Lateral Pelvic Displacement During Gait: Abnormalities After Stroke and Changes During the First Month of Rehabilitation

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Objectives: To measure the amplitude and symmetry of lateral pelvic displacement (LPD) in patients with acute hemiparetic stroke; to assess the relationship between LPD and walking speed; and to quantify changes in LPD during 1- and 4-week intervals in the early stages of gait rehabilitation.

Design: LPD amplitude and symmetry were measured in stroke patients on admission to acute rehabilitation, 1 week later, and at 4-week follow-up. Performance was compared with sex-, height-, and age-matched control subjects.

Setting: Urban geriatric inpatient rehabilitation facility in Australia.

Participants: Fifteen patients with a single-hemisphere stroke, confirmed by computed tomography, were compared with the data from 12 control subjects. Patients’ FIM™ instrument scores ranged from 54 to 124.

Intervention: Gait rehabilitation involved twice-daily individual physical therapy sessions of 45 to 60 minutes, 5 days a week, incorporating whole and part practice, mental rehearsal, verbal feedback on performance, manual guidance, and strengthening techniques.

Main Outcome Measures: Three-dimensional motion analysis of LPD amplitude and symmetry, and preferred walking speed over 10m.

Results: Compared with controls, stroke patients initially showed increased amplitude of LPD, with no difference in LPD symmetry. A statistically significant linear relationship existed between walking speed and amplitude of LPD (r = −.53; P = .04), yet not between walking speed and symmetry (r = −.41; P = .13). Amplitude and symmetry values remained consistent during the 4-week period of rehabilitation.

Conclusions: These results provide baseline LPD values for patients with acute hemiparetic stroke and demonstrate the relationship between LPD and walking speed. Change in LPD during inpatient rehabilitation was not uniform or predictable, particularly during longer periods. This highlights the need for therapists to regularly reassess each patient during the early rehabilitation phase after stroke, especially given that individual differences can be marked.

Key Words: Gait; Locomotion; Movement disorders; Physical therapy techniques; Rehabilitation; Stroke.

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RESTORATION OF AN EFFICIENT and independent gait is a primary therapeutic goal for many people after stroke. Because of impairments such as paresis, weakness, postural instability, and sensory loss, stroke patients initially have difficulty walking with a normal gait pattern.1,2 Although 65% to 85% of patients regain the ability to walk independently by 6 months,3,4 persistent gait deviations can lead to pain, joint damage,1 and increased energy expenditure.6 Gait disorders after stroke are also associated with an increased incidence of falls.6

A common, yet little-studied gait disorder after stroke is a deficit in lateral pelvic displacement (LPD). To maintain balance while walking, the pelvis and upper body normally displace from side to side in time with the weight-bearing limb. The amplitude of LPD is usually 40 to 50mm, with equal displacement from one side to the other.7,9 In stroke patients, the amplitude of LPD can be altered as a result of problems shifting the pelvis from side to side. The symmetry of LPD can also be affected by impairments such as paresis and spasticity. These gait deviations have the potential to increase energy expenditure and can result in a walking pattern that some people find cosmetically unacceptable. Because LPD is considered a fundamental characteristic of efficient gait,10,11 restoration of a more normal LPD is a goal of physical therapy (PT) for many patients. To make decisions about the severity of impairment and the response of patients to different types of gait retraining, clinicians need data on the characteristics of LPD after stroke and on how much change typically occurs during the initial period of therapy.

Despite subjective clinical evidence suggesting that disordered LPD is common after stroke,10-12 only 1 empirical study13 has described this aspect of hemiparetic gait. Tyson13 documented the pelvic and trunk motion of 20 chronic stroke patients (mean ± standard deviation [SD], 61 ±6.5y; stroke duration median before testing, 10mo). Analysis of data collected from an optical-based, 3-dimensional motion analysis system showed that stroke patients had large amplitudes of LPD and reduced displacement of the pelvis toward the paretic side (ie, more asymmetry) compared with normal values for LPD reported in the literature.9,9 Moderately strong linear relationships were found between walking ability (as measured by walking speed) and LPD amplitude (r = −.6) and symmetry (r = .6). Tyson’s study provides some useful preliminary data about LPD in people with stroke. However, it is difficult to quantify the severity of disordered LPD, because data from the stroke patients were not compared with age-matched control subjects. Yet to be investigated are the characteristics of LPD in patients with acute stroke, the relationship between LPD disorders and walking ability, and the changes in LPD in the early period after stroke, when most patients receive PT.

