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社區腦中風病人之跌倒預防策略：

跌倒預測因子之研究

Fall Prevention Strategies in Community-Dwelling Stroke Patients: An Investigation of Fall Predictors

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國立臺灣大學博士學位論文
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社區腦中風病人之跌倒預防策略：
跌倒預測因子之研究
Fall Prevention Strategies in Community-Dwelling Stroke Patients: An Investigation of Fall Predictors

本論文係魏大森君（學號 D94548011）在國立臺灣大學醫學工程學研究所完成之博士學位論文，於民國 106 年 06 月 23 日承下列考試委員審查通過及口試及格，特此證明

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中文摘要

腦中風為老年人好發疾病之一，為國人十大死因之第四位。隨著我國人口快速老年化、醫療照護進步，死亡率明顯下降，腦中風病患逐年增加。腦中風患者發病後常見併發症有肢體痙攣、肢體控制不良、平衡與步態能力障礙、內翻馬蹄足、憂鬱等；這些因素都會導致患者於日常活動中發生跌倒意外，如行走或移位時(坐到站/站到坐），嚴重者可能造成骨折甚至死亡，衍生之家庭負擔與社會問題不容小覷。因此，如何於腦中風發病住院期間篩檢出跌倒高風險因子、提供安全的起身坐站訓練並完整的治療介入策略，實為目前臨床醫護人員迫切亟待解決的議題。

近年來，腦中風病患者的治療介入模式，已由傳統只單純改善個案的生理狀況，轉變成全人的照護模式，如何兼顧個案生理與心理與社會參與，將是擬定腦中風預防跌倒策略的重要面向，也是有效降低個案跌倒或跌倒發生機會之重要因素。

本論文以多面向與客觀化的評估，探討社區腦中風患者跌倒的預測因子，並分析腦中風個案坐到站、站到坐時，不同手與腳擺位姿勢之運動學及動力學表現，來做為日後臨床醫護人員訓練、治療和跌倒預防、介入之重要參考。

研究結果發現兩個預測腦中風出院後發生跌倒之多變項回歸模型，分別為模型一：步態不對稱性[調整勝算比, adjusted odds ratio, aOR = 2.2, 95% 信賴區間 (1.2–3.8)]、小腿腓腸肌痙攣程度[aOR = 3.2 (1.4–7.3)] 與憂鬱[aOR = 1.4 (1.2–

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1.8)]，模型準確度 (Area under curve, AUC)為 0.856；模型二: 功能獨立評估量表分數低 [aOR = 0.9 (0.9–1.0)]、步態不對稱性 [aOR = 3.6(1.4–9.2)]與內外側重心晃動程度[aOR = 1.7 (1.0–2.7)]，模型準確度為 0.815。

不同手與腳擺位姿勢之動力學結果發現，偏癱腳在後且手成交握狀時，腦中風患者由坐姿起身到站立之預備時間最短，過程中雙腳承重對稱性佳，因此證實臨床治療師訓練患者坐到站時，透過手與腳的姿勢變換，可改善雙腳承重對稱性外，亦可做為訓練偏癱側下肢承重的訓練方法。

而腦中風由站到坐時，腳的擺位顯著影響腳承重策略及坐下時的衝擊力，但手的姿勢並無影響。個案若因前腳（健側）無法代償後腳（偏癱腳）的控制時，將在站到坐過程中產生較大的衝擊力，故為了訓練目的，可將健側腳放置於前方來誘發偏癱腳的肌肉用力與控制能力。

結論:本論文藉由分析腦中風出院前收集之病患臨床資料與功能性評估結果，歸納出兩個跌倒預測模型，並透過坐到站與站到坐的動力學實驗，分析個案對不同姿勢下，肢體動作的調變機制，研究結果提供臨床人員擬訂腦中風個別化防跌介入與治療之重要參考依據。

關鍵字：腦中風、跌倒、步態不對稱性、憂鬱、痙攣、姿勢晃動、

功能獨立評估

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Abstract

Cerebrovascular disease is one of common chronic disease in the elderly and is the 4th leading cause of death in Taiwan. The numbers of stroke are gradually increasing annually due to rapid aging of population and excellent healthcare system which decreases the incidence of mortality. The common complications after stroke are limb spasticity, poor coordination, balance & gait impairment, equinus-varus foot, depression and etc. It often results in accidental falls during activity of daily living, such as sit to stand or stand to sit and may cause fractures or even death. It is of no doubt that family and society are also having great impact and challenges. Therefore, it is crucial to predict the risk factors of fall, provide sit-to-stand training and comprehensive interventions for stroke patients during hospitalization.

Recently, the mode of care and intervention is moving from improving the physical functioning toward building a holistic health care in stroke patients. A comprehensive fall prevention strategy, including physical, psychological and biosocial dimensions is essential to meet the unmet needs in clinical practice and reduces the incidence of accidental falls in the stroke patients.

In this dissertation, it will discover the predictors of fall by using objective assessments in the community-dwelling stroke patients. It also analyzes the strategies

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of leg load discrepancy on bilateral legs during sit to stand and stand to sit tasks according to different postural configuration of foot and hand.

The key findings of this dissertation are as followings:

(1) Two predictive models of fall in the community-dwelling stroke patients are found. Model one: asymmetrical gait pattern [adjusted odds ratio, aOR = 2.2, 95% CI (1.2–3.8)], spasticity of gastrocnemius [aOR = 3.2 (1.4–7.3)], and depression [aOR = 1.4 (1.2–1.8)]; the accuracy of model is 0.856; Model two: low score of functional independent measure [aOR = 0.9 (0.9–1.0)], asymmetrical gait pattern [aOR = 3.6 (1.4–9.2)] and postural sway in mediolateral direction [aOR = 1.7 (1.0–2.7)], the accuracy of model is 0.815.

(2) The paretic foot backward and hand clasped (FabHc) position leads to shorter movement durations before rising up and increased leg load symmetry during SitTS. Using the FabHc position for rising up and releasing clasped hands for more stability after standing is a useful strategy for stroke patients performing the SitTS task. Using this strategy, to train stroke patients according to the purpose of training, clinicians can provide more effective therapeutic interventions for specific underlying impairments.

(3) Altering arm placements does not significantly influence the leg load sharing strategy and sitting impact forces. The leg load sharing strategies are ruled by the

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preferred use of the non-paretic side and the favored leg position for the biomechanical load. The paretic leg is incapable of modulating the sitting-down process, placing the paretic leg posterior induces notably greater sitting impact forces compared with the counter leg placement. From the strength-training point of view, however, placing the paretic leg posterior would facilitate exertions of the paretic leg.

Conclusions: Patient falls are a major health concern in the care of patients with stroke. Two predictive model of fall risks are defined and the loading strategies during sit to stand and stand to sit are analyzed. The findings of this dissertation may provide an important information for making individualized fall prevention strategies in the stroke patients.

Keywords: stroke, fall, gait asymmetry, depression, spasticity, postural sway functional independence measure

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Chapter 1. Falls and Fall-related injuries in the Elderly and Stroke

1.1 Introduction

The most common fractures related to osteoporosis are distal radial fracture vertebral fracture, and hip fracture [1]. Hip fractures result in higher mortality and morbidity in the elderly. This devastating condition also causes economic and psychological stress to the patients' families and results in large amounts of insurance payments. The number of hip fractures is estimated to triple from the year 1999 to 2030 [2]; globally, the total figures could rise from 1.7 million in 1990 to around 6.3 million by 2050 [3]. Hip fracture will be the major public health issue of the elderly in the twenty-first century. The common risk factors of fall and fall related injuries were summarized in Table 1-1~1-5.

Cmmings and Nevitt [4] hypothesized that four important factors may determine whether a fall will cause a hip fracture: (1) fall orientation, (2) protective responses, (3) local shock absorbers and (4) bone strength at the hip. Studies have shown that hip fracture in the elderly is closely associated with low bone mineral density (BMD) of the proximal femur [5] and accidental falls are the predisposing factor [6], [7]. Greenspan et al. proved that a sideways fall was an independent risk factor for hip fracture either in the ambulatory community elderly [8] or in frail nursing home

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elderly [9]. Hayes et al.'s study showed that impact near the hip dominated fractures in elderly nursing home residents who fell[10]. Researchers have also reported that low body weight [11], [12] or reduced physical activity[13], [14] increases the risk of hip fractures.

For effective prevention, high-risk groups need to be identified see the Table 1-4. Though many researchers have investigated the risk factors of hip fracture, most of them determined the risk factors by bivariate analysis. Few researchers have approached the risk factors from different aspects, especially as regards the fall characteristics, functional mobility and BMD. We investigated these risk factors concurrently to determine in what circumstances an accidental fall may cause a hip fracture in the elderly and to provide an appropriate strategy for prevention. The results showed that there were 6 independent risk factors of hip fracture when the elderly fall, including (1) body mass index (kg/m2), OR=1.8 (1.1~2.8) ; (2) functional mobility, OR=2.0 (1.1~3.5) ; (3) previous stroke, OR=2.9 (1.3~6.3) ; (4) sideways falls, OR=2.5 (1.6~3.9) ; (5) direct hip impact, OR=4.9 (2.7~8.8) ; (6) femoral neck bone density (g/cm2), OR= 1.7 (1.0~2.8)。

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From the results of these studies, the prevention strategy for hip fracture in the elderly can be summarized into three categories: (1) increase or maintain BMD of the proximal femur; (2) modify the risk factors and characteristics of a fall; (3) decrease the local impact force on the hip after a fall. The preventive strategy for hip fracture should be focused on easier-to-modify factors. In addition to the maintenance of BMD, it may be crucial to keep a physically active lifestyle (to modify fall severity) and to maintain an appropriate body weight (to decrease local impact on the hip). Owing to the complex interaction of the independent risk factors, the practical effect of intervention to reduce hip fracture needs to be further investigated. Therefore, the next aim of fall prevention is to evaluate the predictors of fall in stroke patients who are in high volume and high risk for hip fracture.

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1.1.1 Risks of fall and fall related injury in the stroke patients

Table 1-1 Risk factors for the elderly falls by multivariate analysis.

Author	**Tsai, Y.J.**[15]	**Lin, M.R.**[16]	**Huang, S.C.**[17]	**Tinetti, M.E.**[18]	**Cesari, M.**[19]	**Rekeneire, N.**[20]
Title	The prevalence and risk factor assessment of the fall of the community	Risk factors for elderly falls in a rural community of central Taiwan	Cumulative incident rate and associated factors of falls among the elderly in Shih-Pai, Taiwan	Risk factors for falls among elderly persons living in the community	Prevalence and risk factors for falls in an older community-dwelling population	Correlates of falling in healthy older persons
Journal (Year)	Project Report, D.O.H (1997)	Taiwan J Public Health (2002)	Taiwan J Public Health (2005)	New Engl J Med (1988)	J Gerontol A Biol Sci Med Sci (2002)	J Am Geriatr Soc (2003)
Age	above 70 years old	above 65 years old	above 65 years old	at least 75 years old	65 years and older	aged 70 to 79
Sample size	n=1092	n=368	n=2045	n=336	n=5570	n=3075
Methods	cross-sectional	prospective	cross-sectional	prospective	observational	cross-sectional
Risk factor 1	Female 2.1 (1.3~3.4)	Previous fall history 1.8 (1.1~2.9)	Female 1.7 (1.2~2.2)	Sedative use 28.3	Wandered 2.4 (1.8~3.1)	White race 1.4 (1.2~1.6)
Risk factor 2	Self concern common health condition 2.0 (1.1~3.8)	Impaired number of instrumental activity of daily living 1.2 (1.1~1.4)	Gout 1.7 (1.2~2.4)	Cognitive impairment 5.0	Gait problems 2.1 (1.8~2.5)	Slower 6-meter walk speed 1.1(1.0~1.3)
Risk factor 3	Self concern poor health condition 2.5 (1.2~5.4)	Longer duration of timed UP & Go 2.0 (1.0~4.0)	Depression 1.5 (1.1~2.3)	Disability of the lower extremities 3.8	Depression 1.5(1.4~1.7)	Poor standing balance 1.2 (1.0~1.4)
Risk factor 4	Balance impairment 2.3 (1.3~3.8)		Othostatic hypotension 1.4 (1.0~1.9)	Palmomental reflex 3.0	Lived in an unsafe place 1.5 (1.3~1.7)	Inability to do 5 chair stands1.7(1.3~1.9)
Risk factor 5				Abnormalities of balance and gait 1.9		Urinary incontinence 1.5(1.1~2.0)
Risk factor 6				Foot problems 1.8		Mid-quintile of leg muscle strength 0.6(0.4~0.9)

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Table 1-2 Risk of fall-related injury by multivariate analysis in the elder.

Author	Grisso JA[6]	Herndon JG[21]	Colon-Emeric CS[22]	Wei T-S[23]	Liu W-L[24]
Title	Risk factors for falls as a cause of hip fracture in women.	Risk of fall injury events at home in older adults	Predict Fractures in Older Adults	Risk Factors of Hip Fracture in the Elderly	Serious Fall-Related Injury in an Eldery (III)
Year	1991	1997	2002	2001	1999
Age	Average 80	Above 65	Above 65	65-84	Above 65
Subjects	174	1185	7654	314	806
Journal	New Engl J Med	J Am Griatr Soc	Osteoporosis Int	Osteoporosis Int	Department of Health, Executive Yuan
Method	Case-control	Case-control	Cohort study	Case-control	1st year: cross sectioal 2nd year: prospective
Factor1 OR(95%CI)	lower-limb dysfunction 1.7(1.1~2.8)	**stroke** 1.7(1.0~3.0)	Female 1.9~2.3	direct hip impact 4.9 (2.7~8.8)	Age over 80 1.6 (0.9~2.8)
Factor2 OR(95%CI)	**previous stroke** 2.0(1.0~4.0)	anemia 1.5(1.0~2.2)	Low BMI 1.3	**previous stroke** 2.9 (1.3~6.3)	Previous fall 2.0 (1.3~3.2)
Factor3 OR(95%CI)	Parkinson 9.4(1.2~76.1)		Caucasian 2.1~2.8	sideways fall 2.5 (1.6~3.9)	Diabetes 2.0 (1.2~3.2)
Factor4 OR(95%CI)			Rosow–Breslau impairments 1.8~2.1	functional mobility 2.0 (1.1~3.5)	ADL 2.5 (1.3~4.6)
Factor5 OR(95%CI)			age over 75 years 2.1	BMI 1.8 (1.1~2.8)	Balance impairment 2.3 (1.0~5.4)
Factor6 OR(95%CI)			**history of stroke** 1.9	femoral neck BMD 1.7 (1.0~2.8)	Gait impairment 1.5 (1.0~2.3)

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Table 1-3 Risks of fall related injury in stroke patients.

