©Journal of Sports Science and Medicine (2005) **4**, 556-562
http://www.jssm.org

Research article

A PILOT STUDY TO INVESTIGATE EXPLOSIVE LEG EXTENSOR POWER AND WALKING PERFORMANCE AFTER STROKE

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Received: 27 June 2005 / Accepted: 18 October 2005 / Published (online): 01 December 2005

ABSTRACT

We examined explosive leg extensor power (LEP) and gait in men and women after a stroke using an experimental observational design. A convenience sample of consecutively referred individuals (8 men, 6 women) with chronic stroke mean age ± SD, range, 46.4 ± 8.4, 32 – 57 years, and able to walk for four minutes were recruited. The test re-test reliability and performance of LEP was measured together with walking parameters. LEP (Watts·kg^{-1}) and gait measures during a four-minute walk; temporal-spatial gait parameters (GAITRite ®) and oxygen cost of walking (mL·kg^{-1}·m^{-1}) were recorded. Percentage Asymmetry LEP (stronger LEP - weaker LEP/stronger LEP x 100) was calculated for each person. LEP was reliable from test to re-test ICC [3, 1] 0.8 - 0.7 (n = 9). Greater Asymmetry LEP correlated strongly with reduced walking velocity, cadence, stance time, and swing time on the weaker leg (n = 14) ($p < 0.01$). Findings demonstrate explosive LEP, in particular Percentage Asymmetry LEP, can be measured after stroke and is both reliable and related to walking performance. LEP training of the stronger or weaker leg warrants further investigation in this group.

KEY WORDS: Stroke, leg extensor power, walking, asymmetry.

INTRODUCTION

Walking has been shown to be limited after stroke by a variety of factors including spasticity (Bohannon and Andrews, 1990; Hsu et al., 2003), decreased balance (Bohannon, 1987; Nadeau et al., 1999; Suzuki et al., 1990), impaired sensation (Brandstater et al., 1983; Dettmann et al., 1987; Friedman, 1990; Keenan et al., 1984), and muscle weakness (Bohannon, 1991; Nadeau et al., 1999; Nakamura et al., 1988). Investigations of muscle weakness in this clinical group have shown that the strength of knee extensor (Bohannon, 1986; 1987; 1991; 1997; Nakamura et al., 1988; Suzuki et al., 1990) and hip and ankle flexor muscle groups (Nadeau et al., 1999) correlates with walking velocity. Moreover, dynamic muscle measures such as isokinetic torque (Lockhart et al., 2003) or the rate at which a contraction can be generated (Pohl et al., 2002) have been shown to have a stronger relationship with walking performance than measures of static strength.

Explosive leg extensor power (LEP) is a measure of a person's ability to generate fast functional movement and may give a better indication of walking performance than strength measures per se. LEP has been shown to be a simple, easy to use field measure that correlates well with walking velocity in healthy older men and women (Bassey et al., 1992; Skelton et al., 1994). Reduced LEP has also been correlated with lowered walking velocity following proximal femur fracture (Lamb et al., 1995). Lower limb explosive power, and in particular asymmetry in LEP (Asymmetry LEP) has been shown to be predictive of functional difficulties such as slow walking and falls in the elderly (Skelton et al., 2002) and it may well be related to mobility and independence following stroke (Bean et al., 2002).

To date, an individual's ability to generate leg extensor power and the latter's relationship with walking velocity and other measures of walking performance has yet to be investigated after stroke. Explosive LEP and Asymmetry LEP were investigated in relation to walking performance in men and women after a stroke.

METHODS

Participants

Individuals attending a specialist neuro-rehabilitation unit who were greater than six months after a stroke, were identified through consultant referral. All patients who could walk continuously for four minutes or more were included in the study. Anyone with anyone with an unstable medical condition or cognitive impairment affecting his or her ability to perform the testing procedure was excluded. Fourteen participants (8 men, 6 women) with stroke (12 ischaemic, 2 haemorrhagic) were recruited during the study period of six months. Nine people were available for re-testing and the reliability study is therefore reported with n = 9.

Procedure

Individuals participated after giving informed consent in accordance with the declaration of Helsinki (1979) and local ethical committee approval. All individuals then attended for a familiarisation session with the equipment and procedures to be used in the study. Testing was conducted in a physiotherapy gymnasium. Participants were asked to refrain from the consumption of food, caffeine, alcohol and medication and to avoid strenuous exercise during the two hours prior to testing. On arrival information was recorded about age, height, body mass, compliance with pre-test requirements, physical activity levels, medication, and general health. Mobility level, Rivermead Mobility Index (RMI), disability, Barthel Index (BI) and leg spasticity, Ashworth Scale, were measured.

