行政院國家科學委員會專題研究計畫　成果報告

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(3/3)

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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(3/3)

Influence of Assistive Devise Use on Dynamic Balance and the Associated Attentional Demands during Standing and Walking in Patients with Stroke (3/3)

計畫類別：■ 個別型計畫　□ 整合型計畫
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中　華　民　國　94　年　10　月　31　日

中文摘要

恢復病患獨立站立與步行的能力是中風復健治療中最重要的目標之一。單枴是中風病患常使用的站立與步行輔助工具或訓練工具。單枴的使用雖有其生物力學上的助益，但也可能有反效果。例如：單枴的使用可能增加中風病患站立與步行時的左右不對稱性、減少病患患肢承重或使力之機會、以及增加病患對單枴的心理依賴等。而正確操作單枴所需之注意力需求是否會導致病患站立與步行控制能力或對周遭環境警覺度之下降，致使其跌倒機率增加，亦是個值得深究的問題。

本三年研究計畫逐年之主要目的各為: (一)探討並比較腦中風病患與健康成人使用與不使用單枴站立對其作快速自主性跨步動作的動作表現與動力學變化之影響; (二)探討並比較腦中風病患與健康成人使用與不使用單枴站立對其作快速自主式跨步動作時維持動態平衡注意力需求之影響; (三)探討並比較腦中風病患與健康成人使用與不使用單枴步行對其以舒適速度步行時之步態與注意力需求之影響。

第一年研究之主要發現為：中風病患不持枴跨步時之足底施力型態雖與健康成人的類似，但其施力值較小、穩定性較差，尤以患肢跨步時較明顯。持枴跨步會增加病患患肢跨步時之跨步步長、健肢跨步時之跨步動作時間與跨步反應時期之足底壓力中心移動速率(p＜0.05)，且降低中風病患之垂直足底施力，並增加其垂直足底施力穩定性。枴杖在中風病患執行跨步動作中主要扮演協助推進與支撐的角色，尤以健肢跨步時較明顯。因此，持枴跨步確實能改善中風病患跨步時之動作表現與動態平衡，但亦同時減少病患自身之足底施力。

第二年研究之主要發現為：中風病患與健康成人於雙項任務情境下(同時執行跨步與口語選擇性反應任務)之口語選擇性反應時間均顯著較單項任務情境(只執行口語選擇性反應任務)時長(p＜0.001)，且其中以中風患肢跨步時其口語選擇性反應時間增長的程度最大；顯示中風患肢跨步時所需之注意力顯著高於健康成人跨步所需的注意力。至於持枴與否對兩組受試者跨步時之注意力需求則無顯著影響。

第三年研究之主要發現為：當腦中風病患與健康成人於靜態站立下只執行口語選擇性反應任務此單項任務時，持枴與否對兩組受試者之口語選擇性反應時間無顯著影響(p > .05)，亦即持枴與否並不影響兩組受試者站立時之注意力需求。然而，持枴步行時腦中風病患與健康成人兩組受試者之口語選擇性反應時間間(969.1msec)均較不持枴步行時長(858.3msec) (p <.05); 顯示腦中風病患與健康成人持枴步行所需之注意力較不持枴步行時為多。

綜合而言，本研究發現持枴確實能改善中風病患跨步與步行時之動作表現與動態平衡，然而持枴亦減少病患自身之足底施力。此外，持枴雖不增加中風病患站立時執行跨步動作之注意力需求，但卻會增加中風病患步行時之注意力需求。因此，臨牀上訓練中風病患動態平衡與步行能力時是否採用單拐作為輔具應同時考慮單拐之正負面效益。

關鍵詞：腦中風、步行輔具、注意力、站立跨步移位、步行、動態平衡

Abstract

Restoration of the ability to independently stand and walk is one of the primary goals of stroke rehabilitation. The regular cane is one of the most commonly used assistive devices in standing and ambulation training for patients with stroke. Although the use of a regular cane does present some biomechanical advantages, the use of can may, on the other hand, inevitably introduce some negative influences on patients. For instance, the use of a regular cane may increase standing and walking asymmetry, decreased weight bearing or force generation demands on the affected lower extremity, and increased psychological dependence on the device. Furthermore, these patients need to operate the devices with certain degree of temporal and spatial accuracy during movements. It remains unanswered as to whether the use of such devices would increase the demands on patients' attention, which in turn, may reduce patients' level of control over the mobility tasks at hand or degree of vigilance to attend to the changing environment, and consequently leads to more falls among these patients.