Author	Melton LJ[25]	Sze KH[26]	Yates JS[27]	Lamb SE[28]	Tong P-F[29]	Ta-Sen Wei[30]
Title	Fracture risk following ischemic stroke	Falls among Chinese stroke patients during rehabilitation	Falls in community-dwelling stroke	Risk factors for falling in stroke women	Balance recovery and training on fall prevention in stroke	Gait asymmetry, ankle spasticity, and depression as independent predictors of falls in ambulatory stroke patients
Year	2001	2001	2002	2003	2003	2017
Age	28-96	≦65 vs. ≥65	Age ≥ 18	Over 65	35~83	65~80
Subjects	387	677	280	124	25	112
Journal	Osteoporosis Int	Arch phys med rehabil	J Rehabil Res Dev	Stroke	NHRI	PLOS One
Method	Retro-cohort	Cohort	Cohort	Prospective 1 y	Cohort	Prospective
Factor 1 OR(95%CI)	increased with age 1.6(1.4~2.0)	Barthal Index admission 2.6(1.3~5.5)	motor impairment 2.2(1.0~4.7)	balance problems while dressing 7.0	Use quadricane	the asymmetry ratio of single support 2.2(1.2±3.8)
Factor 2 OR(95%CI)	moderate functional impairment 1.6(1.0~2.5)	dysphasia 1.81(1.0~3.2)	motor + sensory impairments 3.1(1.5~6.8)	esidual balance, dizziness, or spinning 5.2		the level of spasticity in the gastrocnemius 3.2 (1.4±7.3)
Factor 3 OR(95%CI)	hospitalization at onset of stroke 2.0(1.3~3.2)					depression 1.4 (1.2±1.8)

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Table 1-4 Interventions for preventing falls in elder people living in the community.

	Rate ratio (RaR)* (95% CI)	Risk ratio (RR)* (95% CI)
Single Interventions		
Exercises		
Multiple-component group exercise	0.71 (0.63~0.82)	0.85 (0.76~ 0.96)
Tai Chi	0.72 (0.52~1.00)	0.71 (0.57~ 0.87)
Multiple-component home-based exercise	0.68 (0.58~0.80)	0.78 (0.64 ~ 0.94)
Balance training	0.72 (0.55~0.94)	0.81 (0.62~1.07)
Strength/ Resistance training		3.6 (1.5~8.0)
Medication		
Vitamin D	1.00 (0.90~1.11)	0.96 (0.89~1.03)
Withdrawal of psychotropic medication	0.34 (0.16~0.73)	0.61 (0.32~1.17)
Prescribing modification programme for primary care physicians		0.61 (0.41~0.91)
Surgery		
Pacemakers	0.73 (0.57~0.93)	0.78 (0.18~3.39)
First eye cataract surgery	0.66 (0.45~0.95)	0.95 (0.68~1.33)
Oral nutritional supplementation		0.95 (0.83~1.08)
Cognitive behavioural interventions	1.00 (0.37~2.72)	1.11 (0.80~1.54)
Environment/assistive technology		
Home safety assessment and modification	0.81 (0.68~0.97)	0.88 (0.80~0.96)
Anti-slip shoe device	0.42 (0.22~0.78)	
Multifactorial Interventions	0.76 (0.67~0.86)	0.93 (0.86~1.02)

*Rate ratio (RaR): to compare the rate of falls between intervention and control groups.
Risk ratio (RR): the number of people falling (fallers) in each group to assess the risk of falling.

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Chapter 2. Gait Asymmetry, Ankle Spasticity, and Depression as Independent Predictors of Falls in Community-Dwelling Ambulatory Stroke Patients

2.1 Introduction

A fall is the common injury in stroke patients. Fall occurrence in stroke survivors is 25–37% within 6 months and 23–50% 6 months post-stroke [1–6]. Accidental falls and fall-related injuries, such as hip fracture, often lead to serious disability and affect the patient's overall health. Many studies have attempted to identify fall risk factors as predictors and established a sensitive prediction model for stroke patients. Therefore, early interventions for preventing falls may be beneficial to stroke patients.

The causes of fall are complicated, and several factors may result in falls, including impaired balance and gait, declining cognition, muscle weakness, and presence of neurological diseases. Previous studies have demonstrated that balance, walking ability, and physical performance assessments are useful predictors of fall occurrence in stroke patients post-discharge from rehabilitation units [7–9]. These studies have demonstrated that physical performance assessments, including asymmetrical gait pattern, Berg Balance Score (score ≦ 29 at admission), Fall Efficacy Scale (score ≥ 33), and spasticity, predicted the risk of fall in stroke patients to a certain accuracy

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[10–13].

These findings also suggest that existing predictors of falls exhibit some limitations, especially gait and balance assessments. For example, clinical measures typically assign numerical values to determine the level of performance on tests (e.g., Berg Balance Scale, Performance-Oriented Mobility Assessment, and Dynamic Gait Index). These measurements depend on expert ratings and subjective judgments, and the tests are mostly skill orientated without direct connection to the physiological mechanisms of temporal and spatial characteristics. Therefore, quantified assessments have been developed, and these measurements are more objective than the measurements mentioned above.

A previous study associated impaired balance and gait to increased risk of falls in stroke survivors using quantified measurements [14]. However, the models used for this study did not provide high sensitivity or specificity. Another study also demonstrated that gait and postural variability predicted accidental falls in nursing home residents [10]. The Interactive Balance System correlated with physiological mechanisms of fall, but the predictive ability in this study was limited [10]. Psychological factors may also play an important role in fall occurrence in stroke

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patients. This concept was supported by results that impaired balance and gait negatively affected psychological distress in stroke survivors [15]. Another study also demonstrated that 30% of stroke patients suffered depression in the early- or late-stage post-stroke [16]. Depression was also a risk related to falls in stroke patients in a previous study [17].

No comprehensive analyses integrate the identified fall risk factors. Quantified gait and balance measurements are more objective and should be used for clinical evaluations. Psychological factors may also be important risk factors for predicting falls in stroke patients. However, studies of fall prediction using objective, quantified gait and balance assessments and psychological evaluations after stroke are limited. Therefore, a prediction model for falls in stroke patients should be developed using a multidimensional assessment to increase prediction accuracy. The present study used physical assessments, including objective computerized gait and balance measurements, and psychological evaluation to identify risk factors related to falls in stroke patients after discharge from hospital and develop a fall prediction model with high sensitivity and specificity.

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2.2 Materials and Methods

The Institutional Review Board of a tertiary medical center, Changhua Christian Hospital, approved this prospective cohort study, which was performed in a rehabilitation ward and patients' homes.

2.2.1 Participants

A total of 140 hospitalized patients who suffered their first stroke were enrolled according to the following criteria: (1) stroke confirmed on MRI or CT; (2) ability to walk independently (with/without assistive device) at least 10 meters; (3) no fall history within 1 year before stroke onset; and (4) written informed consent. Only patients who met the above entry criteria were included to specifically identify the fall risk factors related to stroke.

A ten-meter walk test was included because it is a valid, reliable assessment for predicting falls in subjects with stroke [12,18]. This test collected dynamic gait parameters as predictors of fall. Therefore, subjects who walked with a person's assistance had an external supportive force that may interfere with the assessment of gait, and these patients were not included in the present study. No fall history within 1 year before study entry was selected because subjects who experienced falls may

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exhibit subsequent factors while walking independently, including fear of a fall, decreased mobility, and changes in gait pattern. Subjects with a history of falling previously may also have their movements closely monitored by their family members or caregivers [12]. These conditions may confound the relationship between variables and fall risk assessment.

Subjects dropped out during the follow-up for the following reasons: nursing home residency (11 subjects), unstable internal disease (8 subjects), unable to complete the interview due to dementia or severe cognitive impairment (4 subjects), loss of contact due to residence address changes (3 subjects), and epilepsy (2 subjects). Therefore, 112 subjects completed the study, and these subjects were further divided into two groups, faller or non-faller, depending on whether a fall occurred during the study period.

2.2.2 Baseline Measurements

Initial assessments were performed at baseline including demographic data and a standardized recording of history and clinical examinations. Baseline physiological and psychological assessments were performed before subjects were discharged from the hospital (approximately 1 month after stroke). These baseline measurements of

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physical and psychological parameters were used as fall risk factors to develop the fall risk prediction model.

Physical assessments included the Modified Ashworth Scale (MAS), which was used to assess muscle tone in the elbow flexor, knee extensor, and ankle plantar flexor [19]. The level of a patient's disability was assessed according to the Functional Independence Measure (FIM) [20]. Performance of activities in daily life was assessed during hospitalization according to eighteen items, including bathing, dressing, toileting, transferring, urinary continence, cognitive comprehension and social interaction. This assessment is widely used to measure and predict outcome [21].

The objective measurements of gait were completed using computerized systems with wearable inertial sensors. Subjects wore customized shoes (Ultraflex, Infotronic, the Netherlands) with eight load sensors (Figure 2-1 & Figure 2-2) in each shoe to measure the forces under the foot and detect temporal events in the gait cycle prior to the gait measurements. Data were sampled at the rate of 100 Hz and stored in a portable (Walkman size), lightweight data logger that was carried on the lower back of each subject. Several practice tests were performed before actual data were

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collected. Subjects walked at a self-selected speed over a 10-m hallway. The mean values of the two tests were used. Gait parameters were normalized to the subject's body height to account for possible effects of anthropometrics [22,23]. The temporal asymmetry ratios (ASY) for single support time (ASY_ss), double support time (ASY_ds), single swing time (ASY_swing), stance time (ASY_stance), and step time (ASY_step) were quantified using the following equation [24]:

$$Asymmetry\ ratio = \left|1 - \frac{affected\ side}{unaffected\ side}\right|$$

A greater value of this ratio indicates higher asymmetry between the two sides. The objective computerized measurements of balance were completed while the subjects stood on a Stabilo-platform (Ultralfex, Infotronic, the Netherlands) in a comfortable position without footwear or ankle foot orthoses. Subjects kept their eyes open and arms at their sides and were instructed to maintain their balance for 20 seconds [25,26]. Three tests were performed with a 30-second rest between tests. The mean value of three tests is presented. Subjects' performances were recorded as the center of pressure (COP) trajectory paths. Data were sampled at the rate of 100 Hz, and COP stability was calculated as the standard deviation of the anterioposterior (COP_ap) and mediolateral (COP_ml) directions of the points obtained during measurement. The sway area (COP_area) was calculated as the square root of the sum of squares of the COP_ap and COP_ml.

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Figure 2-1 Ultraflex Computerized Dynography data logger, Infotronic, Netherland.

Figure 2-2 Shoes with force sensors to measure ground reaction force.

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Psychological evaluations included the Mini-Mental State Examination (MMSE) [27] and Chinese translated version of the Geriatric Depression Scale (GDS) [28], which were used to screen for cognition and depression, respectively. The modified Falls Efficacy Scale (mFES) was used to evaluate the fear of falling in stroke patients [29].

2.2.3 Assessment of Falls

Falls were defined as incidents when the subject came to rest on the floor due to an unexpected loss of balance. All subjects were followed up for 6 months after the first assessment to collect the record of falls. Trained research nurses visited the subjects at home 4, 12 , and 24 weeks after discharge from the hospital or rehabilitation ward. Phone reports from subjects were also encouraged in this study to prevent errors from retrospective data collection.

2.2.4 Statistics

Descriptive analysis was used for all variables, and results are presented as the means, standard deviations and percentages. Significant differences between fallers and non-fallers were assessed using independent Student's t-test for continuous variables and $\chi 2$ test analysis for categorical variables. The Mann-Whitney U test was

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used to detect mean differences between groups when variable distributions were not normal. Linear correlations between continuous variables were calculated using Pearson's correlation test. Multivariate logistic regression (MLR) analysis was performed using a forward stepwise method with an entry criteria of P =0.1 to identify the factors that were independently associated with falls. Two models were developed based on variables with statistical significance from bivariate analysis and clinical interests. Adjusted Odds Ratios (aOR) were acquired from the estimated coefficients and presented with the corresponding 95% confidence interval (CI) of the ratio.

The predictive accuracy of the model in discriminating fallers and non-fallers was assessed using sensitivity and specificity. The optimal cutoff point with the highest sensitivity and specificity for each model was defined as the Youden index [30,31]. A receiver operating characteristics (ROC) curve was plotted to assess the discrimination of the generated multivariate logistic models. The area under the curve (AUC) of the ROC was also calculated for each model to determine the fitness of individual MLR analysis. An AUC value below 0.5 was considered no discrimination, $0.7 \leqq AUC \leqq 0.8$ was considered acceptable discrimination, $0.8 \leqq AUC \leqq 0.9$ was considered excellent discrimination, and $0.9 \leqq AUC \leqq 1.0$ was considered outstanding discrimination [32]. Commercial statistical software, SPSS version 13.0, was used,

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and a two-tailed P <.05 was considered significant.

2.3 Results

A total of 140 subjects were enrolled, and 112 subjects (60 men and 52 women) completed the study. The mean age, height, and body weight of the subjects were 69.6 ±10.3 years old (range, 45-89 years old), 158.1 ± 6.7 cm (range, 143–175 cm), and 61.2 ± 9.9 kg (range, 41–85 kg), respectively. Approximately half (50.8%) of all the subjects were right hemiplegic patients, and 88.4% of the subjects suffered stroke due to infarction.

Subjects were further divided into non-faller and faller groups depending on whether the subject experienced falls during the follow-up period. A total of 37 patients who experienced falls were classified into the faller group, and 75 subjects were classified into the non-faller group.

No significant differences were found in baseline measurements of age, gender, height, body weight, stroke affected side, stroke type, mental status, ambulation aids, or medications between faller and non-faller groups. However, physical and psychological assessments revealed that the faller group exhibited higher MAS and GDS and lower FIM and mFES scores compared to the non-faller group (Table 2-1). These physical and psychological assessments indicated that the faller group exhibited

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higher muscle tone, more severe depression, poor overall activity performance of daily life and lower confidence.

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Table 2-1 Baseline measurements of the study subjects.

