行政院國家科學委員會專題研究計畫　期中進度報告

使用輔具對腦中風病患站立與步行時之動態平衡及維持動態平衡所需注意力之影響(2/3)

計畫類別：個別型計畫
計畫編號：NSC92-2314-B-002-187-
執行期間：92 年 08 月 01 日至 93 年 07 月 31 日
執行單位：國立臺灣大學醫學院物理治療學系暨研究所

計畫主持人：胡名霞

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行政院國家科學委員會補助專題研究計畫

□ 成果報告
■ 期中進度報告

計畫名稱:
使用輔具對腦中風病腦中風病患站立與步行時之動態平衡及維持動態平衡時所需注意力之影響(2/3)
Influence of Assistive Devise Use on Dynamic Balance and the Associated Attentional Demands during Standing and Walking in Patients with Stroke (2/3)

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計畫主持人：胡名霞副教授　台大醫學院物理治療學系暨研究所
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計畫參與人員： 湯佩芳助理教授、呂麗華、劉宛宜

成果報告類型(依經費核定清單規定繳交)：■精簡報告　□完整報告

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中　華　民　國　93 年　5 月　28 日

行政院國家科學委員會專題研究計畫期中進度報告

使用輔具對腦中風病腦中風病患站立與步行時之動態平衡及維持動態平衡時所需注意力之影響(2/3)

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中文摘要

此第二年期研究計畫的目的有二：(一) 探討使用單拐對中風病患及健康成人執行自主性前跨動作時之動作表現、動態平衡之神經肌肉控制機制、以及注意力需求之影響；(二) 由分析單拐下之力學變化進一步瞭解單拐之生物力學角色。至今本研究已收集 9 位中風與 11 位健康受試者之資料。每位受試者皆接受三種情境之測試：主要單項任務（跨步）情境、次要單項任務（口語反應）情境、及雙項任務（跨步加口語）情境。以上三種情境之測試又再細分為在持拐與不持拐下各執行六次。實驗記錄受試者之跨步表現（含跨步反應時間、跨步動作時間、壓力中心相關參數、及兩下肢腓腸肌與脛前肌之肌電反應)、口語反應表現（含口語反應時間、反應正確率)、及單拐下之力學變化。以 6 位健康及 5 位中風受試者所作之三維重複變異數統計分析之初步結果顯示：對口語反應時間只有任務之主要效應（$p<.05$），兩組人在雙項任務情境下之口與反應時間（929.4ms）皆較單項任務情境下的（685.2ms）長。而對跨步反應時間則有組別與持拐情境之交互作用效應（$p<.05$)。持拐下，中風病患用健側下肢跨步之跨步反應時間由不持拐下之 775.9ms 降至 692.1ms，其用患側下肢跨步時間則為由 740.3ms 降至 669.0ms；然而健康受試者在持拐下（545.7ms）與不持拐下（540.0ms）之跨步反應時間則無顯著差異。單拐下之施力分析則顯示中風病患在持拐下跨步前，其拐下施力出現預期性之調節，而健康受試者則無此現象。這些初步結果顯示健康與中風受試者在跨步時都有顯著之注意力需求。雖然持拐下跨步未降低中風病患這種注意力需求，然而由持拐能減少其跨步反應時間來看，持單拐跨步可能提供較佳之預期性姿勢調節，使患者對跨步作較佳之準備。此研究之拐下力學結果亦支持這種推測。

