An attempt was made to take this into account by measuring for a period of 48 hours. However, it is still possible that variability between days may have affected some of the relationships found in this study.

Both self-preferred and maximal speed in the walking tests were significantly related to perceived physical mobility problems. This is in agreement with the results of a study carried out by Nollet et al. in a different group of polio patients (4). Surprisingly, no significant relationships were found between perceived physical mobility problems and walking duration in daily life. This is in line with the results of a study carried out by Willen et al., who found no significant relationship between the score on the Physical Activity Scale for the Elderly and the score on the NHP^{PM} in patients with PPS (10). The lack of correlation between perceived physical mobility problems and walking in daily life might reflect the fact that certain tasks simply have to be performed in daily life, despite perceived limitations in physical performance. It is well known that patients with PPS tend to ignore or even deny their disabilities (24).

In conclusion, the cardiac response of patients with PPS during walking in daily life was significantly higher than during walking in test circumstances. It may be that walking tests at self-preferred speed tend to under-estimate the physical effort of walking in daily life. Test performance was related to walking in daily life, and this relationship was most pronounced for those with the lowest test performance. Apparently, the limited capacity of these patients largely determined their physical behaviour. Although perceived physical mobility problems were related to walking test performance, they were not related to walking behaviour in daily life. This indicates that patients with PPS do not necessarily adapt their behaviour to their perceived capacities. Ambulatory monitoring of daily activities may be helpful in future studies that focus on changing actual behaviour in daily life.

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