Groups / Variables	All subjects (n = 112)	Non-faller (n = 75)	Faller (n = 37)	P value
Age	69.6 ± 10.3	69.9 ± 10.0	68.9 ± 10.8	0.629
Female (%)	52(46.4)	35(46.7)	17(46.0)	0.943
Height (cm)	158.1 ± 6.7	158.7 ± 6.7	157.1 ± 6.7	0.269
Weight (kg)	61.2 ± 9.9	61.5 ± 9.5	60.5 ± 10.7	0.635
Affected Side - right (%)	57(50.8)	38(50.7)	19(51.3)	0.946
Type - Infarction (%)	99(88.4)	67(89.3)	32(86.5)	0.853
MAS				
Elbow Flexor	0.7 ± 1.1	0.3 ± 0.8	1.4 ± 1.3	< 0.001
Quadriceps	0.6 ± 0.9	0.3 ± 0.7	1.1 ± 1.1	< 0.001
Gastrocnemius	0.6 ± 1.1	0.3 ± 0.7	1.3 ± 1.3	< 0.001
Soleus	0.6 ± 0.9	0.3 ± 0.7	1.1 ± 1.1	< 0.001
MMSE	21.8 ± 5.1	22.4 ± 4.8	20.5 ± 5.5	0.078
FIM				
Motor	79.6 ± 12.9	84.2 ± 10.0	71.1 ± 13.6	< 0.001
Cognition	29.9 ± 4.3	31.0 ± 3.8	28.0 ± 4.6	0.001
Total	109.5 ± 15.4	115.1 ± 12.3	99.1 ± 15.4	< 0.001
mFES	96.7 ± 33.8	108.5 ± 29.0	74.9 ± 31.3	< 0.001
GDS	4.5 ± 3.9	3.2 ± 3.3	7.1 ± 3.7	< 0.001
Ambulation Aids				
Independent walk (%)	35(31.3)	22(31.4)	13(31.0)	
Quadricane (%)	67(58.2)	42(60.0)	25(59.5)	0.947
Walker (%)	10(8.9)	6(8.6)	4(9.5)	
Medications				
Laxative (%)	66(0.59)	40(53.3)	26(70.3)	0.087
Benzodiazepines (%)	39(0.35)	23(30.7)	16(43.2)	0.189
Hypoglycemic (%)	12(0.11)	8(10.7)	4(10.8)	0.981
Antihypertensives (%)	45(0.40)	26(34.7)	19(51.4)	0.090

Values are % or mean ± SD.

MAS, Modified Ashworth Scale; MMSE, Mini-Mental State Exam; FIM, Functional Independence Measure; mFES, modified Fall Efficacy Scale; GDS, Geriatric Depression Scale

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We used an unbiased quantification using a computerized system to measure the balance and gait abilities in patients post-stroke to provide objective analyses. These computerized measurements were considered to be more objective tools than the traditional assessments [33].

The abilities of balance and gait were different between faller and non-faller groups. Computerized gait assessment revealed that the faller group exhibited slower walking velocity and fewer cadences compared to the non-faller group ($P < .001$) (Table 2-2). The temporal asymmetry ratios for ASY_ss, ASY_ds, and ASY_step were significantly greater (approximately twofold) in the faller group ($P < .05$). These results indicated that the faller group exhibited more severe asymmetry gait than the non-faller group.

The faller group exhibited larger COP_area and greater COP_ml in computerized balance assessments ($P < .01$). These results demonstrated that the faller group exhibited worse postural sway in the mediolateral direction and area compared to the non-faller group. Therefore, the computerized gait and balance assessments may be used to accurately predict fall in the faller group.

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Table 2-2 Comparison of balance and gait parameters in study subjects.

Variables \ Groups	All subjects (n = 112)	Non-faller (n = 75)	Faller (n = 37)	P value
Velocity (m/s)	0.48 ± 0.45	0.57 ± 0.51	0.28 ± 0.16	0.002
Cadence (steps/min)	87.75 ± 22.87	93.55 ± 19.26	76.00 ± 25.27	< 0.001
Asymmetry Ratio				
ASY_ss	0.23 ± 0.30	0.15 ± 0.15	0.39 ± 0.43	< 0.001
ASY_ds	0.26 ± 0.34	0.20 ± 0.21	0.38 ± 0.50	0.007
ASY_swing	0.32 ± 0.59	0.25 ± 0.64	0.45 ± 0.46	0.089
ASY_stance	0.07 ± 0.07	0.07 ± 0.07	0.08 ± 0.07	0.284
ASY_step	0.18 ± 0.31	0.11 ± 0.14	0.33 ± 0.47	< 0.001
Trajectory of COP				
COP_ml (mm)	3.43 ± 1.62	3.07 ± 1.59	4.11 ± 1.47	0.001
COP_ap (mm)	3.29 ± 1.41	3.17 ± 1.38	3.51 ± 1.45	0.229
COP_area (mm^2)	37.62 ± 32.51	32.99 ± 30.94	46.51 ± 34.01	0.040

ASY_ss, asymmetry ratio of single support time; ASY_ds, asymmetry ratio of double support time; ASY_swing, asymmetry ratio of single swing time; ASY_stance, asymmetry ratio of stance time; ASY_step, asymmetry ratio of step time; COP, center of pressure; ml: medial-lateral; ap: anterior-posterior.

Correlation analysis was also performed based on the results in Table 2-2 to determine the risk factors for predicting fall occurrence. Correlations between gait and balance variables were evaluated (Table 2-3). All parameters of the temporal asymmetry ratios negatively correlated with walking velocity and cadence. The COP_ml and COP_area exhibited a low-to-medium positive correlation with all parameters of the temporal asymmetry ratios. Therefore, the computer automatically selected ASY_ss and COP_ml to represent the gait and balance assessments, respectively, for further analysis.

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Table 2-3 Correlation coefficients of balance and gait parameters (n = 112).

Variables	Cadence	Velocity	Trajectory of COP		
			ml	ap	area
Cadence (steps/min)	1.00	0.31†	−0.34‡	−0.16	−0.32‡
Velocity (m/s)	0.31†	1.00	−0.10	−0.02	−0.08
Asymmetry Ratio					
ASY_ss	−0.62‡	−0.26†	0.40‡	0.09	0.28†
ASY_ds	−0.50‡	−0.20*	0.23*	0.12	0.23*
ASY_swing	−0.54‡	−0.30†	0.49‡	0.20*	0.48‡
ASY_stance	−0.50‡	−0.23*	0.34‡	0.12	0.34‡
ASY_step	−0.61‡	−0.23*	0.32‡	0.14	0.29†
Trajectory of COP					
COP_ml (mm)	−0.34‡	−0.10	1.00	0.34‡	0.82‡
COP_ap (mm)	−0.16	−0.02	0.34‡	1.00	0.70‡
COP_area (mm^2)	−0.32‡	−0.08	0.82‡	0.70‡	1.00

ASY_ss, asymmetry ratio of single support time; ASY_ds, asymmetry ratio of double support time; ASY_swing, asymmetry ratio of single swing time; ASY_stance, asymmetry ratio of stance time; ASY_step, asymmetry ratio of step time; COP, center of pressure; ml: Medial-Lateral; ap: Anterior-Posterior

*$P < .05$; † $P < .01$; ‡ $P < .001$

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Correlations between computerized gait and balance assessments and other physical or psychological assessments were further analyzed. The MAS of the gastrocnemius exhibited a low-to-medium positive correlation with COP_ml, ASY_ss, and GDS (Table 2-4). FIM also exhibited a medium negative correlation with MAS. This correlation analysis demonstrated that FIM negatively correlated with most of the physical and psychological assessments. The strength of the correlation was low-to-moderate between variables (Table 2-3and Table 2-4), but most correlations revealed significant differences. These results were used as variables for the subsequent MLR analysis.

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Table 2-4**.** Correlation between predictors of risk of falls in stroke subjects (n = 112).

Variables	GDS	FIM	ASY_ss	COP_ml	MAS_gas
GDS	1.00	−0.48‡	0.17	0.42‡	0.39‡
FIM	−0.48‡	1.00	−0.46‡	−0.33‡	−0.34‡
ASY_ss	0.17	−0.46‡	1.00	0.39‡	0.20*
COP_ml	0.42‡	−0.33‡	0.39‡	1.00	0.26‡
MAS_gas	0.39‡	−0.34‡	0.20*	0.26‡	1.00

GDS, Geriatric Depression Score; FIM, Functional Independence Measure; ASY_ss, asymmetry ratio of single support; COP_ml, center of pressure in mediolateral direction; MAS_gas, Modified Ashworth Score of the gastrocnemius

* $P < .05$; ‡ $P < .001$.

The variables in Table 2-3 and Table 2-4 were used for MLR analyses to determine the risk factors for predicting fall in stroke patients. Two models were subsequently generated. Table 5 shows that the significant predictors of fall occurrence (with P<0.05) in stroke patients were as follows in model I of the MLR analysis: (1) GDS (adjusted OR, 1.4; 95% CI, 1.2–1.8; P = .001); (2) gait asymmetry (ASY_ss) [aOR, 2.2; 95% CI, 1.2–3.8; P =.006]; and (3) spasticity of the gastrocnemius (aOR, 3.2; 95% CI, 1.4–7.3; P =.006). The sensitivity and specificity of this model were 82.6% and 86.5%, respectively, with a Youden index of 0.69. The model I analysis suggested that GDS, Gait Asymmetry (Single Support), and Spasticity (Gastrocnemius) were strong

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predictors for fall in stroke patients.

Notably, the commonly used measurement for regular functional assessment during stays in the rehabilitation unit, FIM,[34] was not automatically selected as one of the predictors after the MLR analysis in model I. This result may be attributed to the results that GDS exhibited the strongest negative correlation with FIM (-0.48) in the correlation analysis between risk factors in stroke subjects (Table 2-4). Therefore, GDS was excluded in another round of MLR analysis, and prediction model II was generated. Table 2-5 shows that the predictors of determining fall occurrence in model II included (1) FIM (aOR, 0.9; 95% CI, 0.9-1.0; P = .002), (2) gait asymmetry (ASY_ss) (aOR, 3.6; 95% CI, 1.4-9.2; P =.009), and (3) postural sway (mediolateral, COP_ml) (aOR, 1.7; 95% CI, 1.0-2.7; P = .033). Model II also exhibited relatively high sensitivity (76.9%) and specificity (75.7%) with a Youden index of 0.53, but the sensitivity and specificity were lower than model I.

The ROC curves of the two models (Figure 2-3) for predicting falls in stroke patients were plotted to discriminate the two multivariate logistic models presented in Table 2-5. The ROC analysis revealed that model I (AUC value: 0.856) was better fitted than model II (AUC value 0.815). However, both models exhibited excellent fitness to

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predict fall occurrence in stroke patients with high sensitivity and specificity, with AUC values greater than 0.8[32].

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Table 2-5. Multivariate logistic regression for predictors of accidental falls.

Model	Factor	Coefficient **(ß)**	Adjusted odds ratio (95% CI)	P value
I	Geriatric Depression Scale	0.361	1.4 (1.2-1.8)[a]	0.001
	Gait Asymmetry (Single Support)	0.783	2.2 (1.2-3.8)[b]	0.006
	Spasticity (Gastrocnemius)	1.164	3.2 (1.4-7.3)[a]	0.006
Youden Index = 0.69; Sensitivity = 82.6%, Specificity = 86.5%				
II	Functional Independence Measure	−0.090	0.9 (0.9–1.0)[a]	0.002
	Gait Asymmetry (Single Support)	1.267	3.6 (1.4–9.2)[b]	0.009
	Postural Sway (Mediolateral)	0.518	1.7 (1.0–2.7)[a]	0.033
Youden Index = 0.53; Sensitivity = 76.9%, Specificity = 75.7%				

a: predicted change in odds for a unit increase in corresponding variables

b: predicted change in odds for a standard deviation (SD = 0.3) in corresponding variable

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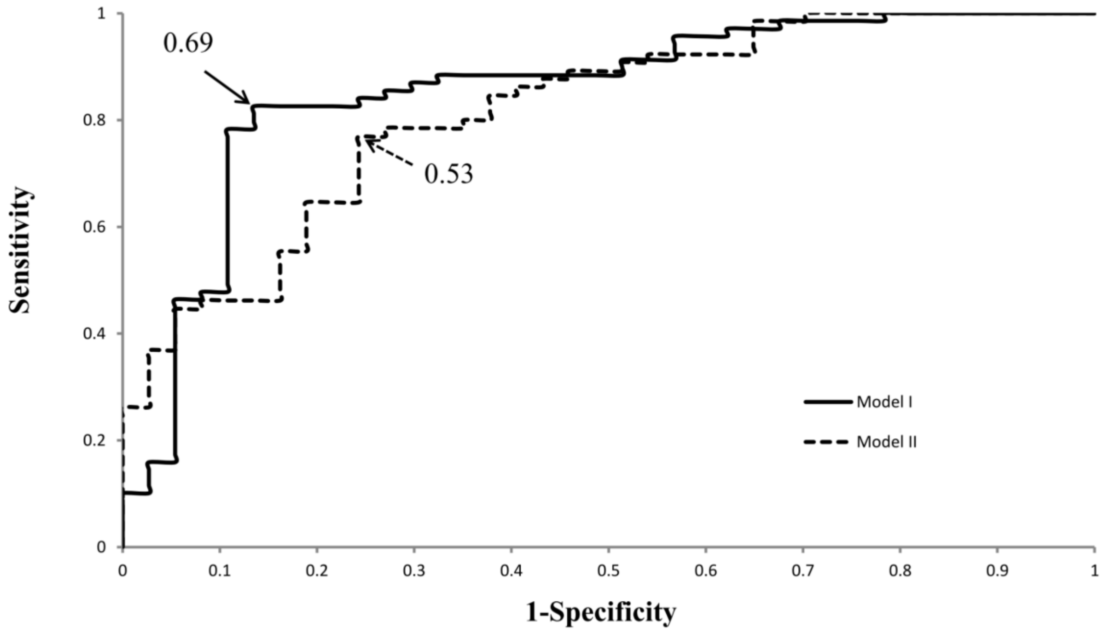

Figure 2-3 The ROC curves for predicting the occurrence of falls in stroke patients using models I and II. AUCs were 0.856 and 0.815, respectively. Arrowheads indicate the identified optimal cutoffs (Youden Index) for these prediction models (0.69 in model I and 0.53 in model II).

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2.4 Discussion

To our knowledge, this study is the first to include physical and psychological variables for determining the predictive risk factors of fall in stroke patients. The results underscore the significance of quantitative gait and balance assessments before discharge from rehabilitation units for predicting fall in stroke subjects by comparing the functional and baseline variables between the faller and non-faller groups of stroke subjects.

The faller group exhibited slower walking speed, asymmetrical gait, unstable balance, and lower functional performance than the non-faller group at baseline. Thirty-seven of the 112 enrolled subjects had at least one falling accident within 6 months after a stroke in this study (33% fall incidence).

Impaired gait symmetry, depression, and higher abnormal muscle tone were found in stroke patients who experienced falls. Prediction models for falls in stroke patients were developed using these physical and psychological parameters. The current findings provide sufficient information for predicting future falls, and early intervention strategies may be implemented to prevent falls in stroke patients.

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2.4.1 Assessment of Falls

Previous studies reported that the "gold standard" for collecting information on falls (e.g., prospective collection with calendars or postcards, regular reminders, and follow-up telephone calls) was prone to errors (e.g., memory, forgetting to write diaries and ambiguous definitions of fall)[14]. To minimize these types of errors in this study, falls were recorded regularly by nurses during home visits 4, 12, and 24 weeks post-discharge and by subjects' self-report. Recordings of fall history, environmental risk exam, and medical consultations were performed during the interviews with each subject. One advantage of the interview was to provide better interaction between subjects and research team workers. Therefore, subjects could fully understand the risk of falls and the ultimate goal of this study to prevent fall occurrence.

2.4.2 Balance and Gait Performance

Poor postural balance was linked to increased fall risk in previous studies[11,35,36]. Mediolateral COP displacement during normal standing may be used as an indicator of accidental falls in the elderly because it was significantly associated with future falls [37]. The results of this study also demonstrated that postural sway in the mediolateral direction and area were greater in fallers compared to non-fallers.

