2.1 Participants

30 Subjects who fulfilled the inclusion criteria were recruited by means of convenience sampling from rehabilitation wards in Tung Wah Hospital in Hong Kong.

The inclusion criteria were:

(1) First stroke, less than 6 months.

(2) Can walk unaided for at least 15 meters indoor under supervision.

(3) Had no orthopedic and other neurological condition such as Parkinson’s disease that could affect walking performance.

(4) Had no medical contraindication to walking or exercising.

(5) Able to understand and follow simple instructions.

The exclusion criteria were:

(1) Brainstem or cerebellar strokes.

(2) Unable to use walking aids.

(3) Using walking aids before stroke.

(4) Can walk unaided independently.

(5) Need to use ankle-foot orthosis or drop foot sling in walking.
2.2 Design

The study was a within group repeated measures design. The subjects were assessed individually in a single attendance for around one and half hours. Their gait pattern and speed were assessed in three conditions:

1) Walk unaided with supervision.
2) Walk with stick.
3) Walk with quadripod.

The parameters obtained from the three conditions were dependent variables. The only independent variable was the type of walking aids.

2.3 Instrumentation

2.3.1 Equipment for gait analysis

The foot contact pattern was assessed by using the portable computer DynoGraphy (CDG) of the Infotronic Ultraflex Gait Analysis System. It consists of three pair of instrumented shoes (size large, medium and small) and a portable compact CDG measuring unit (Figure 3).

Figure 3. A pair of instrumented shoes and a portable compact CDG measuring unit
Each shoe was instrumented with eight force sensors. The center of pressure within each shoe will be the summation of the resultant ground reaction forces obtained. The ground reaction force value under each sensor was set at a frequency of 100 Hz, for a 20 seconds walking period. The measured values were temporary saved in the internal memory unit after each measurement and was then transferred to the computer for data analysis. The CDG has been proved to have a high test-retest reliability ($r>0.8$). Its validity was also good because it has strong correlation with the parameters obtained by the conventional gait analysis system (Wong et al 2004).

Moreover, a standardized stick and a small base quadripod with adjustable height were provided for all the subjects to walk during gait assessment (Figure 4).

![Figure 4. A standardized stick and a small base quadripod with adjustable height](image)

2.3.2 Apparatus for balance and gait speed assessment

A stop watch, an arm chair, a ruler and a step was used for balance and gait
speed assessment.

2.4 Procedures

Each subject admitted to the rehabilitation ward in Tung Wah Hospital was screened by the researcher. The purpose and procedure of the study were explained to the subjects who fulfilled the inclusion criteria and the exclusion criteria. A participant information sheet (Appendix C) was given to them. One to two days was allowed for them to discuss with their family members to make the decision. Once they agreed to participate in the study, they needed to sign a written consent form (Appendix D). Then the subjects were advised to wear suitable loose trousers and a pair of their usual comfortable shoes before attending the assessment. Each subject was assessed individually in approximately one and half hours.

After arrival, his/her blood pressure and pulse rate were measured to make sure that he/she is stable for the assessments. Afterwards, his or her balance, Berg’s balance scale (BBS) was assessed. The subject was then assisted to wear a pair of suitable size instrumented shoes over their shoes and carried the compact CDG measuring unit on his/her posterior waist (Figure 5 and 6).

Figure 5

Figure 6

The back and side view of a subject who is wearing a pair of suitable size of
instrumented shoes and carrying a compact CDG measuring unit on their waist.

Then the height of the standardized stick and quadripod was adjusted to fit individual use. The subject should stand erect with hands hanging loosely from the side, the unaffected hand was hold the walking aids and the tip of the stick or the center of the quadripod was placed approximately 6 inches in front and 6 inches lateral to the subject’s unaffected forefoot. While in this position, the researcher aligned the subject’s distal wrist crease with the top of the walking aids and had the subject hold the cane with the elbow flexed between 20°-30° (Sloan, Haslam & Foret; 2001). This degree of elbow flexion is the ideal indicator of cane height and allows the arm to shorten or lengthen during the different phases of walking (Kumar, Roe & Scremin; 1995).

After the walking aids’ height adjustment, the subject was allowed to get familiar with the walking aids and the experimental environment by walking with the adjusted stick and quadripod for several times. Then the subject was assessed to make sure that he/she could use the stick and the quadripod properly and comfortably.

After that, the gait assessment started. The subject was instructed to walk along a straight line in a rehabilitation center’s corridor with a self-selected and comfortable speed for 14 meters for two trials for each of the three walking conditions. The priority of walk unaided, using stick or quadripod was randomly decided by drawing a lot to nullify any effect from practice or fatigue. During each
trial of walking, a timer was used to record the time used for walking for the middle 10 meters. Data was not collected for the first 2 meters and the last 2 meters while the subject was accelerating or decelerating. At the same time, the subject’s foot contact pattern during walking for 20 seconds was recorded. Five minutes rest was allowed between each trial. Then the subject needed to repeat the above procedure in order to finish all the three walking conditions. The mean values of the two trials under each walking condition were used for data analysis.