English Abstract

The purposes of this second-year part of the three-year research project were two-fold: first, to examine the influence of regular cane use on the movement performance, neuromuscular control mechanisms of dynamic balance, and the attentional demands associated with performing a voluntary forward stepping movement in patients with stroke and in age-matched healthy adults; second, to further understand the biomechanical role of a regular cane when being used in the above-mentioned task by investigating the kinetics recorded from the cane. Nine stroke patients and 11 healthy adults participated in the study to date. All subjects were tested in 3 task conditions: single primary task (stepping alone), single secondary task (verbal reaction time alone), and dual task (stepping plus verbal reaction tasks) conditions. All three conditions were further stratified into cane-use and cane-free sub-conditions. Performance of stepping movements (step reaction time, step movement time, center of pressure measures, and EMG of bilateral tibialis anterior and gastrocnemius and unilateral triceps brachii) and verbal responses (verbal reaction time and accuracy of verbal response), as well as the kinetics of cane were recorded and analyzed. Preliminary results of the 3-way (group x cane x task) repeated measures of ANOVA on 6 healthy and 5 stroke patients revealed only the task main effect ($p<.05$) on verbal response, with both groups showing increased verbal reaction time (929.4ms) in the dual-task condition compared with the single-task condition (685.2ms). There was a significant group x cane interaction effect on step reaction time ($p<.05$). With the use of a cane, patients with stroke significantly ($p<.016$) reduced the step reaction time when stepping with the unaffected leg (reduced from 775.9ms to 692.1ms) and with the affected leg (reduced to from 740.3ms 699.0ms), whereas healthy adults showed no significant changes in step reaction time (no cane: 545.7ms; with cane: 540.0ms). The kinetics of the cane showed anticipatory adjustments of the forces applied on the cane before initiating the stepping movements in patients with stroke, but not in healthy controls. The results suggest that both healthy adults and patients with stroke require substantial attentional demands when performing a volitional stepping task. Although the use of a cane does not significantly change such attentional demands, the shortened step reaction times under the cane use condition in patients with stroke indicate that using a cane may provide better anticipatory postural adjustments in preparation for making a volitional stepping movement for these patients, as revealed from our kinetic data of the cane.

Keywords: hemiplegia, assistive device, stepping, dynamic equilibrium, attention, dual task,

Background and Purposes

Research has shown the effectiveness of using ambulatory assistive devices to increase standing stability of patients with stroke in clinical practice (Maeda et al., 2001). However, literature has also suggested that manipulation of ambulatory assistive devices in dynamic motor tasks, such as walking, inevitably requires additional attention, even in healthy adults (Wright & Kemp, 1992). Given that the majority of patients with stroke suffer from balance control difficulty, which subsequently increases their attentional demands associated with maintaining balance (Brown et al., 2002), it remains an important question as to whether the use of ambulatory assistive devices would take away some attentional resources that would otherwise be used for maintaining balance. Therefore, the purposes of this second-year part of the three-year research project were two-fold: first, to examine the influence of regular cane use on the movement performance, neuromuscular control mechanisms of dynamic balance, and the attentional demands associated with performing a voluntary forward stepping movement in patients with stroke and in age-matched healthy adults; second, to further understand the biomechanical role of a regular cane when being used in the above-mentioned task by investigating the kinetics recorded from the cane.

Methods

Subjects. Nine patients with a single onset of stroke, recruited from the National Taiwan University Hospital, and 11 healthy adults have participated in this study as of May 30, 2004. Tables 1 and 2 show the demographic information and performance on some clinical tests of 7 patients and 10 control subjects. All subjects signed an informed consent approved by the Human

Subjects Committee of the National Taiwan University and undertook one session of clinical assessments and another session of laboratory tests within one week.

Clinical Assessments. Health survey questionnaires and clinical assessments were used to record subjects' relevant medical history. The clinical assessments used in this study included the Mini-Mental State Examination (MMSE) (Folstein et al., 1975), Step Test (Hill et al. 1996), Stop Walking When Talking test, (Lundin-Olsson, et al., 1997), Timed "Up and Go" Test (Podsiadlo & Richardson, 1991), 10-meter walking speed test, and Berg Balance Scale (Berg et al., 1989). In addition, all stroke patients also received the lower extremity motor and coordination test portion of the Fugl-Meyer Assessment (Fugl-Meyer, et al., 1975), the Modified Ashworth Scale (Gregson et al., 1999), and the Star Cancellation Test (Halligan et al., 1989). It took approximately 1 to 1.5 hours for each subject to complete the clinical assessment session.