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A hemiparetic gait is described as slow and asymmetrical [38, 39]. Walking velocity and cadence were lower in the faller group than the non-faller group in the present study. Gait speed is generally selected as the outcome measurement in clinical practice and a predictor of fall after a patient has a stroke, but gait speed is often confounded with balance, motor function, and endurance [40]. The current study adopted a quantitative gait analysis to help assess the risk of fall and further describe gait performance adequately.

A previous study reported that temporal gait symmetry measurement appeared to better reflect components related to weight shift, and it was superior to spatial symmetry ratios for identifying the risk of falls in impaired ambulators [38]. An "asymmetry ratio" was used to represent the level of temporal asymmetry (ASY_ss, ASY_ds, and ASY_step) in the present study, which was significantly different between fallers and non-fallers. An increase of one standard deviation in ASY_ss was associated with a 2.2 and 3.6 times higher fall risk in models I and II, respectively.

2.4.3 Spasticity Related to Falls

An asymmetrical gait pattern caused by impaired balance and abnormal muscle tone is commonly seen in stroke patients. The present results demonstrated that the severity of spasticity in the upper and lower extremities was markedly higher in the faller group

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compared to the non-faller group. These findings are consistent with another study that also reported spasticity as a risk factor for predicting falls in chronic stroke patients. Motor control and functional status of stroke patients declined with increasing spasticity [13]. Logistic regression model I in this study also demonstrated that spasticity of the gastrocnemius was a predictor of fall in stroke patients. Another study found that the degree of spasticity of the affected ankle plantar flexors primarily influenced gait asymmetryp[24]. A spastic gait in stroke patients diminished power generation, decreased hip and knee flexion during the swing phase, and reduced stability during the stance phase due to the affected hip flexors, knee extensors, and ankle plantar flexors[41]. The present study revealed that the risk of fall increased 3.2 times when the severity of spasticity in the gastrocnemius increased by one grade. The results also support that the combination of gait asymmetry and abnormal muscle tone may increase falls in the stroke population.

Previous studies reported that spasticity reached a peak within 1–3 months after a stroke [41-45]. Thirty-nine percent of patients who suffered a first stroke exhibited sustained spasticity after 12 months [19]. Therefore, the early detection of spasticity and improvement in motor dysfunction using specific interventions, such as stretching, splinting, electrical stimulation, and botulinum toxin injection, may be crucial to reduce

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accidental falls[46].

2.4.4 Effects of Functional Performance

The Functional Independence Measure (FIM) is widely used to evaluate the performance of a patient's daily activity to determine the level of a patient's disability. All functional performance assessment results were significantly higher in non-fallers than fallers in our study. The fall risk decreased by 10% when the FIM score increased by one point. Previous studies also reported the significant correlation between FIM and fall occurrence [47-49]. A previous 10-year retrospective study also demonstrated the same correlation between the FIM score and fall risk [50], which is consistent with present results. However, the FIM score as a single variable may not be sufficient to accurately predict fall risk because falls generally resulted from multiple factors. The finding is also consistent with our MLR model, which enhanced the sensitivity and specificity of fall prediction.

2.4.5 Effects of Depression in Stroke Patients

Depressive symptoms are common in the acute phase after stroke, and symptoms are associated with the persistence of depression and mortality after 12 months [51]. The

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current MLR model in this study demonstrated that the risk of fall increased 1.4 times with a one-unit increase in GDS. Moreover, fall risk may cumulatively increase due to a high cognitive load if the patient also had multiple motor impairments and depression combined with gait asymmetry and spasticity.

2.4.6 Fall Prediction Model

A bivariate correlation between risk predictors of accident fall in stroke subjects was performed to determine which variables to include in the MLR analysis. The results of bivariate correlation test revealed that the FIM and GDS exhibited the highest strength of negative correlation (Table 2-4). Therefore, two logistic regression models, including FIM or GDS, were developed in this study to determine the best fit of fall predictive factors. Notably, model I, which included GDS, gait asymmetry, and spasticity, exhibited slightly higher specificity, sensitivity, and Youden index than model II. Gait asymmetry, spasticity, and depression represented the functional, physical, and psychological domains of the subject's impairments in function, respectively. Therefore, these results suggest that model I provides more comprehensive fall prediction than model II. ROC analysis further verified the discrimination of fitness of model I with a slightly greater AUC value (0.856) than model II (AUC value 0.815).

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A previous study model with six predictors, including the Berg Balance score and functional performance, exhibited high predictive values (AUC = 0.712) in community stroke patients [52]. Both models in the present study used three predictors and demonstrated AUC values greater than 0.8. Several differences were observed between the two studies, including the race of enrolled subjects, time of assessment of falls post-stroke, and the selection of variables for MLR analysis. The present study included computerized gait asymmetry as a predictor in model II in addition to balance and functional predictors. The predictive values of model II reached AUC = 0.815 despite the inclusion of only three predictors. Computerized gait assessment was included in both models, and the computerized system may provide a more objective and accurate evaluation. Overall, these findings suggest that gait asymmetry is an important factor for the prediction of falls.

An earlier study also found that sideways fall was an independent risk factor (aOR, 2.5; 95% CI, 1. 6-3.9) for hip fractures in the elderly, in which 20% of their population had a history of stroke. Therefore, preventing sideways fall may decrease the occurrence of hip fractures in the elderly [53]. Both prediction models in this study included gait asymmetry as one predictor of a fall. Model II included gait asymmetry and balance factors. Therefore, the fall prediction models, including computerized gait and balance assessments, may be

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used in stroke patients and the elderly for preventing possible falls.

2.4.7 Study Limitations

Several limitations may result from the present study design. First, the present study results cannot be extrapolated to all people with stroke, particularly patients at lower functional levels with walking disability or severe cognitive impairments. Second, the subjects were not separated into a construction data set and a validation data set to test the multivariate logistic regression function because of the small number of subjects enrolled.

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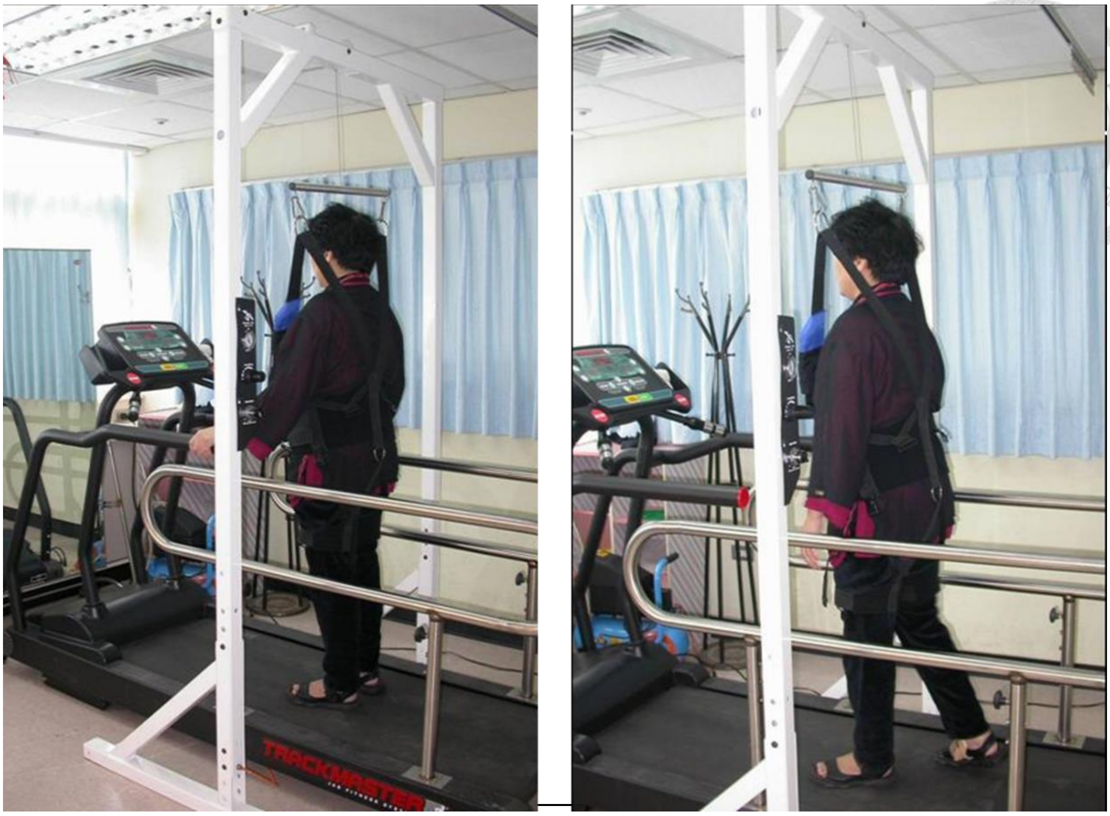

Figure 2-4 Balance and gait training for a stroke patient.

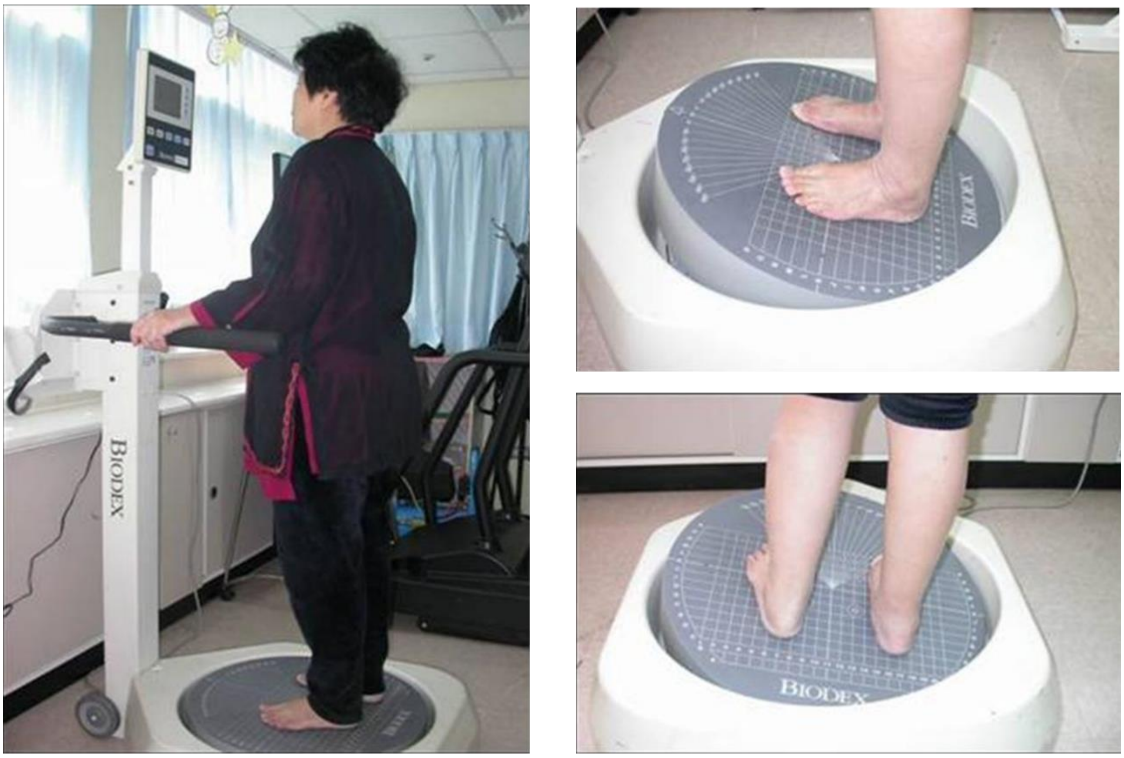

Figure 2-5 Dynamic balance testing and training.

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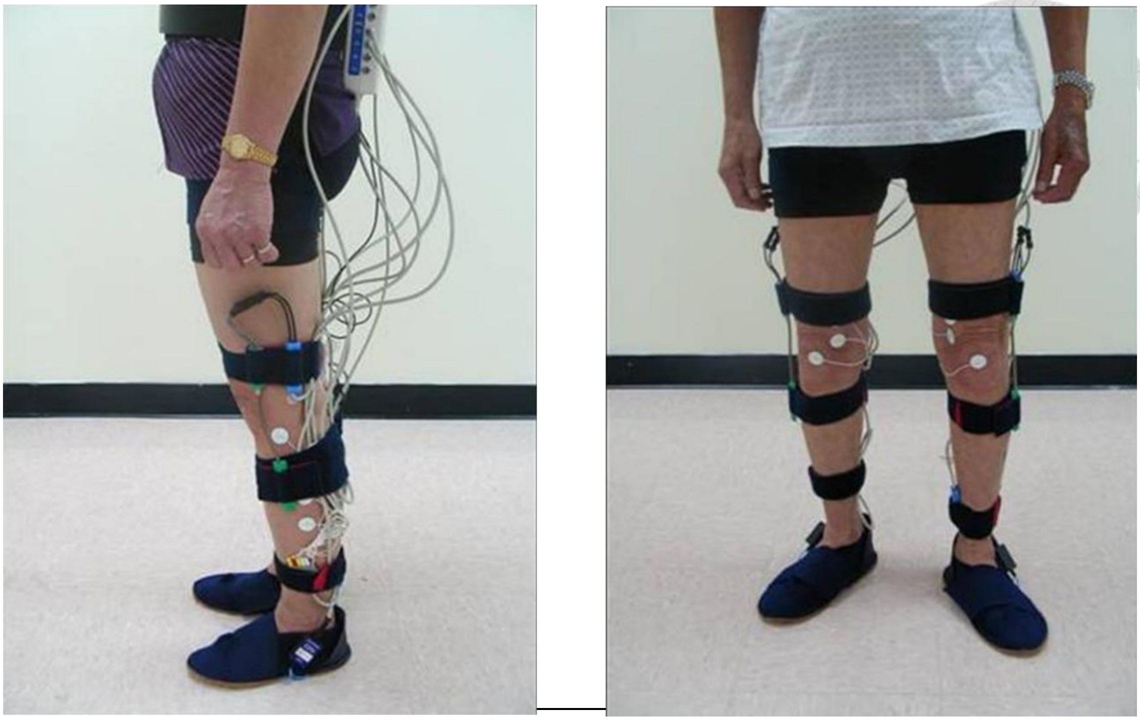

Figure 2-6 A protable gait analysis instruments.