There three specific aims for this three-year research project were: first, to investigate the influence of using a regular cane on the movement performance and kinetics during voluntary forward stepping task in standing for patients with stroke and healthy adults; second, to investigate the influence of using a regular cane on the attentional demands associated with performing a voluntary forward stepping task in standing for patients with stroke and healthy adults; and third, to investigate the influence of using a regular cane on the gait performance and attentional demands while performing comfortable-speed walking in patients with stroke and healthy adults.

Results of the first-year project showed that while performing a volitional forward stepping task, patients with stroke demonstrated similar ground reaction force patterns, but of smaller magnitudes and with poorer smoothness, compared to age-matched healthy adults. This was especially true when these patients stepped with the affected lower extremity. When the patients stepped with the affected lower extremity and with the use of a regular cane held on the unaffected hand, their step length (SL) increased compared to the stepping without a cane condition. When the patients stepped with the unaffected lower extremity and with the use of a regular cane, the movement time (MT) duration, during which the affected lower extremity supported the majority of the body weight, and the center of pressure speed (COPsp) in the reaction time (RT) phase were significantly increased, the patterns of the vertical ground reaction forces became smoother, whereas the magnitude of the vertical ground reaction forces decreased, compared to the stepping with the unaffected lower extremity and without a cane condition. Therefore, it is evidence that the regular cane played a role of assisting the forward propulsion and weight support especially when these patients stepped with the unaffected lower extremity. Although the use of a cane indeed improved the movement performance and dynamic balance associated with the stepping task for these patients, the use of a cane inevitably reduced the need for them to generate active vertical ground reaction forces by the affected lower extremity of

these patients.

The major findings of the second-year project were that the patients with stroke showed a significantly greater increase in the verbal reaction time (VRT) from the single task (verbal choice reaction time (VCRT) task) condition to the dual task (stepping plus VCRT tasks) condition than the age-matched healthy adults ($p < .001$). Such increase was the greatest when the patients were stepping with the affected lower extremity, indicating that patients with stroke required a much greater amount of attention while performing the stepping with the affected lower extremity task than age-matched healthy adults. The use of a regular cane did not significantly change the needed amount of attention associated with performing the stepping task for both groups of subjects.

In the third-year project, we found that the use of a regular cane did not significantly affect the VRT performed in a single task VCRT condition for both patients with stroke and healthy adults. The use of a regular cane, however, increased the VRT from a mean of 858.3 msec in the single task (VCRT task only) condition to an average of 969.1 mses in the dual task (VCRT task was performed simultaneously with a comfortable-speed walking task) condition for both groups of subjects ($p < .05$). These findings suggest that the use of a regular cane to walk required a greater amount of attention than not using a cane for both patients with stroke and healthy adults.

Together, our results suggest that the benefits of using a regular cane to perform a voluntary forward stepping task or a walking task primarily include the effectiveness in improving the movement performance and dynamic stability. The negative influences of using a cane to perform these tasks are the reduced need to generate active forces with the affected lower extremity for patients with stroke and increased attention demands for walking for both patients with stroke and healthy controls. Therefore, the decision as to whether a regular cane ought be used as an assistive device for mobility and ambulation training for patients with stroke or not has to be based upon case-specific relative weighting between the positive and negative influences of cane use.