Experimental Apparatus. A custom-built Multi-stimuli Generator (DoLu Technologies Co, Ltd., Taiwan) was used to provide a yellow warning light signal, a red stimulus light signal, and voice stimulus signals to the subjects as well as to record voice signals generated by subjects in the voice reaction time task condition. Two force plates (AMTI OR6-7, Advanced Mechanical Technology, Inc., USA) were used to record ground reaction forces of the subjects, which then were used to derive center of pressure data. One instrumented cane (Model Z-CT6-500, Advanced Mechanical Technology, Inc., USA) was used to record the horizontal and vertical reaction forces on the cane in the cane-use conditions. Six foot switches (Motion Lab Systems, Inc., USA) were used to signal the time the heel and the 1st and 5th metatarsal heads of each foot were in contact with or off the floor. The stimulus light, stimulus voice, force and foot switch signals were all recorded on a PC computer using the DATAPAC A/D acquisition board and acquisition software (Run Technologies, USA). The DATAPAC2000 software (Run Technologies, USA) was used to analyze the light, voice, force plate, cane, and foot switch data. Two video cameras (Video Hi8 SONY) were used to record subject's behaviors during the experiment from the frontal and sagittal views. A custom-written software is now being programmed and will be used to quantitatively analyze the center of pressure data. Behavioral analysis using the video data was performed to characterize subject's balance behaviors before, during, and after the stepping movements.

Laboratory Stepping and Verbal Reaction Time Tests. All subjects were tested in 3 task conditions: single primary task (stepping alone), single secondary task (verbal reaction time alone), and dual task (stepping plus verbal reaction tasks) conditions. All three conditions were further stratified into cane-use and cane-free sub-conditions with 6 trials being tested in each sub-condition. For the sub-conditions in which subjects' stepping performance was tested, each leg performed 3 stepping trials. The sequence of task conditions and sub-conditions were all randomized among subjects in order to eliminate sequence effects. There were a total of 36 trials.

Each subject was standing on one of the force plates with symmetric stance initially. The Multi-stimuli Generator was positioned 1.5 meters in front of the subject at the eye level. Each subject was instructed to make a quick forward step of comfortable step length toward the other force plate after a red stimulus light was lit in the single primary task and dual task conditions and to make a quick verbal response ("high" or "low") when hearing a tone signal in the single secondary task and dual task conditions. A yellow warning light was lit up before the red stimulus light or the voice signal to remind the subjects of paying attention to the incoming signals in each trial. It took approximately 1 to 1.5 hours for each subject to complete the clinical assessment session.

Data and Statistical Analyses. Performance of stepping movements (step reaction time, step movement time, center of pressure measures, and EMG of bilateral tibialis anterior and gastrocnemius and unilateral triceps brachii) and verbal responses (verbal reaction time and accuracy of verbal response), as well as the kinetics of cane were recorded and analyzed. Three-way (group x cane sub-conditions x task conditions) were used to analyzed the data. Only step reaction time, step movement time, and verbal reaction time, verbal response accuracy rate are reported here. Other data are undergoing intensive analysis at this point. An alpha level of .05 was selected as the criterion for statistical significance.

Results

Tables 1 and 2 show the demographic information and performance on some clinical tests of 10 healthy controls and 7 patients, respectively. The healthy and stroke patients were significantly different on all clinical assessments ($p<.05$), except the MMSE, indicating that the stroke patients had residual mobility and balance problems after stroke.