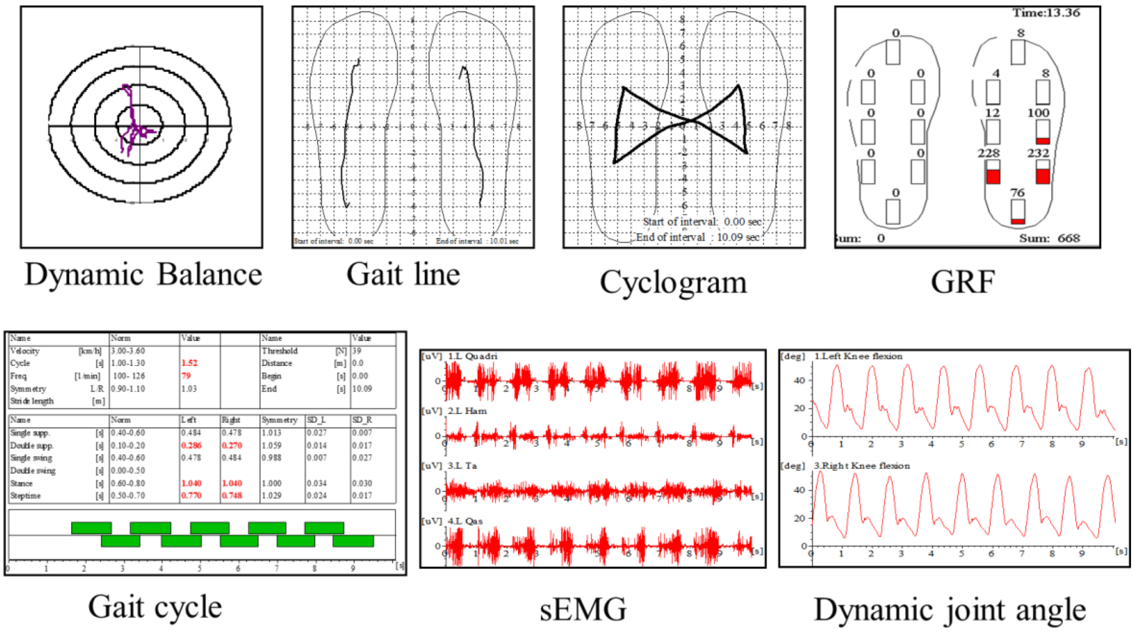

Figure 2-7 Results of balance and gait Analysis.

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2.5 Conclusions

Multiple factors determine the risk of a fall in stroke patients, and a comprehensive assessment is needed to better understand the complex correlation between motor impairment, psychological factors, and the risk of falls in stroke patients.

The results of the present study revealed that the degree of depression, in addition to gait asymmetry and ankle spasticity, may play a crucial role in predicting a fall in stroke subjects. Therefore, more attention should be paid to emotional and social consequences in stroke patients in addition to regular intervention to improve physical function. The predictive factors determined in the present study provide additional prevention strategies for the healthcare team to prevent future falls in stroke patients after they return home.

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Chapter 3. Postural influence on Stand-to-Sit leg load sharing strategies and sitting impact forces in stroke patients

3.1 Introduction

Sit-to-Stand (SitTS) and Stand-to-Sit (StandTS) are both considered essential activities in everyone's daily life [1, 2]. Many studies have investigated the characteristics of SitTS in healthy subjects [3–13], elderly people [11–14], and stroke patients [2–7,13,15–20], but fewer are focused on StandTS [2,3,10–12,15,16]. Although StandTS seems like a reverse movement of SitTS, the sitting impact accounts for the inherit difference. Unlike heel strike during gait, sitting impact cannot be diminished by the active and passive damping components of lower extremities. Thus, for stroke patients, excessive impact caused by poor modulation of body descending velocity may result in a damaging load to spine. Further, the instantaneous instability at impact moment coupled with the position changes of StandTS [1,3,12] increases the risk of falls. Despite the clinical significance, we could find no research published investigating the sitting impact in stroke patients.

Following stroke, patients often present asymmetrical leg load due to abnormal muscle synergy and muscle weakness during their functional activities such as standing [17,21], SitTS [2–7,15–17,20], and StandTS [2,3,15,16]. The clinical

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significance of asymmetrical leg load during StandTS in connection to sitting impact was not reported. In stroke rehabilitation, training paretic legs in muscle coordination and strength is an important goal [16, 20, 24–26] since it can prevent the overuse of the non-paretic side through reduced leg load asymmetry. Also, when patients perform daily living activities in various situations where safety considerations are top priority, the use of the non-paretic leg becomes a desirable strategy since the function of the paretic side is limited.

Previous studies have shown that altering the leg placement significantly affects the leg load of stroke patients for SitTS and/or StandTS [5, 6,15, 16]. The main finding was that placing paretic legs posterior improves asymmetry of vertical reaction forces or knee extensor moment between two sides. This evidence thus suggests that adopting different postural configurations alters the leg load sharing strategy used to accomplish various functional tasks for stroke patients. In addition to the leg placement, a specific arm placement was suggested by neurodevelopmental techniques (NDT) in order to facilitate symmetrical movements for stroke patients [18,22,23]. Similarly, another study demonstrated that arm movements affect the force production in lower limbs [9]. However, to our knowledge, the influence of various combinations of arm and leg placements on leg load sharing strategy during

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functional tasks has not been investigated.

The purpose of this study was, therefore, to investigate leg load sharing strategies and sitting impact forces in stroke patients during StandTS movement during different postural configurations. The hypothesis was that adopting different arm placements, combined with leg placements, would alter the leg load sharing strategy of sitting down while performing StandTS and influence the subsequent sitting impact. Four configurations of arm and leg placements were evaluated on leg load sharing strategies and sitting impact forces, respectively. This research could provide useful information for clinicians involved in exercise design for stroke patients with a view to take sitting impact into account as a safety requirement during rehabilitation.

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3.2 Methods

3.2.1 Subjects

Subjects were diagnosed as first ever stroke by regular medical procedures of a medical center. Exclusion criteria were as follows: (1) apparent degenerative joints or neurological disorders, e.g. knee osteoarthritis and Parkinson's disease (2) unable to finish successful StandTS with the postural configurations designed in this study, (3) younger than 40 years, and (4) history of fall-related fracture after stroke. Eighteen hemiplegic stroke patients (three females,15 males) were recruited from the rehabilitation department. Eight were left hemiplegics and ten were right hemiplegics. The mean age was 60.83 years with a range from 43 to 75 years and the mean (±SD) time since lesion was 13.9(±11.2) months. Mean (±SD) body height and weight were 165.2 (±7.5) cm and 71(±10.7) kg, respectively. All the participants were evaluated by functional independence measure (mean ±SD:108.6 ±17.3) and mini-mental state examination (mean ±SD:27.3 ±1.4), which revealed that they were in relatively high functional level among people with stroke. This study was approved by Institutional Review Board of the medical center and informed consent was received from each participant after thoroughly explaining the study procedures.

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3.2.2 Experiment protocol

There were three force plates (AccuGait, Advanced Mechanical Technology Inc., Newton, MA, USA) used in the experiment setup (Figure 3-1a). During StandTS, subjects placed each leg on one force plate and were asked to sit down on a stool which was placed on another force plate. The height of the stool was adjusted while sitting until the thighs were parallel to the ground. The knees of anterior/posterior legs flexed $80^0/100^0$ and thus the distance between anterior/posterior leg placements was set individually. Each subject was asked to perform four postural configurations (Figure 3-1b), which were the combinations of two arm placements (SA: symmetrical arms; GA: grasped arms) and two leg placements (NPLP: non-paretic leg posterior; PLP: paretic leg posterior). The SA placement referred to that the subjects relaxed and hung their arms sideways whereas the GA placement referred to that the subjects flexed forward the shoulder 90^0 with hands grasped and fingers interlaced which was the way physiotherapists usually taught for StandTS. Before trials, a table of four postural configurations was randomly prescribed for each subject. According to the prescribed postural configurations sequentially, each subject followed given oral instructions and performed StandTS.

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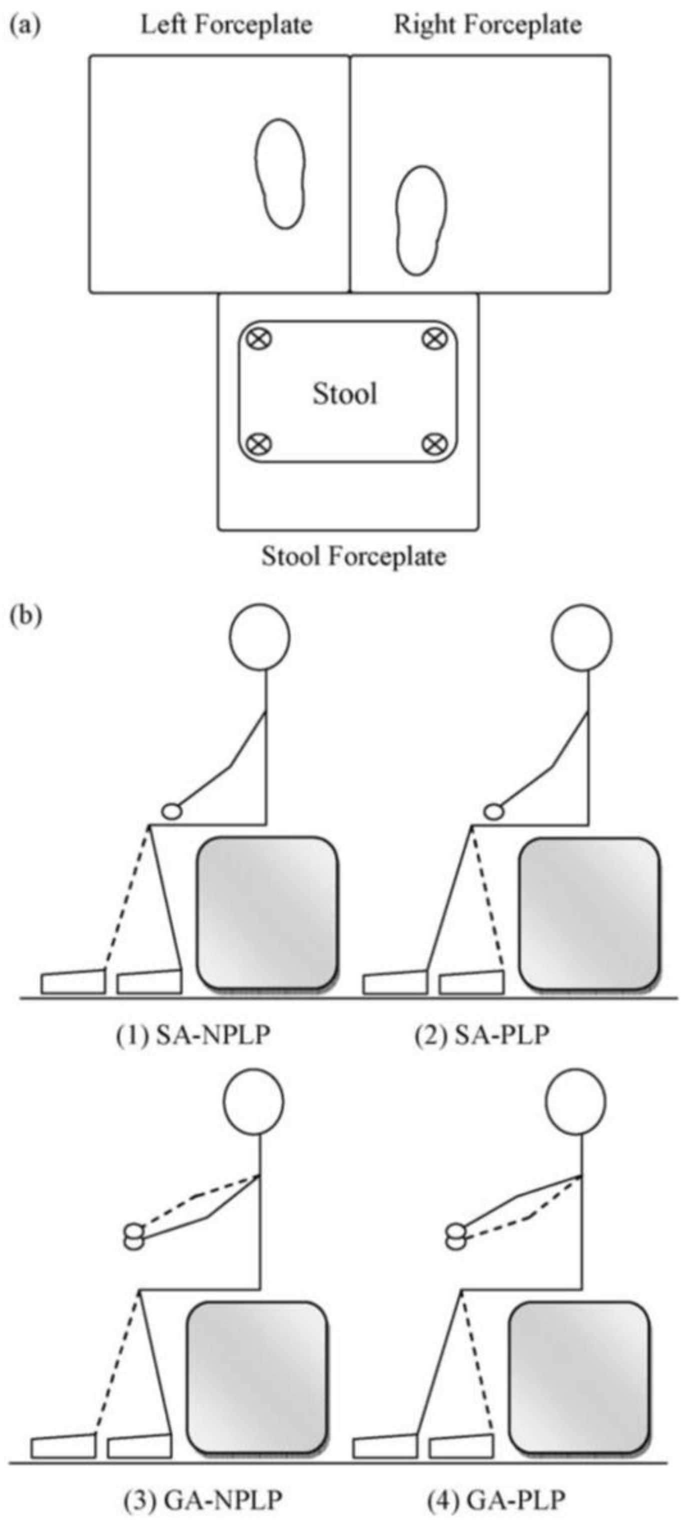

Figure 3-1 Experiment setup

configurations of arm and foot placements (- - - paretic and — non-paretic) &

forceplates (from top view)

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Descending period was measured as the length of time required to sit down. An infrared-emitting diode (IRED) placed on the mid-point of two bony landmarks of PSISs was tracked by an optoelectric sensor (Optotrak Certus, Northern Digital Inc., Waterloo, Canada) in order to detect the initiation of sitting down which was defined as the onset of sacrum descending from quite standing. The end of descending period was determined as the instant when the body initially contacted the stool.

In addition to detect the end of descending period, the force plate underneath the stool was also used to determine the sitting impact force which was recognized as the first transient peak of vertical stool reaction force. The vertical ground reaction force on the foot was acquired by the force plate underneath it to show the dynamic leg load on each leg. Examples of the sitting impact force and dynamic leg load corresponding to each postural configuration were shown in Figure 3-2 and Figure 3-3, respectively.

Kinematic and force plate data were collected at both 50 Hz simultaneously. Data processing and automatic event recognition were finished by an in-house-developed program using Microsoft Visual Studio 2005 (Microsoft Corp.).

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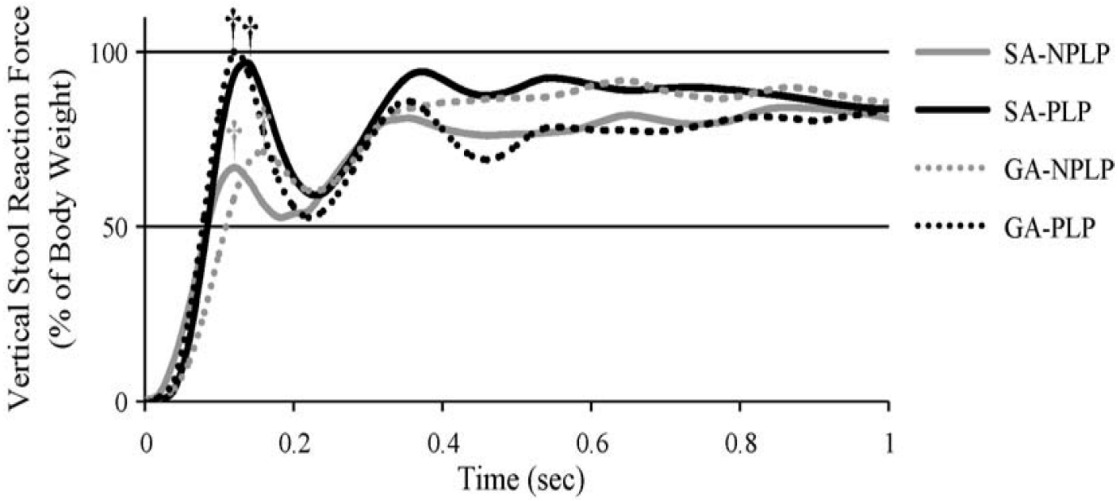

Figure 3-2 Typical normalized stool reaction forces. y indicates the first transient peak, i.e. sitting impact force.