Key Words: stroke patients, ambulation assistive device, attention, stepping during standing, walking, dynamic equilibrium

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Introduction

Background

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 and mobility control difficulty, which subsequently increases their attentional demands associated with maintaining balance and walking (Bowen et al., 2001; Brown et al., 2002; Haggard et al., 2000), 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 or walking.

Purposes

Therefore, the purposes of this three-year research project were three-fold. First, we investigated the influences of using a regular cane on the movement performance and kinetics during voluntary forward stepping task in standing for patients with stroke and healthy adults. The purpose of the second-year project was to investigate the influence of using a regular cane on the attentional demands associated with performing a voluntary forward stepping task in standing for patients with stroke and healthy adults. The third-year project was aimed to investigate the influence of using a regular cane on the gait performance and attentional demands while performing comfortable-speed walking in patients with stroke and healthy adults. The first and second purposes were fulfilled in a joined experiment, Experiment 1, and the third purpose was achieved in Experiment 2. The dual-task paradigm was used for both experiments.

Methods

Experiments 1 for Purposes 1 and 2

Subjects. Eleven patients with a single onset of stroke (mean age= 54.1 ± 9.8 y; 10 males and 1 female), recruited from the National Taiwan University Hospital, and 11 age-matched healthy adults (mean age= 55.5 ± 7.7 y; 10 males and 1 female) participated in this experiment. Patients with stroke all met following inclusion criteria: (a) first onset of stroke causing contralateral hemiplegia defined as ICD-10 (The Tenth Revision of International Classification of Diseases, ICD-10, WHO), (b) being able to independently stand for at least 10 minutes and to step forward without wearing ankle-foot orthosis or using any assistive device, (c) no cognitive deficit as determined by a score of 24 points or above on the Mini-Mental State Examination (MMSE), (d) no signs of hemi-neglect and hemi-anopia, and (e) no symptoms or history of other neurological or orthopedic problems which may affect their ability to stand or step forward. The healthy adults were aged- and gender-matched volunteers with no history of neurological and severe orthopedic problems. Informed consent was obtained from all participants. This study was approved by the Ethics Committee of the National Taiwan University Hospital.

Design. This was a cross-sectional case-control study. All subjects 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 (MSG) (DoLu Technologies Co, Ltd., Taiwan) was used to provide a yellow warning light signal, a red stimulus light signal, and tone stimulus signals ("high" (2000Hz) or "low" (500Hz) tone signals) to the subjects as well as to record voice responses 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 task alone), single secondary task (verbal choice reaction time (VCRT) task alone), and dual task (stepping plus VCRT 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.

Procedure of Laboratory Tests. Each subject stood on one of the force plates with symmetric stance initially. The MSG 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 laboratory tests.

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 (VRT) and verbal response accuracy (VRA)), as well as the kinetics of cane were recorded and analyzed. Three-way (Group x Cane conditions (with v.s. without) x Task (single v.s. dual conditions)) repeated measures of analysis of variance (RM ANOVA) were used to analyze the data. An alpha level of .05 was selected as the criterion for statistical significance.

Experiment 2 for Purpose 3

Subjects. Six patients with a single onset of stroke (mean age= 56.7 ± 7.3 y), recruited from the National Taiwan University Hospital, and 5 age-matched healthy adults (mean age= 54.5 ± 1.8 y) participated in this experiment. Patients with stroke all met following inclusion criteria: (a) first onset of stroke causing contralateral hemiplegia defined as ICD-10 (The Tenth Revision of International Classification of Diseases, ICD-10, WHO), (b) being able to independently walk for 10 meters without wearing ankle-foot orthosis or using any assistive device and bweing able to tolerate an exercise program lasting for 30 minute, (c) no cognitive deficit as determined by a score of 24 points or above on the Mini-Mental State Examination (MMSE), (d) no signs of hemi-neglect and hemi-anopia, and (e) no symptoms or history of other neurological or orthopedic problems which may affect their ability to stand or step forward. The healthy adults were aged- matched volunteers with no history of neurological and severe orthopedic problems. Informed consent was obtained from all participants. This study was approved by the Ethics Committee of the National Taiwan University Hospital.