Performance of both groups on the step and verbal reaction time tasks in the single and dual task conditions and different cane use sub-conditions is presented in Table 3. Because of the time constraint, statistical analyses were performed on only 6 healthy (He01-He06) and 5 stroke (St01-St05) subjects so far. Preliminary results of the 3-way (group x cane x task) repeated measures of ANOVA on these 6 healthy and 5 stroke patients revealed only the task main effect ($p<.05$) on verbal response, with both groups showing increased verbal reaction time (929.4ms) in the dual-task condition compared with the single-task condition (685.2ms). There was a significant group x cane interaction effect on step reaction time ($p<.05$). With the use of a cane, patients with stroke significantly ($p<.016$) reduced the step reaction time when stepping with the unaffected leg (reduced from 775.9ms to 692.1ms) and with the affected leg (reduced to from 740.3ms 699.0ms), whereas healthy adults showed no significant changes in step reaction time (no cane: 545.7ms; with cane: 540.0ms).

The kinetic data recorded from the force plates and cane of one stroke patient and one healthy adult are illustrated in Figures 1 and 2, respectively. It was of interest to note that in the stroke patient, but not in the healthy adult, the unloading of the vertical force on the cane occurred prior to that on the force plates. This important finding indicates that the stroke patient may use the cane to provide anticipatory postural adjustments in preparation for initiating a stepping movement.

Discussion and Conclusions

Our preliminary results suggest that both healthy adults and patients with stroke require substantial attentional demands when performing a volitional stepping task. Past research has shown that the maintenance of balance, especially dynamic balance, requires considerable attention even for healthy adults (Brown et al., 1999). Different from what Wright and Kemp (1992) reported, in our preliminary results, the use of a cane does not seem to significantly change such attentional demands for both healthy adults and stroke patients. However, the shortened step reaction times under the cane use condition in patients with stroke indicate that using a cane may provide better anticipatory postural adjustments in preparation for making a volitional stepping movement for these patients, as revealed from our kinetic data of the cane, and thus shortened the step reaction time. Our finding that anticipatory postural adjustments may be exerted on a cane held in the hand of a stroke person who is performing a balance task is congruent with that reported by Jeka (1997).

Evaluation of the Outcomes of the Present Study

1. Although our progress on this study is slightly behind, we have made substantial progress on this project. We will continue to work on the custom-written software and use it to complete our quantitative analysis of the COP data. We will also continue the analysis of EMG data. We

expect to recruit a few more subjects for each group.

2. Our preliminary results have shed some light on the role of cane use on the dynamic balance control and attentional demands of stroke patients. These findings have important clinical implications and will provide some important guidelines for assistive device use in stroke rehabilitation.
3. Results of this study are definitely suitable to be published in an internationally peer-reviewed journal. To date, no similar study has been reported. We will write it up for publication after the completion of this project.

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Table 1: Demographics and Clinical Tests Performance of Healthy Subjects (n=10)

Subject (ID)	Age (year)	Sex (M/F)	MMSE (score)	WS1 (m/sec)	WS2 (m/sec)	TUG (sec)	STR (# of steps)	STL (# of steps)	BBS (score)
He 01	54.8	M	30	1.93	1.70	5.5	13	15	56
He 02	68.1	F	28	1.11	1.39	10.1	12	12	56
He 03	68.1	M	30	0.79	0.87	9.2	9	10	55
He 04	59.4	M	30	1.38	1.13	10.3	11	11	56
He 05	54.2	M	29	1.48	1.33	7.2	13	12	56
He 06	52.0	M	29	1.34	1.51	7.3	10	11	56
He 07	53.0	M	28	1.17	1.12	7.7	11	10	56
He 08	70.3	M	29	1.28	1.22	7.9	10	10	55
He 09	53.2	M	30	1.30	1.34	8.8	15	13	56
He 10	68.5	M	29	1.33	1.28	7.7	13	13	55

Notes:

He: Healthy
MMSE: Mini-Mental State Exam
WS1: Comfortable walking speed
WS2: Comfortable walking Speed at “Stops Walking When Talking” test
TUG: Timed “Up & Go” Test
STR: Step Test (Right Leg)
STL: Step Test (Left Leg)
BBS: Berg Balance Scale