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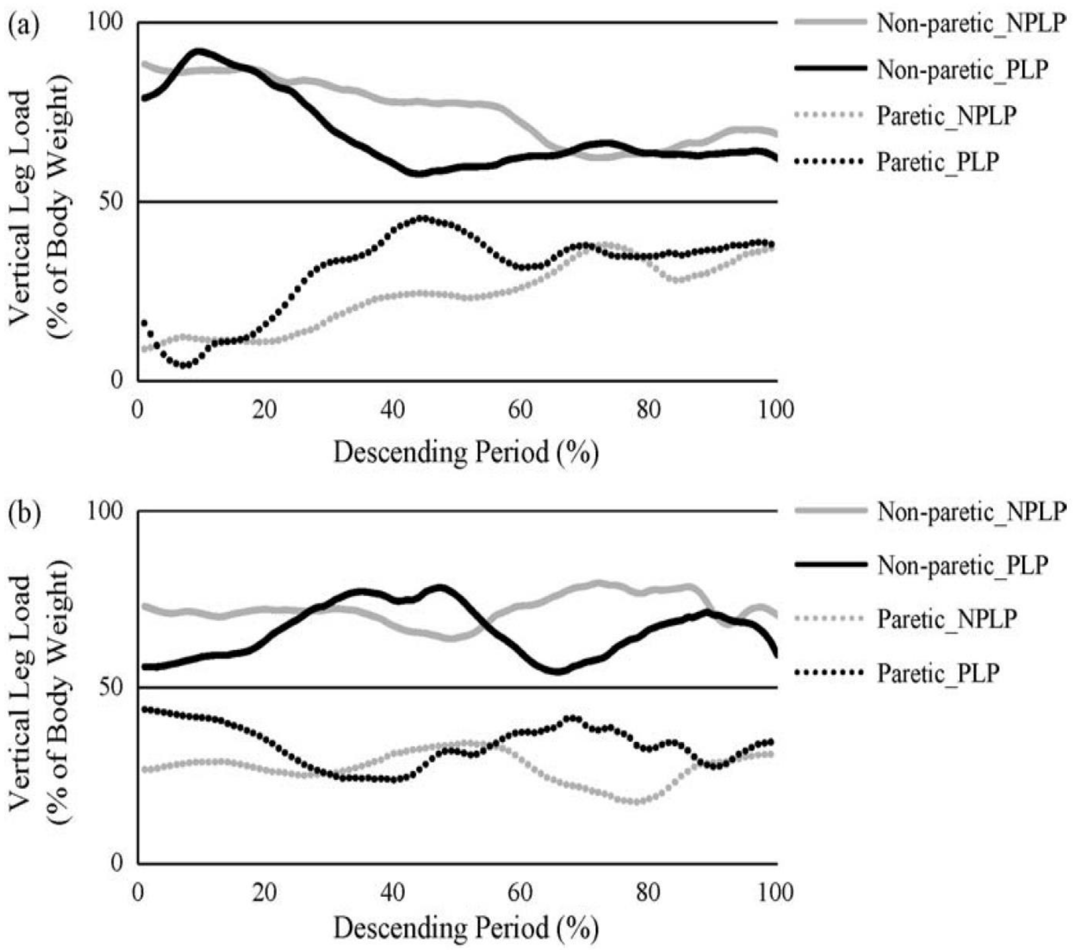

Figure 3-3 Typical normalized dynamic leg load responded to two leg placements and (a) SA arm placement and (b) GA arm placement during descending period.

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3.2.3 Data analysis

Before the group means were computed, a set of dynamic data of leg load was processed for each subject to obtain the leg load discrepancy between two sides, load shared by the non-paretic leg, load shared by the paretic leg, posterior leg load, and anterior leg load during descending period. The averaged values of leg load discrepancy were defined according to the following formula:

$$\text{Loading discrepancy} = \frac{\int_0^T (R_{\text{np}} - R_{\text{p}})dt}{T}$$

where T is the descending period, and Rnp and Rp are the loads shared by the nonpareticleg and by the paretic leg.

3.2.4 Statistical analysis

Interactions of arm placements and leg placements on descending period, leg load kinetics, and sitting impact were analyzed by two-way repeated-measure ANOVA. Pairwise tests were utilized for post hoc analysis. In addition, the leg load differences between non-paretic and paretic legs as well as between anterior and posterior legs corresponding to each postural configuration were identified by paired t-tests in order to evaluate the change of leg load sharing strategy. All statistical analyses were performed using SPSS 11.0 software with a significance level of $P < 0.05$ (two-tailed).

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3.3 Result

3.3.1 Normality check

The skewness and kurtosis of all data were within a range from -1 to 1. The results of Shapiro–Wilk test on all data showed insignificant difference from normal distribution of samples while the alpha level was set to 0.05.

3.3.2 Two-way ANOVA with post hoc comparisons

There was no interaction of arm and leg placements on all variables. Regardless of arm placements, leg placements demonstrated significant influences on leg load discrepancy, loads on non-paretic and paretic legs, and sitting impact force. During StandTS, adopting the PLP leg placement increased the load on the paretic side but decreased the load on the non-paretic side such that the load shifted from the non-paretic side to the paretic side. Quite the opposite, with the NPLP leg placement, because the load on the non-paretic side was augmented and that on the paretic side was reduced, the load shifted from the paretic side to the non-paretic side. Leg load discrepancy of PLP was therefore smaller than NPLP. In addition, the PLP leg placement induces significantly greater sitting impact force compared with the NPLP placement. Group means and results of post hoc analysis are summarized in Table 3-1. It should be noted that the values of total load were not equal to body weight because

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of the typical process of accelerating/decelerating body center-of-mass (BCOM) during descending period.

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Table 3-1 Group means and statistical results of descending period, leg load kinetics, and sitting impact force corresponding to each postural configuration (N= 18).

Parameter	SA			GA		
	NPLP(SD)	PLP(SD)	P-value	NPLP(SD)	PLP(SD)	P-value
Descending period(s)	1.91(0.80)	1.83 (0.58)	0.518	1.79(0.76)	1.70(0.61)	0.339
Average non-paretic leg load (%BW)	62.10(8.01)[a]	58.71(7.70)[b]	0.035*	62.98(7.01)[c]	59.26(8.37)[d]	0.014*
Average paretic leg load (%BW)	37.14(7.85)[a]	40.63(7.89)[b]	0.029*	36.08(6.83)[c]	39.70(8.30)[d]	0.014*
Average anterior leg load (%BW)	37.14(7.85)	58.71(7.70)	0.000**	36.08(6.83)	59.26(8.37)	0.000**
Average leg load discrepancy (%BW)	24.96(15.86)	18.08(15.57)	0.032*	26.90(13.82)	19.56(16.66)	0.014*
Sitting impact force (%BW)	70.63(28.02)	80.83(35.72)	0.020*	75.32(31.87)	84.67(37.57)	0.036*

%BW: % of body weight.

* P<0.05 from paired-samples tests.

** , a, b, c, d P<0.001 from paired-samples tests.

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3.3.3 Leg load sharing strategy

The loads on the non-paretic leg were greater than loads on paretic legs in all postural configurations (P < 0.001), which led a rather consistent leg load sharing strategy for the two leg placements (Figure 3-4). The load on the anterior leg (the non-paretic side) in PLP was greater (P < 0.001) than that on the posterior one. In NPLP, the load on the posterior leg (the non-paretic side) was greater (P < 0.001) than that on the anterior one. In addition, the load on the non-paretic side in PLP was smaller (P < 0.05) than that in NPLP, but the load on the paretic side in PLP was greater (P < 0.05) than that in NPLP. Whether non-paretic or paretic, the leg placed posterior is in a more favored position for accepting biomechanical load than the same leg otherwise placed during StandTS movements.

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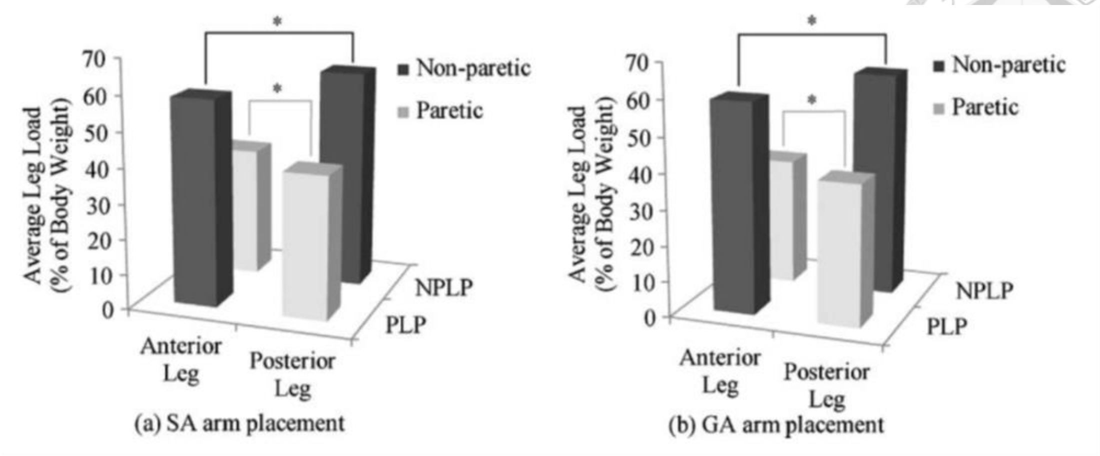

Figure 3-4 Illustrations of leg load strategies of two leg placements corresponding to (a) SA arm placement and (b) GA arm placement. * represents that there is a significant difference between two bars.

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3.4 Discussion

No significant differences regarding the parameters utilized in this study were found between the two arm placements adopted. Leg load discrepancy was not reduced by adopting the arm grasped placement which however has been a common practice to facilitate symmetrical functional movements [23]. This result might be due to the criteria used in this research of subject selection, which required the participants to be in high functional levels. More sophisticated assessment of postural control, such as COP-BCOM relationship [27] and angular momentum modulation [28], might be required to detect the influence of arm placement on StandTS.

In this study, the descending periods of participants did not demonstrate any significant difference among different postural configurations. From previous research, the length of time required to finish SitTS, which reflects the gross muscle strength to accelerate the body rising up, has been related to task performance [2,7,13,14,20]. Some authors have pointed out that a shorter ascending period would correlate to better performance of SitTS [2,20]. Since the primary concern during StandTS is how well the patient modulates the body downwards velocity, rather than how fast the patient drops, the length of descending period may not be an appropriate indicator for evaluating performance of StandTS. Because not only muscle strength

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but also muscle coordination is involved in the deceleration process, descending faster may actually reflect poor control during sitting down rather than good performance. Our results imply that the duration of the descending period (in the patients with relatively good functioning level recruited in this research) was not able to differentiate performance quality.

The pathological joint movements of stroke subjects play an important role during StandTS in order to differentiate the performance of postural configurations. The types of leg muscle contraction for SitTS and StandTS are quite different since rising up requires concentric contractions of hip extensors, knee extensors and ankle plantar flexors for acceleration whereas eccentric contraction is demanded for deceleration while sitting down [15,29]. However, eccentric contractions of paretic muscles, in which the selective control of joints is limited in stroke patients, may account for the difficulty to modulate StandTS movement [30]. The StandTS with PLP leg placements would be more difficult than that with NPLP leg placements because PLP leg placement requires the paretic muscles to be primary power to perform the eccentric contractions for the deceleration during sitting down. Clinicians should let stroke patients be aware that adopting the PLP leg placement to sit down without the supervision of medical professionals may put them in a dangerous circumstance

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particularly for those in low functional levels.

In addition to abnormal muscle synergy, disuse muscle atrophy is also an important issue in stroke rehabilitation. Research has shown that improvement of paretic muscle strength prevents overuse of the non-paretic side [16,25] and decreases disability [19,22,26]. In accordance with previous studies [5,6,15,16], placing the paretic leg posterior in this research not only increases activity of the paretic leg, which is suitable for strength-training, but also improves the asymmetrical load condition of StandTS due to the decrease of leg load discrepancy. However, these improvements cannot transfer to better postural control for stroke patients because the sitting impact is increased with the PLP leg placement. Hence, more symmetrical load condition accomplished by more exertions of paretic muscles cannot explicitly relate to better StandTS performance although it is beneficial in strength-training rehabilitation.

The asymmetrical load condition of NPLP is not a source of postural instability but rather a result of safe postural configurations during StandTS since the sitting impact can be reduced with NPLP placement as shown in Table 3-1. Due to the fundamental characteristic of stroke patients regarding their preferred use of the non-paretic side, the dominant role of the non-paretic leg on bearing loads consistently ensures safety

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despite the alteration of postural configurations. The leg load sharing strategy of StandTS with the NPLP leg placement achieves an effort-efficient status because the posterior leg bears more load than the anterior leg (Figure 3-4) due to the preferred use of the non-paretic leg and the favored position for accepting biomechanical load. In contrast to the NPLP leg placement, adopting the PLP leg placement to sit down for hemiplegics is unlikely to achieve an effort-efficient status, i.e. the posterior (paretic) leg bears more loads than the anterior (non-paretic) leg. In other words, the non-paretic leg is placed anterior in an awkward position with the PLP leg placement for sitting and thus is unable to adequately compensate paretic muscles on modulating body descending velocity, which consequently induces the greater sitting impact as we found in this research. Our result echoes previously published findings [21] concluding that the postural instability is caused by the inability of the non-paretic leg to compensate the postural impairment of the paretic leg, rather than by asymmetrical load condition. Despite the load asymmetry, we found that the NPLP leg placement reduces sitting impact in addition to the effort-efficient movements when patients perform StandTS.

This study has demonstrated the sensitivity of the sitting impact on the changes of leg load sharing strategy due to postural configurations. Hence, sitting impact can be a

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performance indicator of StandTS since it not only reflects the sitting down efforts of both legs on decelerating but also represent the smoothness of the weight-transfer process from legs to a stool. When smooth weight-transfer can be achieved, the risk of falls may be reduced. Further research is needed to correlate other characteristics of StandTS to sitting impact in order to uncover the relationship between postural control and the sitting impact in more detail. Possible predictors of sitting impact might be the impacting velocity of BCOM, muscle strength of lower extremities, COP-BCOM relationship, and angular momentum modulation. The ultimate goal of our study group is to develop reliable predictors on falls, which would contribute to fall prevention for stroke patients. A longitudinal project has been launched for this purpose.

The main limitation of this study was that only a chronic population with a high functional level was examined and hence, the relevance of our findings to an acute stroke population or to less able chronic patients has not clarified by our current work. In conclusion, this study confirmed that, in stroke patients with good functional levels, leg placement significantly influences leg load sharing strategies and sitting impact forces whereas arm placements do not. The preferred role of the non-paretic leg in load-bearing and the favored biomechanical load position of the posterior leg

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accounts for the leg load sharing strategies with the two leg placements investigated. Consequently, the inability of the anterior non-paretic leg to compensate the poor controlled paretic leg induces greater sitting impact compared with the non-paretic leg posterior placement. For training purposes, placing the non-paretic leg anterior would increase exertions of the paretic leg.

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Chapter 4. Postural Configuration on Phase Duration and Vertical Force Asymmetry during Sit-to-Stand Tasks in Patients with Stroke

4.1 Introduction

Cerebrovascular accidents, a leading cause of death in many countries with a high morbidity rate, have become a significant public health problem. Complications often occurring as a direct result of injury to the brain following stroke include an inability to move freely or to sustain balance. As a result, stroke patients have a high risk of falling: with 14 to 39% of patients falling in the first month following stroke, and 75% in the first six months [1,2]. The injury rate in such falls has been reported between 13 and 29% [3–8]. Previous stroke has been demonstrated as a risk factor (adjusted OR, 2.9; 95% CI, 1.3–6.3) for fall-induced hip fractures among elderly persons dwelling in communities [9]. Poor force exertion in the lower extremities and impaired coordination of body segments during the SitTS tasks are correlated with fall risk [2,10].

Past studies have demonstrated longer task duration, larger displacements of the COM, and asymmetrical weight bearing during SitTS is commonly observed in

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patients following stroke [11–14]. By comparing fall and non-fall stroke patients, it was found that asymmetrical distribution of body weight and greater postural sway were predictors of falls [14]. The asymmetry of body-weight distribution can be estimated from the vertical ground-reaction forces on feet, and used to quantitatively assess SitTS movement.