Design. This was a cross-sectional case-control study. All subjects 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), 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 (MSG) (DoLu Technologies Co, Ltd., Taiwan) was used to provide "high" (2000Hz) or "low" (500Hz) tone signals to the subjects as well as to record voice signals generated by subjects in the voice choice reaction time (VCRT) task condition. The GaitMatII system (GaitMat^{TM}II, E.Q. Inc., USA) was used to record and analyze walking speed and the spatal and temporal characteristics of gait in the comfortable speed walking task. The Pedar Insole system (Novel gmbh, Munich, Germany) and the Novel multi-mask and COP-velocity software (Novel gmbh, Munich, Germany) were used to record and analyze the foot pressure data, respectively, under both feet during the standing and walking trials of this experiment. A gait mat (3.8 meter long x .6 meter wide) (GaitMat^{TM}II, E.Q. Inc., USA) was placed at the center of a 8-meter-long walkway to record spatio-temporal

information of gait. 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. The stimulus tone, voice responses, onset of GaitMatII recording 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 stimulus tone, voice responses and cane kinetics. One video camera (Video Hi8 SONY) was used to record subject's behaviors during the experiment from the frontal view. Behavioral analysis using the video data was performed to provide references for synchronizing data recorded from the three different systems- the GaitMatII, Pedar, and DATAPAC.

Laboratory Comfortable-Speed Walking and Verbal Reaction Time Tests. All subjects were tested in 3 task conditions: single primary task (walking alone), single secondary task (VCRT task alone), and dual task (walking plus verbal reaction tasks) conditions. All three conditions were further stratified into cane-use and cane-free sub-conditions with 8 trials being tested in each sub-condition. The sequence of task conditions and sub-conditions were all randomized among subjects in order to eliminate sequence effects. There were a total of 24 trials.

Procedure of the Laboratory Tests. Each subject stood with symmetric stance initially on one end of a 8-meter-long walk way in which the 4-meter-long GaitMatII walkway was inserted in the middle. The MSG was positioned approximately 2-3 meters away from the subject in the same laboratory such that the subject can hear the tone signals from the MSG clearly. Each subject was instructed to walk across the 8-meter-long walkway at self-selected comfortable speed in the single primary task condition 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. It took approximately 1 hours for each subject to complete the laboratory tests.

Data and Statistical Analyses. Walking speed in the walking tests and verbal responses (verbal reaction time (VRT) and verbal response accuracy (VRA)) in the VCRT tests were recorded and analyzed. Three-way (Group x Cane conditions (with v.s. without) x Task (single v.s. dual conditions)) repeated measures of analysis of variance (RM ANOVA) were used to analyze the data. An alpha level of .05 was selected as the criterion for statistical significance.

Results and General Discussions

Primary Results of Experiment 1

Cane effects on stepping performance and kinetics (for Purpose 1). While performing a volitional forward stepping task, patients with stroke demonstrated similar ground reaction force patterns, but of smaller magnitudes and with poorer smoothness, compared to age-matched healthy adults. This was especially true when these patients stepped with the affected lower extremity. When the patients stepped with the affected lower extremity and with the use of a regular cane held on the unaffected hand, their step length (SL) increased compared to the stepping without a cane condition. When the patients stepped with the unaffected lower extremity and with the use of a regular cane, the movement time (MT) duration, during which the affected lower extremity supported the majority of the body weight, and the center of pressure speed (COPsp) in the reaction time (RT) phase were significantly increased, the patterns of the vertical ground reaction forces became smoother, whereas the magnitude of the vertical ground reaction forces decreased, compared to the stepping with the unaffected lower extremity and without a cane condition (Figure 1). Therefore, it is evidence that the regular cane played a role of assisting the forward propulsion and weight support especially when these patients stepped with the unaffected lower extremity. Although the use of a cane indeed improved the movement performance and dynamic balance associated with the stepping task for these patients, the use of a cane inevitably reduced the need for them to generate active vertical ground reaction forces by the affected lower extremity of these patients.