Measures of expired air were taken at rest, following this measures of leg extensor power and walking performance were recorded. For the purpose of the present study walking performance was defined as the measurement of walking velocity, together with temporal-spatial gait parameters (e.g. cadence, step length) and oxygen cost ($mL \cdot kg^{-1} \cdot m^{-1}$) was taken a measure of walking effort.

Expired air was collected by means of lightweight respiratory valves and hoses in a 100 litre Douglas bag (Waters et al., 1988). Individuals were initially familiarised with wearing the Hans Rudolf facemask and then rested supine for a period of six minutes, immediately followed by the collection of expired air for a further period of six-minutes. The composition of the expired air was determined by oxygen and carbon dioxide analysers (Servomex Series 1400, Crowborough, East Sussex, UK) and the volume of expired air was measured by means of a dry gas meter (Harvard Apparatus Limited, Edenbridge, Kent). The gas analysers were calibrated on each testing occasion by means of gas mixtures of known concentration. Oxygen consumption was calculated using standard open circuit methodology and the values expressed under standard conditions (STPD).

Measurement of explosive leg extensor power

The explosive leg extensor power (LEP) rig (Medical Laboratory Workshops, Nottingham) originally described by Bassey and Short (1990) has been found to be a safe and acceptable method of measuring explosive LEP across a wide range of age and levels of ability. Power measurements from the rig have been shown to correlate strongly with peak isokinetic power and with power produced by a vertical two-legged jump on a force plate (Bassey and Short, 1990). It has also been shown to be reliable (inter-observer and test-retest) in normal elderly control subjects and those with a history of falls (Lamb et al., 1995; Skelton et al., 2002). The instrument itself consists of an adjustable seat and large foot pedal connected to a flywheel, the final angular velocity of which indicates the power output. LEP was measured according to the method described by Skelton et al. (2002). A value for the LEP in Watts was obtained for each leg by taking the maximum power achieved when the power output reached a plateau during an average of five attempts following familiarisation. As the measurement of explosive LEP has not been previously reported following stroke, stability of LEP was examined within one week under standard conditions in a sub-sample of nine individuals.

Measurement of walking performance

Following the measurement of LEP, the walking test was explained verbally and demonstrated to each individual. Subjects were asked to walk at their normal, comfortable walking pace around a measured 40-m track in a physiotherapy gymnasium. During walking trials individuals were accompanied by a researcher to ensure maximum safety. To ensure physiological steady state conditions patients walked for four minutes in total. During the walking tests, the researcher walked behind the subjects, continuously monitoring walking velocity. Expired air was collected in a 100-litre Douglas bag mounted on a wheelchair during min 3-4 using light-weight ducting and a facemask. Steady-state oxygen uptake, gross (walking) ($mL·kg^{-1}·m^{-1}$) was measured. Net oxygen consumption was calculated (walking oxygen consumption - resting oxygen consumption). The net oxygen consumption values were used to calculate the oxygen cost of walking ($mL·kg^{-1}·m^{-1}$).

Temporal and spatial parameters of gait were recorded using a GAITRite ® (SMS Technologies, Harlow) mat (180 x 35.5 inches) positioned on the track during minutes 3-4 when individuals had established a comfortable rhythm. The system has previously demonstrated test re-test and concurrent validity (McDonough et al., 2001). For each variable the system calculated the mean over two passes. One researcher collected and analysed the data for all individuals. The variables included velocity, cadence, step length and stance time. The GAITRite® system was checked for accuracy using a known measure prior to each testing session. The system consisted of a mat containing embedded pressure sensors (active area 144 x 24 inches), which was connected to a laptop computer where the GAITRite® software analysed the data collected.

Data analysis

Descriptive statistics were calculated for demographic characteristics and for measures of LEP and gait parameters. For each leg, power output was divided by body mass to give LEP ($W·kg^{-1}$) (Bassey et al., 1992; Lamb et al., 1995; Skelton et al., 1994; 2002). The following measures of LEP were calculated: LEP of the stronger leg (Stronger LEP), LEP of the weaker leg (Weaker LEP), and the difference between legs as a percentage of the strongest leg, giving an asymmetry index (Percentage Asymmetry LEP) (Skelton et al., 2002).