In previous studies, the hand placement position of crossed-arms-on-chest has been adopted in experimental settings simulating the SitTS task [15]. However, clinically, crossed-arms-on-chest deprives the patient of the ability to adjust postural sway and may result in atypical patterns of movement.

The aims of this study were to evaluate the effect of different postural configurations of the hands and feet on weight bearing in stroke patients during SitTS tasks. The hands-clasped position is frequently used in clinical practice for SitTS task training of stroke patients as it is believed to provide better control of upper limbs and trunk. In addition, activity with hands-clasped position is believed to inhibit the flexor synergy of upper limbs and facilitate body and joint proprioception in the stroke patients. Positioning the affected foot backward is also used to facilitate weight bearing of the weakened leg. We hypothesized the hands-clasped position with the

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affected foot backward will decrease time expenditure and asymmetry of vertical ground-reaction forces (GRF) in stroke patients during the SitTS task.

4.2 Methods

4.2.1 Participants

Subjects were recruited from the rehabilitation program at a tertiary medical center. A total of 21 stroke patients (17 males, 4 females) were enrolled in this study. The mean age was 58.8 years (SD = 12.4), and the time post-onset ranged from 1.7 to 44 months. The mean Functional Independence Measure (FIM) was 108.6 (SD = 17.3).

4.2.2 Ethics

This study was approved by the institutional review board of Changhua Christian hospital and was conducted in accordance with the Declaration of Helsinki. All participants received verbal and written information about the study, and signed a consent form.

4.2.3 Experimental settings

An Optotrak motion capture system (Optotrak Certus, Northern Digital Inc,

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Waterloo, Ontario, Canada)[a] was used to track a marker placed on the sacrum (Figure 4-1). Three force plates (AMTI, Watertown, MA, USA)[b] were employed: two under each leg and one under the seat. A stool without back or armrests was used to avoid blocking the tracking marker and to prevent movement of the seat during the SitTS task. In keeping with finding the finding by Roy et al [16] that seat height has no significant effect on the level of asymmetry of vertical ground-reaction forces, a standard seat height was adjusted to the height of knee joint center. For the asymmetrical foot position, the placement of feet were adjusted to achieve an anterior/posterior knee flexion of 80°/100° (Figure 4-2). The locations of both feet were recorded to ensure foot positions were consistent between repeated trials. All experimental settings were illustrated in Figure 4-4 and Figure 4-5.

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Figure 4-1 Experimental setting: Marker placement and foot position.

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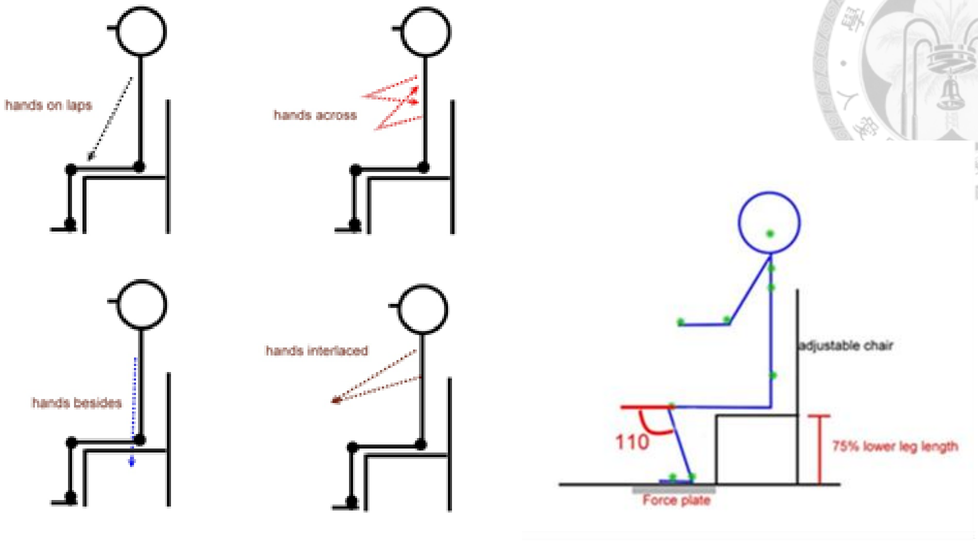

Figure 4-2 Arm positions and Knee flexion angle.

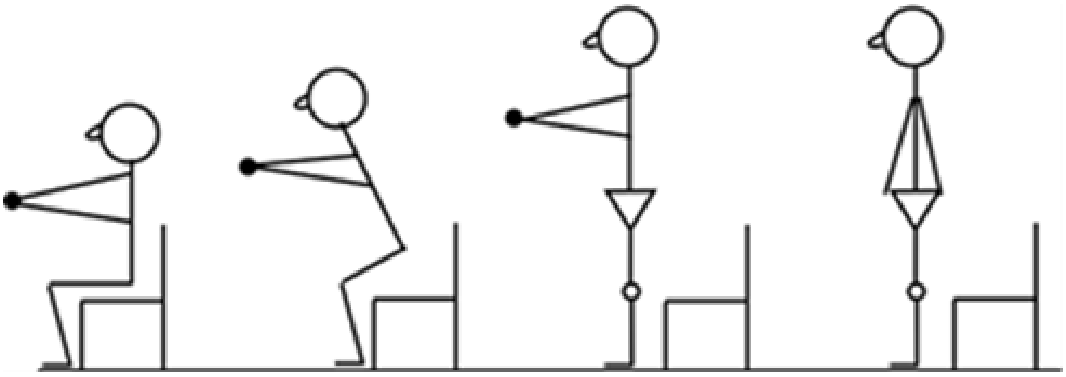

Figure 4-3 Example of hand grasp during the task of sit to stand.

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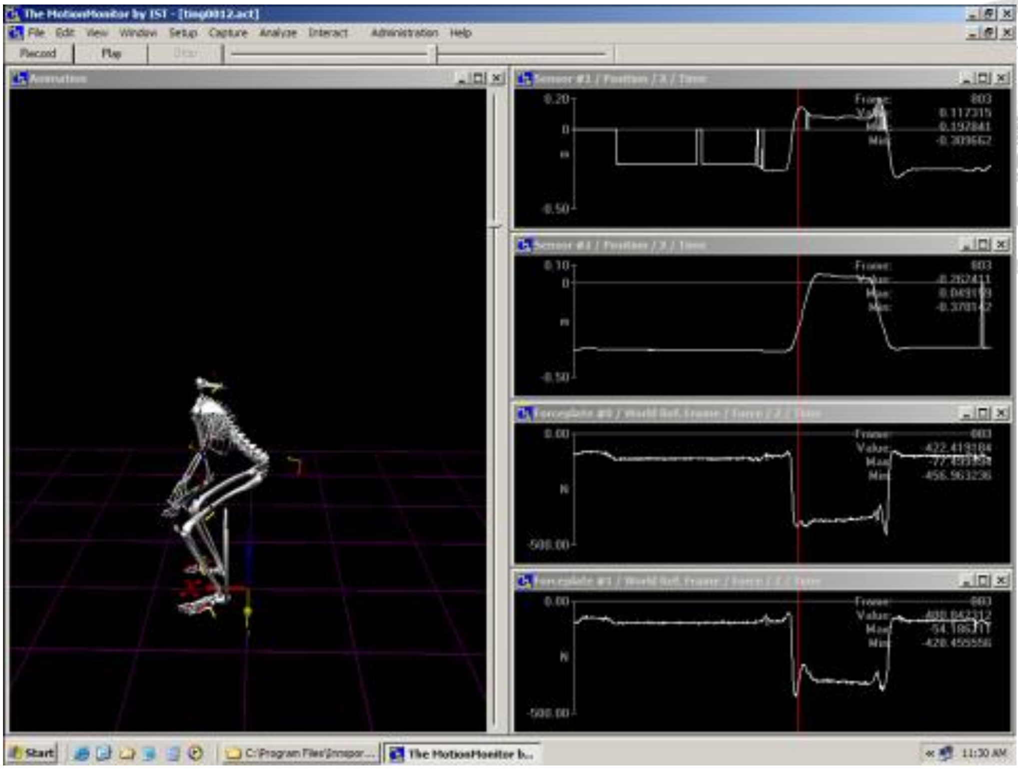

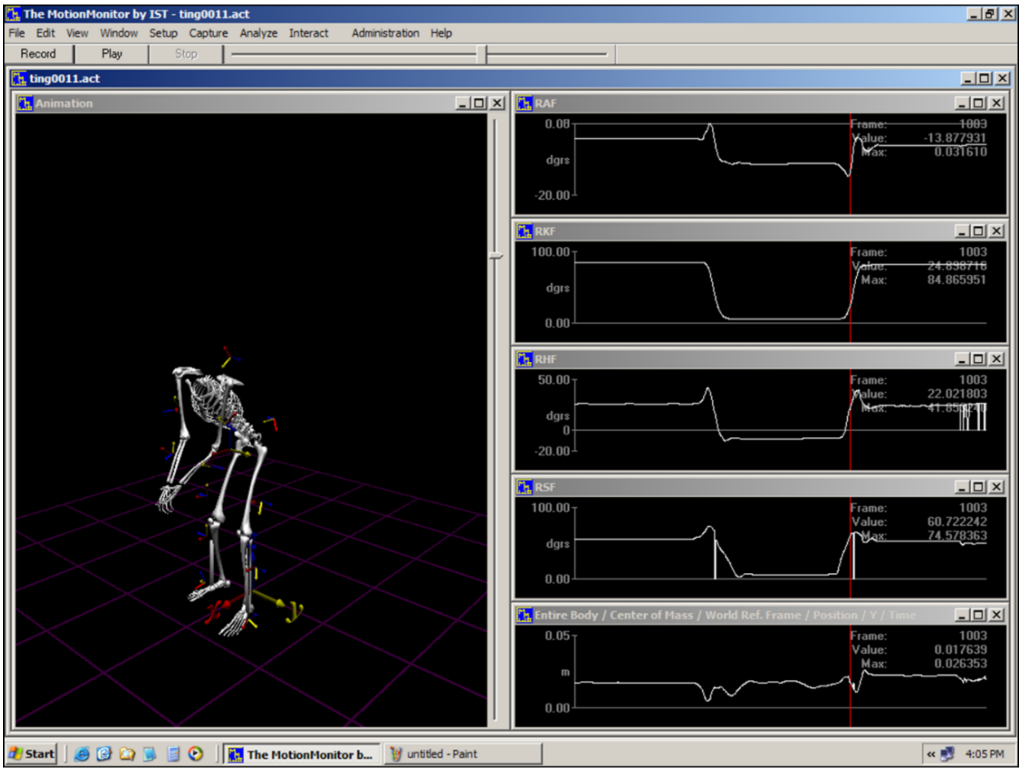

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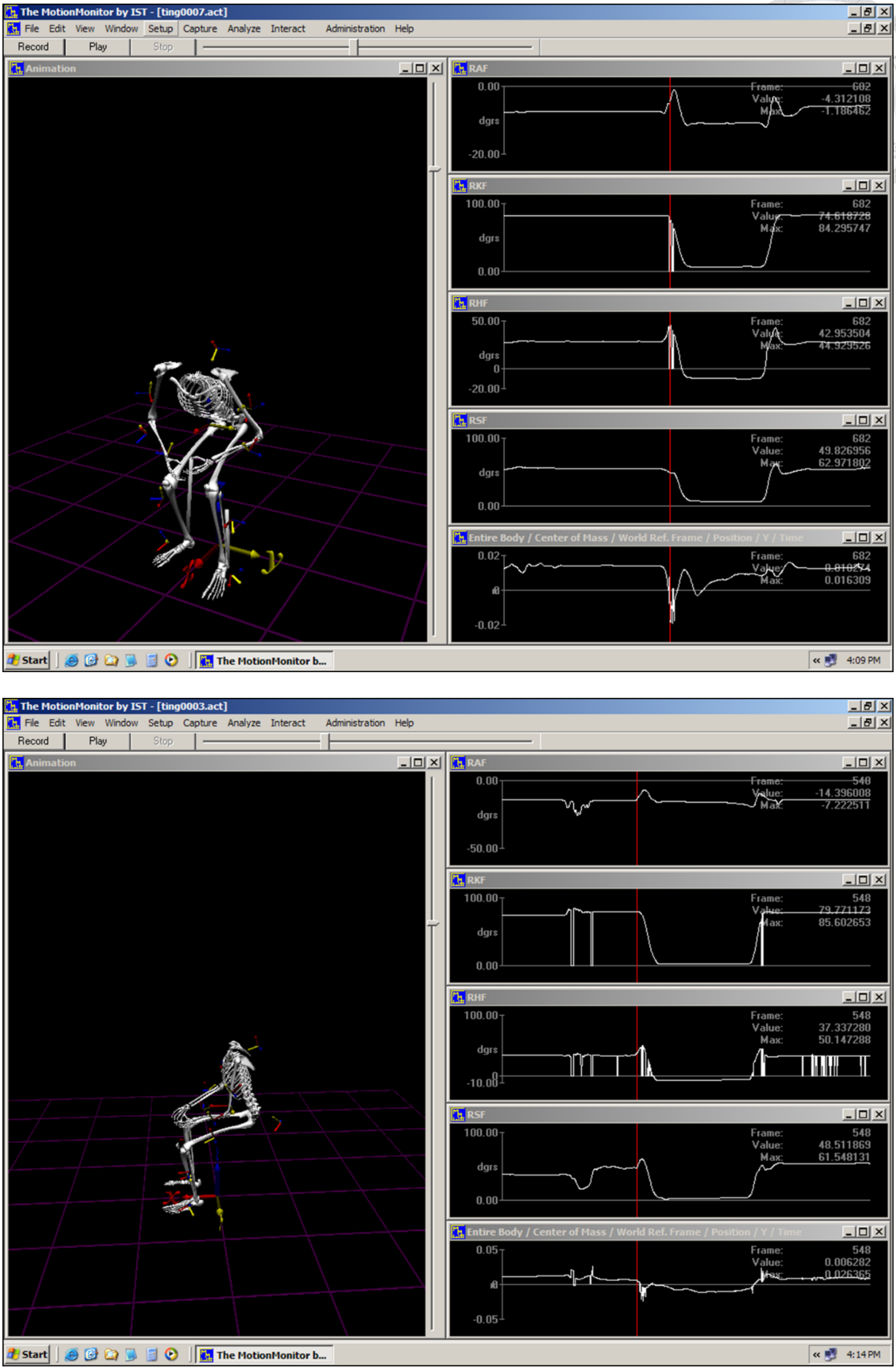

Figure 4-4 The kinematic and kinetic data collected by optotrak motion system.

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4.3 Procedures

Combinations of three hand positions and four foot placements were tested in a random sequence (Figure 4-3). Hand positions studied were: hands on knees (Hk), where subjects were asked to rest their hands lightly on their thighs but not to push them when standing up; hands aside (Ha); and hands clasped (Hc). Foot placements studied were: spontaneous (Fsp), symmetrical (Fs), affected forward (Faf), and affected backward (Fab).