Table 2: Demographics and Clinical Tests Performance of Stroke Subjects (n=7)

Subject (ID)	Age (year)	Sex (M/F)	Hemi side (R/L)	Lesion site	MMSE (score)	SW1 (m/sec)	SW2 (m/sec)	TUG (sec)	STU (# of steps)	STA (# of steps)	BBS (score)
St 01	76.1	M	R	Left internal capsule	30	0.33	0.30	33.3	6	1	43
St 02	54.5	M	R	Left putamen	30	0.46	0.41	26.7	6	3	46
St 03	47.6	M	R	Right cerebellar Peduncle	29	0.34	0.46	17.9	8	4	50
St 04	47.8	M	R	Left thalamus	29	0.29	0.23	28.5	7	3	49
St 05	58.0	M	L	Right thalamus	30	0.85	0.89	11.3	7	8	51
St 06	52.9	M	L	Right MCA and basal ganglia	29	0.19	0.17	55.7	3	0	38
St 07	43.6	M	R	Left putamen	29	0.81	0.88	11.0	6	4	52

Notes:

St: Stroke
STU: Step Test (Unaffected Leg)
STA: Step Test (Affected Leg)
Other abbreviations: Same as in Table 1.

Table 3: Performance of the Healthy and Stroke Groups on the Step and Verbal Reaction Time Tasks in Single and Dual Task Conditions

	Healthy (*n* = 10)		Stroke (*n* = 7)			
			Unaffected Side		Affected Side	
	No cane	With Cane	No cane	With Cane	No cane	With Cane
Single Task						
Step RT	455.4 ± 92.4	456.9 ± 75.2	716.2 ± 108.2	659.5 ± 46.1	704.3 ± 152.3	634.3 ± 125.3
Step MT	413.9 ± 100.6	404.2 ± 79.9	507.3 ± 162.2	618.5 ± 245.5	716.1 ± 231.8	729.1 ± 206.3
VRT*	671.9 ± 270.7	705.5 ± 250.8	683.0 ± 58.0	683.9 ± 54.8	683.0 ± 58.0	683.9 ± 54.8
Accuracy Rate	97.2 ± 6.8%	94.4 ± 8.6%	96.7 ± 7.5%	93.3 ± 9.1%		
Dual-Task						
Step RT	636.1 ± 164.0	623.1 ± 159.0	835.6 ± 172.3	724.8 ± 145.2	776.2 ± 192.1	763.7 ± 199.0
Step MT	396.2 ± 85.9	412.5 ± 82.4	461.4 ± 96.0	446.1 ± 48.7	635.9 ± 81.3	703.2 ± 131.3
VRT	839.3 ± 232.4	824.1 ± 245.7	1058.5 ± 295.6	932.4 ± 171.6	972.9 ± 140.8	949.2 ± 125.9
Accuracy Rate	100 ± 0%	100 ± 0%	100 ± 0%	100 ± 0%	73.3 ± 28.0%	100 ± 0%