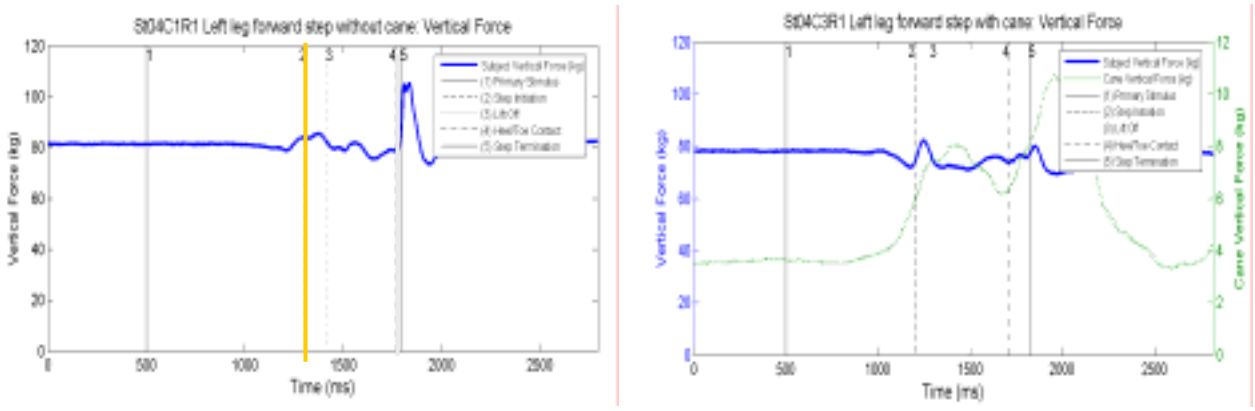

Figure 1. The vertical ground reaction forces under the feet (blue) and under the cane (green) in the stepping with the unaffected leg not using a cane (left figure) and using a cane (right figure) conditions for a patient with stroke.

Task effects on attentional demands associated with stepping (for Purpose 2). Patients with stroke showed a significantly greater increase in the verbal reaction time (VRT) from the single task (verbal choice reaction time (VCRT) task) condition to the dual task (stepping plus VCRT tasks) condition than the age-matched healthy adults ($p < .001$). Such increase was the

greatest when the patients were stepping with the affected lower extremity, indicating that patients with stroke required a much greater amount of attention while performing the stepping with the affected lower extremity task than age-matched healthy adults (Figure 2). The use of a regular cane did not significantly change the needed amount of attention associated with performing the stepping task for both groups of subjects.

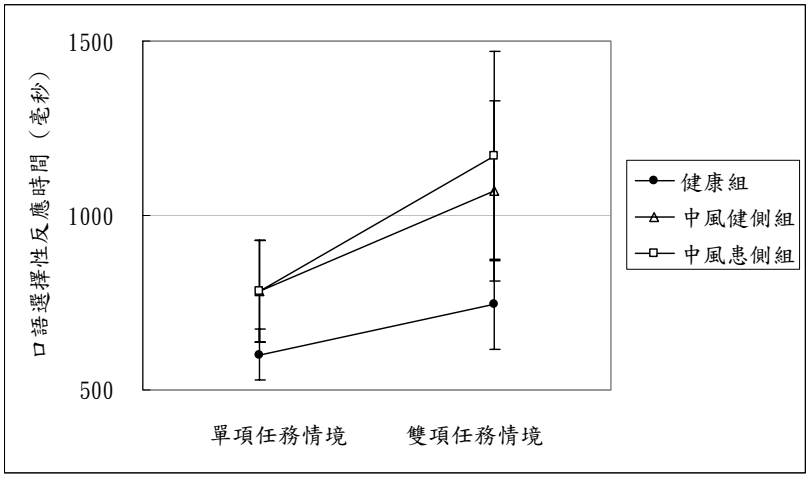

Figure 2. Changes in VCRT from the single task to the dual task conditions in healthy adults and patients with stroke.