Accordingly, the aims of our study were (1) to describe the characteristics of LPD in the acute period after stroke; (2) to determine the strength of the relationship between LPD and walking speed; and (3) to measure the changes in LPD during 1- and 4-week intervals in the course of inpatient movement rehabilitation. Based on Tyson’s findings,13 and other studies14 showing that more normal gait patterns usually emerge
during movement rehabilitation, we tested the predictions that (1) patients with acute hemiparetic stroke would demonstrate increased amplitude of LPD at the initial test compared with control subjects; (2) patients with acute hemiparetic stroke would demonstrate LPD symmetry, manifesting as reduced pelvic displacement toward the paretic foot at the initial test; (3) a moderately strong linear relationship would exist between walking speed and LPD amplitude and symmetry; (4) during both 1 week and 4 weeks of gait rehabilitation, patients with hemiparetic stroke would decrease their amplitude and asymmetry of LPD; and (5) during 1 week and 4 weeks, control subjects would not change their LPD amplitude or symmetry.

METHODS

Participants

Twenty-seven subjects participated in this experiment. The sample included 15 people with hemiparetic stroke recruited from the inpatient population of Kingston Center, Cheltenham, Australia, and 12 control subjects. To be included, stroke subjects had to be between the ages of 18 and 90 years and had to have sustained a single, unilateral stroke less than 3 weeks before data collection or have commenced walking less than 2 weeks before initial testing. They had to be able to complete at least 2 consecutive 10-m gait trials with no physical assistance. Exclusion criteria were a coexisting neurologic, orthopedic, or cardiorespiratory condition that impaired walking performance. Also excluded were people who were prescribed tranquilizers that reduced arousal and those who required assistive walking devices such as pick-up frames or canes. The stroke sample was composed of 9 women and 6 men with FIM™ instrument scores ranging from 54 to 124 (mean = 100.3 ± 20.4). Mean age was 77.2 ± 8.1 years, mean height was 1.59 ± 0.77m, and mean weight was 61.8 ± 10.1kg. Ten people had paresis on the right side of the body. Mean time since stroke was 28.3 ± 15.4 days.

The stroke subjects participated in twice-daily individual PT sessions of approximately 45 to 60 minutes, 5 days a week. These sessions were conducted by physical therapists employed in the stroke rehabilitation ward. The specific goals of therapy for each individual were set by the patient and their family in consultation with the treating physical therapist. A range of techniques incorporating whole and part practice, mental rehearsal, verbal feedback, manual guidance, and muscle strengthening were used in treatment. On average, subjects spent more than half of their therapy time in upright standing and walking.

Twelve control subjects matched for sex, age (±2y), and height (±0.5m), with no orthopedic, cardiorespiratory, or neurologic condition known to affect walking, were recruited from the Kingston Centre volunteer subject database. Controls were not found for 3 stroke patients, aged 88 to 90 years. The control group was composed of 6 women and 6 men, with a mean age of 74.1 ± 5.6 years, mean height of 1.64 ± 0.70m, and mean weight of 67.3 ± 7.4kg. No significant difference was found between the groups for age (t25 = −1.10, P = .28), weight (t25 = 1.59, P = .12), or height (t25 = 1.95, P = .06). To compare LPD symmetry between the groups, control subjects were allocated a nominal “paretic” side that corresponded with the paretic side of their matched stroke patient.