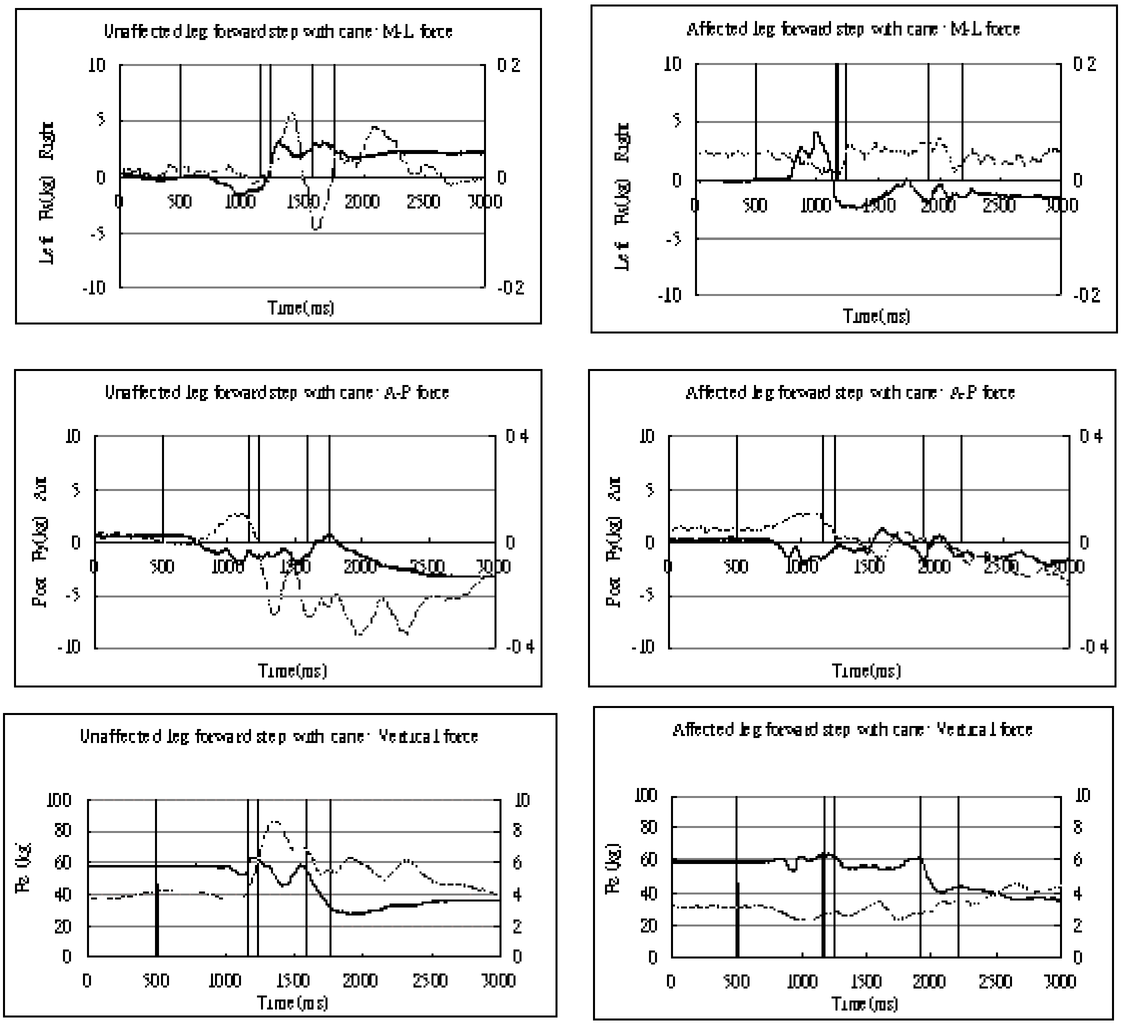
Notes:

Step RT: Step Reaction Time

Step MT: Step Movement Time

VRT*: Verbal Reaction Time. The VRT task was tested in quiet standing position in the single secondary task condition. Therefore, there were only two sets of VRT values, one under the no cane condition and the other under the with cane condition, for patients with stroke.