Primary Results of Experiment 2

Cane effects on walking speed (for Purpose 3). The results showed a significant main effect for Cane ($p < .05$), but no Group x Cane or Task x Cane interaction effects, on comfortable walking speed. The pooled data for the 2 groups of subjects showed that the walking speed (.97 m/sec) was significantly faster in the cane-free condition than that in the cane-use (.91 m/sec) condition.

Task effects on attentional demands associated with walking (for Purpose 3). The results showed a significant Task x Cane interaction effect on the VCRT ($p < .05$). The post-hoc statistical analyses revealed that in the single task condition, the pooled mean VCRT for the 2 groups of subjects were not significantly different between the cane use (773.3 msec) and cane-free (788.6 msec) conditions. On the other hand, in the dual task condition, the pooled mean VCRT was significantly longer for the cane-use condition (969.1 msec) than for the cane-free condition (858.3 msec) (Figure 3). These findings suggest that walking with a regular cane increased the attentional demands for walking for both patients with stroke and healthy adults of similar age.

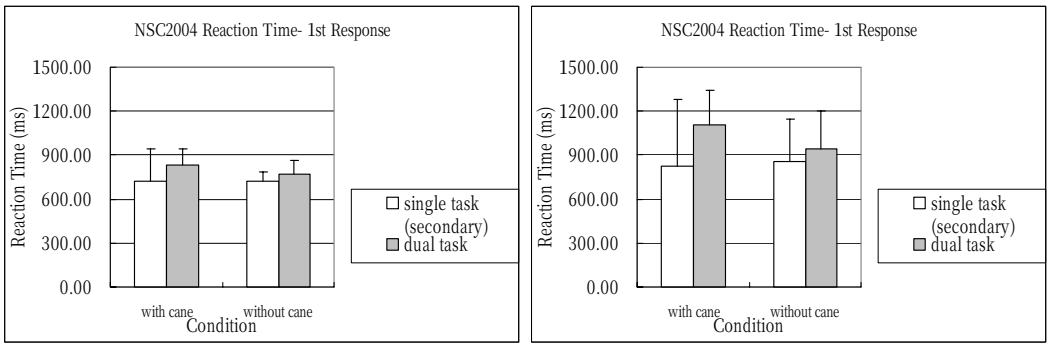

Figure 3. The VCRT of the healthy adults (left) and patients with stroke (right) in the single and dual task conditions and with cane and without cane sub-conditions.

General Discussions

Together, our results suggest that the benefits of using a regular cane to perform a voluntary forward stepping task or a walking task primarily include the effectiveness in improving the movement performance and dynamic stability. The negative influences of using a cane to perform these tasks are the reduced need to generate active forces with the affected lower extremity for patients with stroke and increased attention demands for walking for both patients with stroke and healthy controls. Therefore, the decision as to whether a regular cane ought be used as an assistive device for mobility and ambulation training for patients with stroke or not has to be based upon case-specific relative weighting between the positive and negative influences of cane use.

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Evaluation of the Outcomes of the Projects

1. The extent the contents of the research reported above matches with the original proposal: Approximately 70% of the contents presented above match with the original proposal. We were unable to carry out the second specific aim of the original prposal, examining cane effect on performance and attentional demands on reactive postural responses, due to technical difficulty with re-constructing a computer-driven pulling perturbation system.
2. The extent the goals are achieved: 70%.

Publications: Currently, two manuscripts associated with Experiment 1 are in preparation for publication. In addition, a masters student's thesis (呂麗華, 2004) is completed based on one of the aim and three conference presentations have been made based on our findings. In total, at least 3 manuscripts will be written up for publication within the next 12 months.