Apparatus

Three-dimensional kinematic data were collected using the Vicon 140 motion analysis system.2 The system consisted of 4 video cameras (sampling rate, 50Hz) with infrared strobes mounted on tripods, a personal computer loaded with software for digitizing joint positions and for calculating kinematics, and 4 surveyed calibration rods. From 2-dimensional video images of gait, the Vicon system reconstructed the 3-dimensional motion of the pelvis and lower limbs by tracking the trajectory of light-reflective markers (diameter, 25mm) taped to the subject’s heels and sacrum. To determine when initial foot contact occurred within each gait cycle, pressure-sensitive footswitches were placed inside the shoes. The footswitches were attached to separate Vicon analog channels by a 15-m cable. When the pressure of body weight was applied to the footswitches, the timing of initial foot contact captured within the calibrated space was determined and stored in the computer workstation, along with the kinematic data.

Data were collected from the central 3-m length of a 10-m, unobstructed, linoleum-covered walkway. This allowed a length of 3.5m before and after the data collection area for acceleration and deceleration of walking speed. The 4 video cameras were positioned in a semicircular configuration behind the start of the walkway.

Procedure and Data Reduction

Each subject performed 6 consecutive 10-m gait trials on 3 separate days: session 1, session 2 (held 1 week after session 1), and session 3 (held 4 weeks after session 1). Data from each session were collected at the same time of day. The data collection and reduction procedures were replicated for each of the 3 sessions.

After explaining the procedure, the pressure-sensitive footswitches were carefully placed into the shoes. The reflective markers were then attached to the skin over the second sacral vertebra and to the center of the back of the subject’s shoes, approximately 60mm above the ground. The instruction was to “walk to the end of the walkway at your comfortable pace.” Two practice walking trials were completed to ensure that the equipment was operating and to familiarize the subject with the test protocol. This was followed by 4 further trials from which mean scores for amplitude and symmetry of LPD and walking speed were calculated. At the end of each trial, subjects sat in a wheelchair that had been placed at the end of the walkway, and the chair was wheeled back to the start of the walkway in preparation for the next trial. Subjects were given 1-minute rests between each of the 6 walking trials. The skin-markers and footswitches were not removed between trials. The mean residual calibration error over the 3 sessions was 1.5mm for camera 1, 1.9mm for camera 2, 2.6mm for camera 3, and 2.4mm for camera 4.

The data reduction procedure used to measure LPD amplitude and symmetry has been detailed previously.5,15 Amplitude of LPD is operationally defined as the linear horizontal side-to-side motion of the pelvis during walking. Symmetry of LPD is the horizontal location of the mean axis of LPD quantified relative to a calculated midpoint between the feet. A symmetry score of 0mm indicated equal displacement of the pelvis from side to side. In contrast to the LPD symmetry score, which is calculated by retaining the direction (toward or away from the paretic foot) of the deviation, absolute symmetry of LPD is the magnitude of symmetry, whether or not the axis of LPD deviated toward or away from the paretic foot.

Preferred walking speed over 10m was used as a measure of walking performance because high retest reliability has been established in stroke patients for this variable.4,16 Walking speed also differentiates between different levels of disability.4,14,17 In addition, strong relationships have been established between walking speed and motor recovery,18 lower-limb strength,19 and maximum ankle power.20

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There were a small number of missing data points in the stroke data set. Data from 2 subjects during sessions 2 and 3 and from another subject during session 3 were not collected because these subjects did not return for follow-up testing.

Statistical Analysis

Independent \( t \) tests were used to examine differences between the LPD amplitude and symmetry for the stroke and control groups at session 1. Although K-S Lilliefors tests\(^{21} \) showed that each of these dependent variables were normally distributed, variability appeared greater in the stroke group than in the control group. The Levene tests for homogeneity of variance,\(^{21} \) however, detected no significant differences in variance. Pearson product-moment correlation coefficients were used to summarize the strength of the relationship between walking speed and LPD amplitude and symmetry at session 1. Because data collected over time did not satisfy the assumption of equal variance, Wilcoxon matched-pairs signed-rank tests were used to examine within-group change of LPD over time. Statistical significance was set at .05 for all analyses.