Step with Unaffected Leg Step with Affected Leg

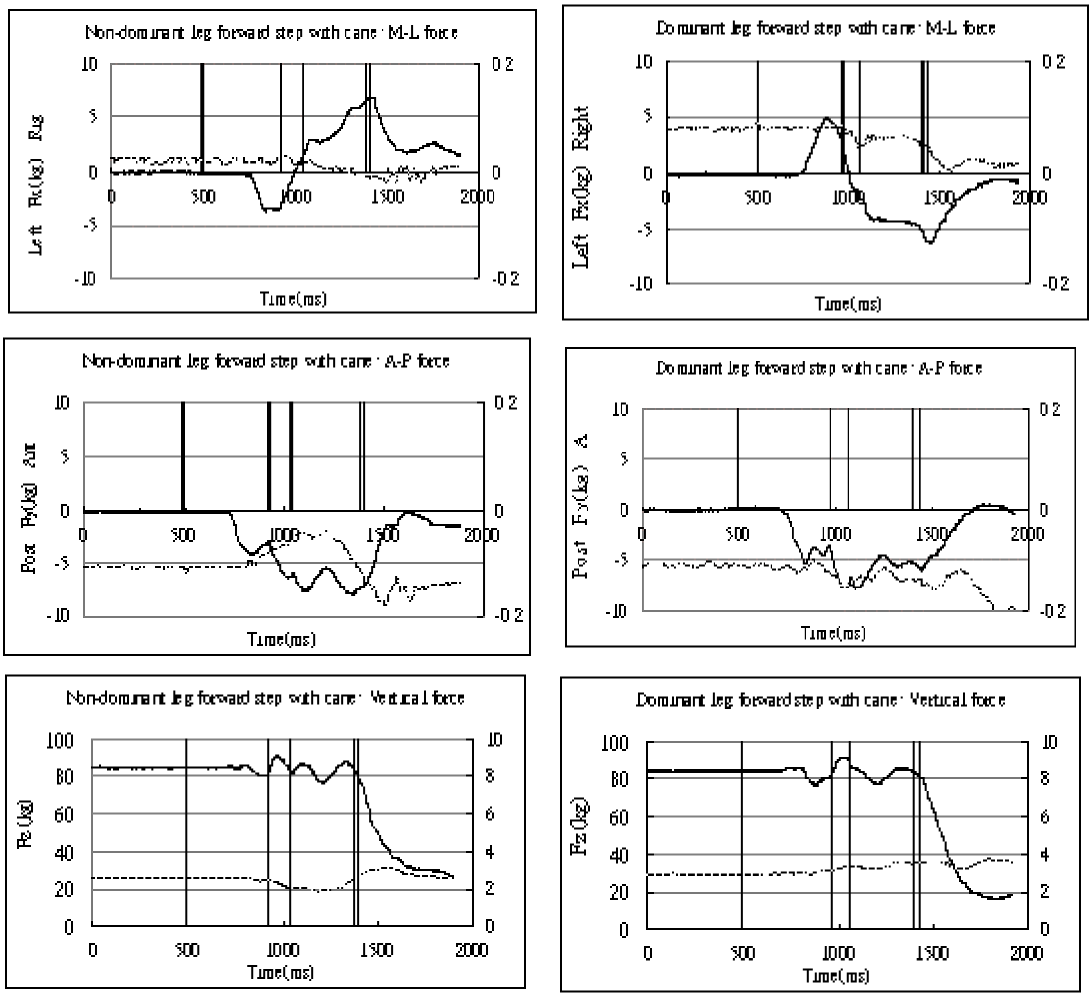


Notes:

Solid force lines: x, y, and z forces from the force plates, scale on the left.
Dotted force lines: x, y, and z forces from the cane, scale on the right.
1st vertical line: Primary stimulus
2nd vertical line: Step initiation
3rd vertical line: Foot lift off
4th vertical line: Heel/Toe contact
5th vertical line: Step termination

Figure 1. Force Plates and Cane Kinetics of A Stroke Patient (St02)

Step with Non-dominant (Left) Side　　Step with Dominant (Right) Side



Notes:

Solid force lines: x, y, and z forces from the force plates, scale on the left.
Dotted force lines: x, y, and z forces from the cane, scale on the right.
1st vertical line: Primary stimulus
2nd vertical line: Step initiation
3rd vertical line: Foot lift off
4th vertical line: Heel/Toe contact
5th vertical line: Step termination

Figure 2. Force Plates and Cane Kinetics of A Healthy Subject (He01)