From temporal-spatial data asymmetry ratios (1 - weaker/stronger) were calculated for step length and single leg support time. The relationship between gait parameters and explosive leg power was examined by a Spearman Rank Correlation Coefficient (ρ) (one tailed). Reliability of LEP measures before the intervention were examined using standard statistical measures: Student's t-test, 95 % Confidence Intervals (CI), upper and lower limits of repeatability (differences of the mean ± 1.96 SD), bias and random error and interclass correlation coefficient (ICC) [3, 1].

RESULTS

Table 1 shows the participants were: relatively young; mobile outside using the following devices: no aid, five; a stick, seven; a wheeled walking frame, two; ankle foot orthosis, seven; functional electrical stimulation (FES), one. Participants were functionally independent with minimal spasticity in their legs.

Table 1. Mean (± SD) and range, for LEP, oxygen cost of walking, velocity and temporal-spatial gait measures.

	Mean (± SD)	Range
Age (years)	46 (8)	32-57
Stronger LEP ($W·kg^{-1}$)	1.99 (.85)	1.04-3.83
Weaker LEP ($W·kg^{-1}$)	1.07 (.50)	.34-1.84
Asymmetry LEP (%)	43 (25)	2-78
Velocity ($m·s^{-1}$)	.70 (.32)	.19-1.39
Cadence ($step·min^{-1}$)	84.9 (23.2)	46.1-125.9
Step length stronger (cm)	46.35 (12.64)	29.95-63.61
Step length weaker (cm)	49.46 (15.32)	18.94-71.09
Stance time stronger (sec)	1.12 (.49)	.61-2.16
Stance time weaker (sec)	.97 (.38)	.56-1.93
Swing time stronger leg (sec)	.43 (.08)	.31-.60
Swing time weaker leg (sec)	.57 (.17)	.40-.94
Oxygen cost ($ml·kg^{-1}·m^{-1}$)	.35 (.22)	.11-.68
Rivermead Mobility Index (RMI)	13 (3)	7-15
Barthel Index (BI)	19 (2)	15-20
Modified Ashworth Scale right hip flexors	0 (1)	
Modified Ashworth Scale left hip flexors	0 (1)	

Table 2. Correlations of LEP measures to oxygen cost of walking and temporal – spatial parameters (Spearman rho rank).

	Stronger LEP ($W·kg^{-1}$)	Weaker LEP ($W·kg^{-1}$)	Asymmetry LEP (%)
Velocity ($m·s^{-1}$)	-.28	.37	-.76 **
Cadence ($step·min^{-1}$)	-.44	.22	-.78 **
Step length stronger (cm)	-.06	.48	-.62 *
Step length weaker (cm)	.06	.54 *	-.50 *
Stance time stronger (sec)	.56 *	-.13	.79 **
Stance time weaker (sec)	.57 *	-.06	.73 **
Swing time stronger leg (sec)	.18	.14	.18
Swing time weaker leg (sec)	.35	-.25	.73 **
Oxygen cost ($ml·kg^{-1}·m^{-1}$)	.38	-.33	.63 *

* $p < 0.05$, ** $p < 0.01$.

Test re-test data of leg extensor power (n = 9) revealed good reliability for Percentage Asymmetry LEP: Student's t-test, t = 0.61, p >0.05, [95% CI -33.66 to 21.11]; ICC [3,1] 0.812, 95.00 % [C.I.: Lower = 0.369 Upper = 0.954] bias -6.28 ± 71.25 and for Weaker LEP: Student's t-test, t =0.57, p > 0.05; [95% CI -13.70 to 22.93]; ICC [3, 10] 0.763, 95.00% [C.I.: Lower = 0.252 Upper = 0.941], mean diff (W) (bias) 4.6 ± 46.7. Reliability was moderate for Stronger LEP: Student's t-test, t =0.52, p > 0.05; [95% CI -26.14 to 47.91]; ICC [3, 1] 0.664, 95.00% [C.I.: Lower = 0.055 Upper = 0.913]; mean diff (W) (bias) ± (1.96*SD diff) random error 10.9 ± 94.3.