RESULTS

Initial Differences in LPD Between Stroke and Control Subjects

Figure 1 shows boxplots of LPD amplitude, symmetry, and absolute symmetry for the 2 groups at session 1. Figure 1A shows that the stroke subjects walked with a larger amplitude of LPD than did the control group. The mean amplitude for the stroke sample was 65 ± 21 mm (range, 39–125), compared with an amplitude of 48 ± 10 mm (range, 34–73) for the control group. This difference was statistically significant (\( t_{25} = 2.60, P = .02 \)). Figure 1B shows boxplots of LPD symmetry for the groups at session 1. A negative symmetry score represents a deviation of the axis of LPD toward the paretic foot. At session 1, 9 stroke subjects deviated toward the nonparetic foot, while 6 deviated toward the paretic foot. For the stroke group, mean symmetry was 3 ± 17 mm (range, -25 to 39). Therefore, the stroke group demonstrated a small trend for greater pelvic deviation toward the nonparetic foot. For the control group, mean symmetry was -6 ± 11 mm (range, -21 to 23). No significant difference was found between the groups.

Figure 1C shows boxplots of LPD absolute symmetry for the 2 groups at session 1. At session 1, mean absolute symmetry for the stroke sample was 12 ± 11 mm (range, 0–39), compared with 10 ± 7 mm (range, 2–23) for the control sample. Both groups demonstrated LPD asymmetry of around 10 mm, with no significant difference detected between the groups.

Relationship Between Walking Speed and LPD

A statistically significant negative linear relationship was found between walking speed and amplitude of LPD (\( r = - .53, P = .04 \)). This finding suggested that stroke patients who walked faster had smaller, more normal amplitudes of LPD. In contrast, LPD absolute symmetry was not significantly associated with walking speed (\( r = - .41, P = .13 \)).

Changes in LPD During 1 Week and 4 Weeks of Rehabilitation

Change during 1 week. Figure 2 shows boxplots of amplitude for the 2 groups at session 1 and 2 (ie, changes during 1 wk). The median amplitude for the stroke sample was 60 mm (interquartile range [IQR] = 24; range, 39–125) at session 1 and 57 mm (IQR = 25; range, 36–115) at session 2. A median reduction in amplitude of 8 mm (range, -32 to 1) was demonstrated during the 1-week period. In comparison, the median amplitude for the control group was 46 mm (IQR = 14; range, 34–73) at session 1 and 45 mm (IQR = 20; range, 30–85) at session 2, with a median reduction of 4 mm. There was a small
trend ($Z_{11} = -1.73, P = .08$) for the stroke subjects to reduce their amplitude during 1 week of gait rehabilitation.

Figure 2B shows boxplots of absolute symmetry of LPD for the 2 groups at session 1 and 2. At session 1, the median absolute symmetry score for the stroke group was 7mm (IQR = 21; range, 0–39). At session 2, the median was 8mm (IQR = 28; range, 1–44). A median 3-mm increase in asymmetry occurred between sessions 1 and 2 (range, −9 to 13). For the control group, the median score was 8mm (IQR = 13; range, 2–23) at session 1 and 9mm (IQR = 15; range, 1–22) at session 2, with a median increase in asymmetry of only −1mm (range, −10 to 11). No significant change was found for the stroke group.

**DISCUSSION**

**Initial Differences in LPD After Stroke**

Because this is the first study to describe the characteristics of LPD in the early stage of recovery after stroke, the results contribute to a greater understanding of gait disturbance in patients with this disabling neurologic condition. Values for amplitude of LPD in our study were similar to those reported by Tyson for subjects with chronic hemiparesis, and confirm clinical impressions that LPD amplitude is frequently atypical.

Disorders of lateral weight transference, and, in particular, the ability to shift body weight from one foot to
another predispose people to disorders in the amplitude of LPD. The Movement Sciences\textsuperscript{11} and Bobath\textsuperscript{10} approaches to PT assume that patients can regain more efficient and independent gait by learning how to selectively control lateral weight shift and improve postural alignment during locomotion. These approaches place particular emphasis on retraining patients to adequately displace the pelvis from side to side. Knowing that many patients with acute stroke experience difficulties in controlling the amplitude of lateral weight transference and the excursion of lateral displacement of the pelvis during walking, it may be useful to incorporate LPD amplitude assessment into standard gait analysis protocols, particularly with the more widespread use of computerized motion analysis systems by rehabilitation clinicians.