After the procedure, the blood pressure and pulse rate of the subject were also checked for safety reason.

2.5 Outcome measures

2.5.1 Subjects’ characteristics

Demographic data including age, sex, onset of stroke, type of stroke and side of stroke was collected from each patient’s medical record.

2.5.2 Gait parameters

Mean vertical GRF at mid-stance phase of each leg (in Newton), temporal symmetry values, and gait speed were measured. The temporal symmetry values and the gait speed were calculated as follows:

Temporal swing symmetry = Paretic swing time / non-paretic swing time

Temporal stance symmetry = Paretic stance time / non-paretic stance time

Temporal swing-stance symmetry = Swing time / stance time
Overall temporal symmetry = Paretic swing-stance symmetry / Non-paretic swing-stance symmetry

Absolute temporal symmetry = \(|\text{overall temporal symmetry} - 1|\)

The measures of the above five symmetry values have been used and reported by previously authors to be valid, reliable and useful in measuring hemiplegic gait (Roth et al 1997 & Patterson et al, 2008). The normal range of temporal asymmetry was assumed to be 0.9 to 1.1 (Patterson et al, 2008). The overall temporal symmetry greater than one indicates a preference to rely on the non-paretic leg during walking. The higher the value, the more the paretic swing duration and the less the paretic stance duration.

Gait speed =10 meters / time used in each trial (in seconds).

2.5.3 The balance performance

The Berg Balance Scale (BBS) were measured. It consists of a hierarchical series of fourteen daily life activities that test one’s ability to maintain his/her balance in varies positions such as sitting, standing in various base of support, changing position and doing some task in standing position. The rating performance in each item is a five-point ordinal scale, with five is the highest score. The BBS is commonly used to quantitatively assess balance and risk of fall in stroke patients clinically. It has demonstrated strong psychometric properties in results of a systematic review done by Blum & Korner-Bitensky (2008) and it was suggested as
an effective and appropriate assessment of balance in stroke patients. It measures both static and dynamic aspects of balance. Each item was scored from zero to four, with a score of zero representing an inability to complete a task and a score of four representing independent to complete the task. Therefore, the full score is fifty-six. Moreover, it involves minimal and non-expensive equipment (a stop watch, an arm-chair, a step and a ruler) and requires only ten to twenty minutes to complete the test.

2.6 Statistical Analysis

The SPSS version 11.5 was used for statistics analysis. Descriptive statistics (mean ± SD) were used to depict the subjects’ demographic characteristics and values of all gait parameters. The parametric test, repeated measures ANOVA, was used to test the effect of walking aids on mean GRF at mid-stance phase on the good leg because the values of Mean GRF in mid-stance phase of the good leg was normally distributed (P>0.05 in Shapiro-Wilk test, refer to table 2 in appendix B) and also fulfilled the Sphericity assumption (P>0.05 in Mauchly’s test, refer to table 2 and 3 in appendix B).

However, the non-parametric test, Friedman test, were used to test the effect of walking aids on the mean GRF in mid-stance phase on the paretic leg, self-selected comfortable gait speed and all temporal symmetry values (swing, stance and overall temporal symmetry) because most of the values in mean GRF in mid-stance phase
of the paretic leg and all the temporal asymmetry values were not normally distributed (P<0.05 in Shapiro-Wilk test, refer to table 2). Although the gait speed was normally distributed (P>0.05 in Shapiro-Wilk test, refer to table 2 in appendix B) but it did not fulfilled the Sphericity assumption (P<0.05 in Mauchly’s test, refer to table 10 in appendix B). Post-hoc test, Wilcoxon Signed Ranks Test, were used to test the difference of 1) mean GRF of the paretic limb 2) gait speed were present in which walking conditions. It is because the two Friedman tests (Table 5 and Table 11 in appendix B) showed that the mean GRF of the paretic limb (p=0.004 and \(\chi^2 =11.11\)) and gait speed (p=0.019 and \(\chi^2 =7.90\)) of the three walking condition had significant difference. Moreover, Mann-Whitney Tests were used to test is there any difference in mean GRF in mid stance phase between the paretic and the non-paretic limbs for the three walking conditions.

In addition, Pearson correlation was used to calculate the correlation between 1) gait speed and mean GRF in mid-stance phase of the paretic limb 2) gait speed and mean GRF in mid-stance phase of the non-paretic limb 3) gait speed and absolute temporal symmetry, in each walking condition.

The significance level will set at p<0.05 for all statistic tests. In order to reduce the risk of committing Type 1 error, Bonferroni’s adjustment will do if necessary.

2.7 Ethical Implications

The study was approved by Institutional Review Board of the University of