Explosive leg extensor power and gait parameters

Table 1 shows measures of explosive leg extensor power (LEP), self selected walking velocity, temporal-spatial gait parameters and oxygen cost (mean ± S.D). Leg extensor power was asymmetrical 1.99 ± 0.85 *vs*. 1.07 ± 0.50 $W·kg^{-1}$ for the stronger and weaker leg respectively ($p < 0.05$).

Table 2 shows there was a modest correlation between Stronger LEP and stance time ($p < 0.05$). There was a similar correlation of Weaker LEP to weaker leg step length ($p < 0.05$). However, there were strong correlations between Percentage Asymmetry LEP and walking velocity, cadence, stance time, swing time of the weaker leg ($p < 0.01$), step length and oxygen cost ($p < 0.05$).

DISCUSSION

We found measuring explosive LEP feasible in this clinical group, with the only required testing adaptation the provision of a supporting hand to prevent the knee from moving in the frontal plane, whilst individuals prepared to perform the explosive 'push' phase with each leg. We found good stability of measures of LEP over the period of a week, particularly when calculated as an asymmetry index, with the difference between legs reported as a percentage of the stronger leg (Percentage Asymmetry LEP). This practice effectively removing variability arising from general fluctuations in a patient's state (such as fatigue or reduced motivation) (Bohannon, 1987).

We found explosive LEP lower than that reported in healthy adults. Stronger LEP was reduced to 56% of that found in healthy men (3.6 ± 1.1 $W·kg^{-1}$) and to 83% of that reported in healthy women (2.4 ± 0.8 $W·kg^{-1}$) aged 50-54 years (Skelton, 1999). The asymmetry we observed in LEP was in line with muscle strength measures recorded following stroke (Bohannon, 1986). Weaker and Stronger LEP ($W·kg^{-1}$) did not correlate strongly with walking performance compared with percentage Asymmetry LEP (%). Asymmetry LEP correlated negatively with walking velocity and temporal-spatial parameters ($r = -0.78$, $p < 0.01$) and less strongly with oxygen cost ($r = 0.63$, $p < 0.05$). It appears from this cross sectional data that an imbalance in power between limbs may be interfere with the general mechanism of coupling between limbs in the gait cycle (Donelan et al., 2002). We measured reduced walking speeds (Nadeau et al., 1999; Witte and Carlsson, 1997) and shorter stride lengths compared with normal healthy controls (Suzuki et al., 1999). We also observed a threefold increase in the effort of walking ($mL·kg^{-1}·m^{-1}$) compared with healthy control subjects (Waters and Mulroy, 1999).

Asymmetry has previously been implicated as affecting walking speed (Lamb et al., 2003) and functional mobility and has been suggested as a factor in falls in the elderly (Skelton et al., 2002). Indeed sixty percent of women over the age of 65 years who fell had Asymmetry LEP (Skelton et al. 2002). The 10% difference between Stronger and Weaker LEP reported by Skelton and co-workers (2002) is relatively small compared with the asymmetry found in our study in individuals after stroke (43%). Individuals after stroke have also been reported as having a higher incidence of falls compared with the healthy population (Lamb et al., 2003). Attaining safe, effective mobility is a major focus in rehabilitation - and investigation of LEP may inform future interventions. The present study focused on individuals who were relatively mobile and in the sub-acute phase of recovery - and our findings may not generalise to other stroke groups. Further investigation should consider a larger sample of both acute recovery and chronic stroke patients and the effect of training weaker and stronger limbs.

CONCLUSIONS

The pilot data suggests that explosive LEP, in particular Asymmetry LEP, is a reliable measure, and is related to walking performance after stroke. Earlier studies have shown that it is possible for training programmes to increase muscle strength and power (Badics et al., 2002; Dawes, 2003; Sharp and Brouwer, 1997). Investigation of LEP training of the stronger or weaker leg in both the acute and sub-acute phase of recovery may provide a means of better understanding the factors that impact on walking performance following stroke and so help guide future interventions.

ACKNOWLEDGEMENTS

Dr. Delva Shamley, School of Health Sciences, Oxford Brookes University, Physiotherapy Dept. at Oxford Centre for Enablement, Charlotte Elseworth and Martyn Morris, Movement Science Group Oxford Brookes University.

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KEY POINTS

- Explosive leg power (LEP) is a reliable measure in individuals recovering from a stroke.
- Significant asymmetry occurred in LEP in this group.
- Greater LEP asymmetry related to reduced walking performance after stroke.

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