Contrary to both Tyson’s findings\textsuperscript{13} and our predictions, no significant differences in the magnitude of LPD symmetry were observed between the stroke and control groups. Both groups demonstrated relatively symmetrical LPD, with 95% of the scores deviating less than 20mm from the calculated midpoint between the feet. This is an interesting finding because most stroke rehabilitation texts emphasize the importance of retraining acute stroke patients to adequately displace the pelvis toward the paretic foot, thus increasing symmetry.\textsuperscript{10,11,22} The need to restore symmetry of LPD is not supported by the results from our sample of stroke patients. In addition, patients with more severe asymmetry may be less prevalent in rehabilitation nowadays, compared with 20 years ago when the Bobath and Movement Sciences methods were conceptualized. Because of advances in medical and pharmacologic care that have reduced the incidence of first-ever stroke in the younger population, the typical age of patients with first-ever stroke is becoming older.\textsuperscript{23} In addition, the criteria used to select patients for rehabilitation has, in some centers, become more restrictive because of the need to conserve therapy resources for those who are likely to benefit most from rehabilitation. In clinical practice, this means that therapists may not dedicate as much time and resources to assessing and reducing asymmetry of gait.

Relationship Between Walking Speed and LPD

There was a negative linear relationship between amplitude of LPD and walking speed. Stroke patients who walked faster had more normal amplitude of LPD than slower walkers, who demonstrated significantly larger amplitudes. No such relationship was found between walking speed and absolute symmetry. A possible reason is that this sample of patients demonstrated relatively symmetrical LPD, with a small range of symmetry scores. The scores were clustered around zero, thereby producing a truncation effect in the data. Further research of larger numbers and different samples of patients with more asymmetrical patterns of LPD may help to clarify the relationship between LPD symmetry and walking speed.

Changes in LPD During Rehabilitation

As predicted, the unimpaired control sample did not alter their LPD amplitude or magnitude of symmetry during either the 1- or 4-week intervals. Contrary to predictions, the stroke sample demonstrated no significant change in LPD during rehabilitation. Inspection of the individual stroke patient data showed substantial variability in the magnitude and direction of change, both between subjects and within individual subjects over time. The control group did not demonstrate the same degree of inconsistency. Variability in the stroke group may be the result of measuring these subjects during the very early stages of gait recovery, when they were relearning to walk, and recovery and reorganization was occurring in the central nervous system. Observations made during test sessions suggested that patients did not always walk with stable walking patterns during this early period after their stroke. It is possible that more consistent and predictable change in measures of LPD may be found over longer periods of time. This highlights the need for therapists to regularly reassess patients during the early stages of stroke rehabilitation to develop treatment plans that remain responsive to individual needs.

It needs to be acknowledged that a relatively small sample of elderly patients with hemiparesis was selected as a sample of convenience from the inpatient population of 1 rehabilitation center. Therefore, the generalizability of our findings to the whole stroke population may be limited. For example, only patients able to independently complete at least 2 consecutive 10-m walking trials were recruited. The findings may not apply to deconditioned patients who are unable to walk more than one 10-m trial.\textsuperscript{24} In addition, the small number of subjects recruited combined with the wide variance of individual change scores may have reduced the power of some analyses. Clinically significant changes in gait over time may be demonstrated by analyzing change over longer periods of time or by using a more homogeneous subgroup of the hemiparetic population. This is a particularly important consideration given the heterogeneity of the stroke population.\textsuperscript{25}

CONCLUSION

Our study has provided baseline values for LPD in patients with acute hemiparetic stroke and has established the relationship between LPD and walking speed. Knowing that after stroke many patients experience difficulties in controlling lateral weight transference and the excursion of LPD during walking, it may be useful for clinicians to incorporate assessments of LPD into clinical gait analysis. However, change may only be detected over longer periods of time when the patient’s gait pattern has become less variable. Further research is required to evaluate the relationship between LPD disorders and energy expenditure, as well as to investigate the extent to which this movement disorder predicts trips and falls after stroke.

References


Suppliers
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