Subjects were trained in the SitTS task prior to testing. Subjects performed three trials of each configuration at their own pace. A verbal cue was used to initiate movement. An assistant accompanied patients on each side in order to prevent falls. Subjects were given a 2-min rest period after every three trials to eliminate the effects of fatigue.

4.3.1 Data processing

Four events (Figure 4-5, E1-E4) were defined by force data and the position of the marker placed on the sacrum. The first, onset (E1), was defined as the point at which the sitting subject starts the first movement by leaning the trunk forward and causing the forceplate under the stool to show force deviating at least 5% from the baseline. The

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second, seat-off (E2), was defined as the point at which the subject changes from a sitting to a standing position, defined as the point in time when the vertical force under the stool becomes equal to the weight of the stool. The third event, standing (E3), was defined as the point at which a standing position is reached, with the marker on the sacrum at its highest position. The fourth event, end of task (E4), represents the instant when a stable standing phase is achieved with no fluctuations greater than 5% of body weight. Thus, the duration of the SitTS task was defined as the elapsed time from E1 to E4, subdivided into three phases: preparation (E1 to E2), ascending (E2 to E3), and stabilization (E3 to E4). Figure 4-6 shows data collected from a representative subject.

Vertical ground-reaction force was measured to calculate weight-bearing asymmetry during the task. The index of asymmetry was defined as follows,

$$\text{Asymmetry index} = \frac{V_{na} - V_{\text{perfect symmetry}}}{V_{\text{perfect symmetry}}}$$

where V_{na} is the vertical GRF measured from the non-affected side, and $V_{\text{perfect symmetry}}$ equals to 50% of the sum of the total vertical GRF under the feet [16]. The unit of index was expressed as a percentage, with 0 representing perfect symmetry, −100% indicating the load was entirely on the affected side, and +100% corresponding to loading entirely on the non-affected side.

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To better understand the fluctuations of vertical GRF during the SitTS task. The vertical GRF under both legs was acquired to calculate the leg load discrepancy during the SitTS task (Figure 4-7). The value of the Leg Load Discrepancy (LLD) was defined according to the following formula, Load discrepancy = $\frac{\int_0^T (V_{na} - V_a)dt}{T}$

$$\frac{\int_0^T (V_{na} - V_a)dt}{T}$$

where T is the duration of the phase and V_a is the vertical GRF measured from the affected side [17].

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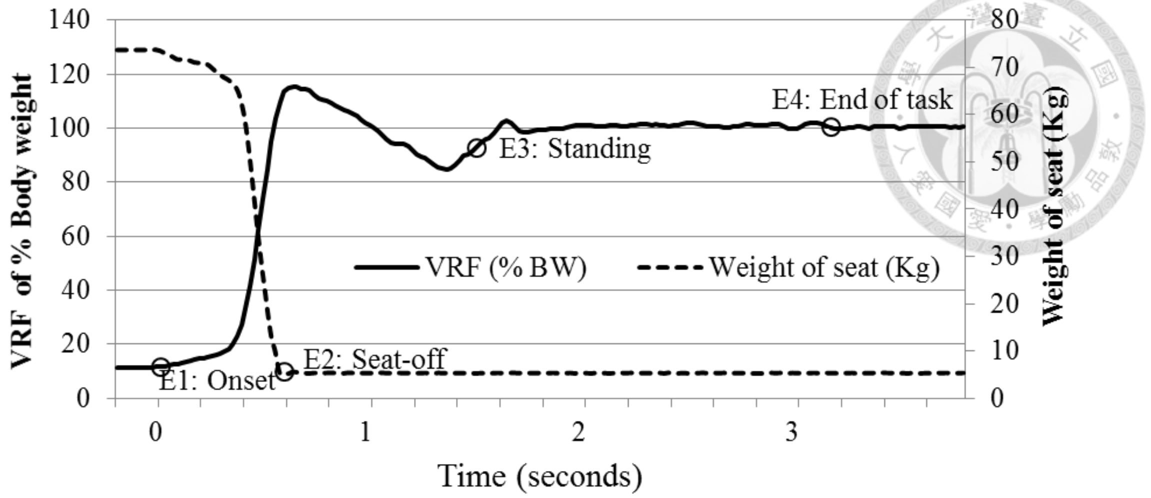

Figure 4-5 Events of sit to stand task.

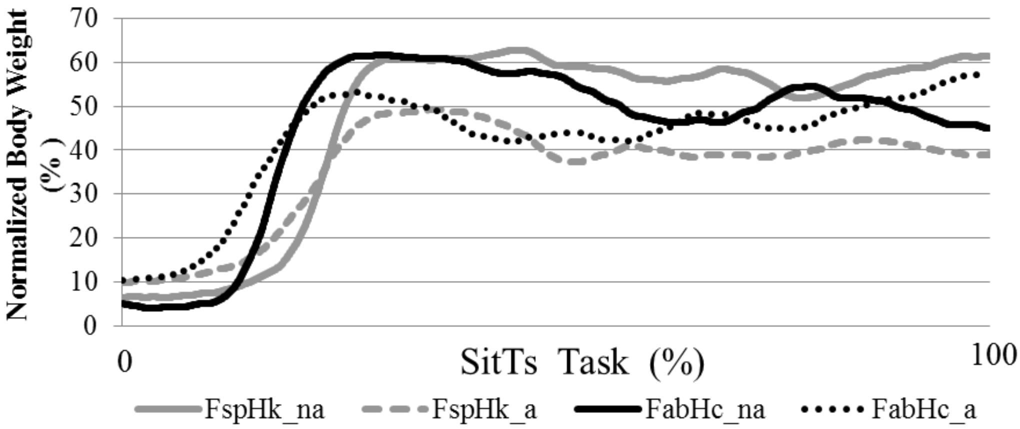

Figure 4-6 Bilateral leg load in FspHk and FabHc position.

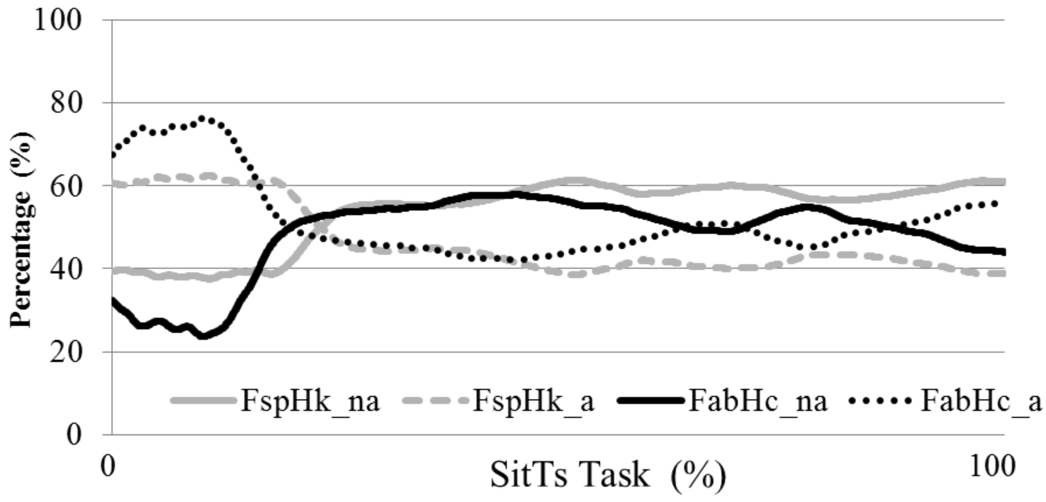

Figure 4-7 Asymmetrical leg load compared to FspHk and FabHc.

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4.3.2 Statistical analysis

Descriptive statistics (means) were calculated for duration, asymmetry index and leg load discrepancy. Results were analyzed to determine the effect of foot and hand positions during the SitTS task for the duration and LLD were assessed for each phase. The asymmetry index was calculated at each event. Because some subjects failed to perform few difficult postural configurations (such as Faf), it led to data missing for further statistical analysis. Therefore, we used the Generalized Estimating Equations (GEE) method to evaluate the effect of foot and hand position on duration, asymmetry index, and leg load discrepancy, instead of using repeated-measure ANOVA. Where results of GEE were significant only in main effect of foot or hand, pair-wise comparisons were tested to determine significant differences for each foot or hand components. If any complex interactions of foot and hand (foot x hand), a further simple effect analysis with pairwise contrasts (a Bonferroni adjustment) to determine where the differences were, such as fixed one independent variable (e.g., foot position) on each of the other positions (e.g., for Hc, Hk, and Ha)

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4.4 Results

The effect of foot and hand position on the duration of SitTS (Figure 4-8). An interaction between foot and hand positioning and the duration of preparation and ascending phases was observed. The FabHc position led to the shortest preparation phase duration (0.51 s) and the FspHa position led to the longest (0.59 s). In the Fab position, Ha position led to a longer preparation phase duration than Hc or Hk positions [the difference of duration between configurations (Δ), Δ (FabHa vs. FabHc) = 0.071 s, P = 0.031 and Δ (FabHa vs. FabHk) = 0.044 s, P = 0.012]. In the Faf position, the Hc position was found to lead to a shorter duration than Ha or Hk positions (Δ (FafHc vs. FafHa) = 0.070 s, P = 0.044 and Δ (FafHc vs. FafHk) = 0.060 s, P = 0.004). No significant differences were observed between other foot and hand positions. For the ascending phase, the FspHc position led to the shortest movement duration (1.21 s) and the FabHk position led to the longest (1.41 s). An effect of foot position and hand position on the duration of the stabilization phase was observed. The mean duration of the stabilization phase significantly differed among different foot (Wald X^2 = 10.03, P = 0.018) and and positions and (Wald X^2 = 32.56, P < 0.001). Therefore, further pairwise tests were performed demonstrating the duration in the Fab position was longer than Faf (Fab > Faf, P = 0.01) or Fsp (Fab > Fsp, P = 0.004) positions, and the duration in the Hc position was longer than in Ha or Hk

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positions ($P < 0.001$ for Hc > Ha, Hk).

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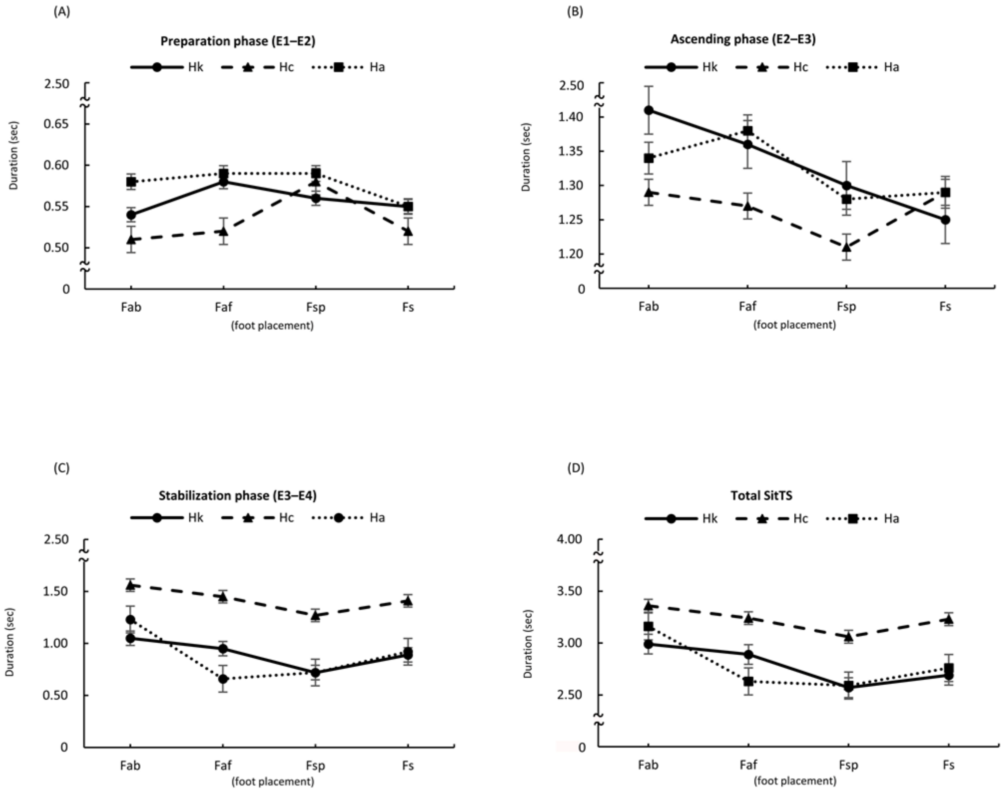

Figure 4-8 The durations of sit to stand by phase: (A) preparation phase. (B) ascending phase. (C) stabilization phase. (D) total sit to stand. The values were plot by mean with standard deviation.

Fab, Affected foot backward; Faf, Affected foot forward; Fsp, Foot spontaneous; Fs, Foot Symmetry; Hk, Hands on knees; Hc, Hands clasped; Ha, Hands aside.

E1, Onset; E2, Seat-off; E3, Standing; and E4, End of Task.

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No interaction (foot x hand) was observed between the total duration of the SitTS task, but for the main effect of foot (Wald X^2 = 9.77, P = 0.021) and effect of hand (Wald X^2 = 19.42, P < 0.001) were significant. The affected foot placed backward (Fab) position led to a longer duration than Faf (Fab > Faf, P = 0.027) or Fsp (Faf > Fsp, P = 0.002) positions. The Hc position led to a longer than duration than Hk or Ha (Hc > Hk, Ha, P < 0.001) positions. The shortest mean duration was 2.57 s (FspHk) and the longest was 3.36 s (FabHc). Compared to the FspHk (2.57 s) position, the normal posture of patients, subjects in the affected foot backward and hands clasped position needed 30% longer (3.36 s) to accomplish the SitTS task.

The effects of hand and foot position on the asymmetry index at each event in the SitTS task (Figure 4-8). In general, no interactions of foot x hand position on the asymmetry index were observed for any events. At standing (E3), no significant difference between the mean asymmetry index and foot and hand position was found. A significant different was found among foot position on the asymmetry index at E4 only (Wald X^2 = 27.79, P < 0.001).

At onset (E1), the mean asymmetry indices were all negative, indicating that the affected leg took more load than the non-affected leg. At this event, the Fs position

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had increased asymmetry than Fsp (Fs > Fsp, P = 0.047) and the Hc position led to decreased asymmetry than Hk (Hc >Hk, P = 0.047).

At seat-off (E2), pairwise comparisons revealed asymmetry in the Fab position was significantly lower than in the Faf, Fsp, or Fs positions (P < 0.001,Figure 4-8), and significantly lower in the Hc position than in the Hk position (P = 0.004, Figure 4-9). Similar results were found for foot positions at the end of the task (E4). Although asymmetry in the Hc position was slightly higher than in other hand positions, it did not reach statistical significance.

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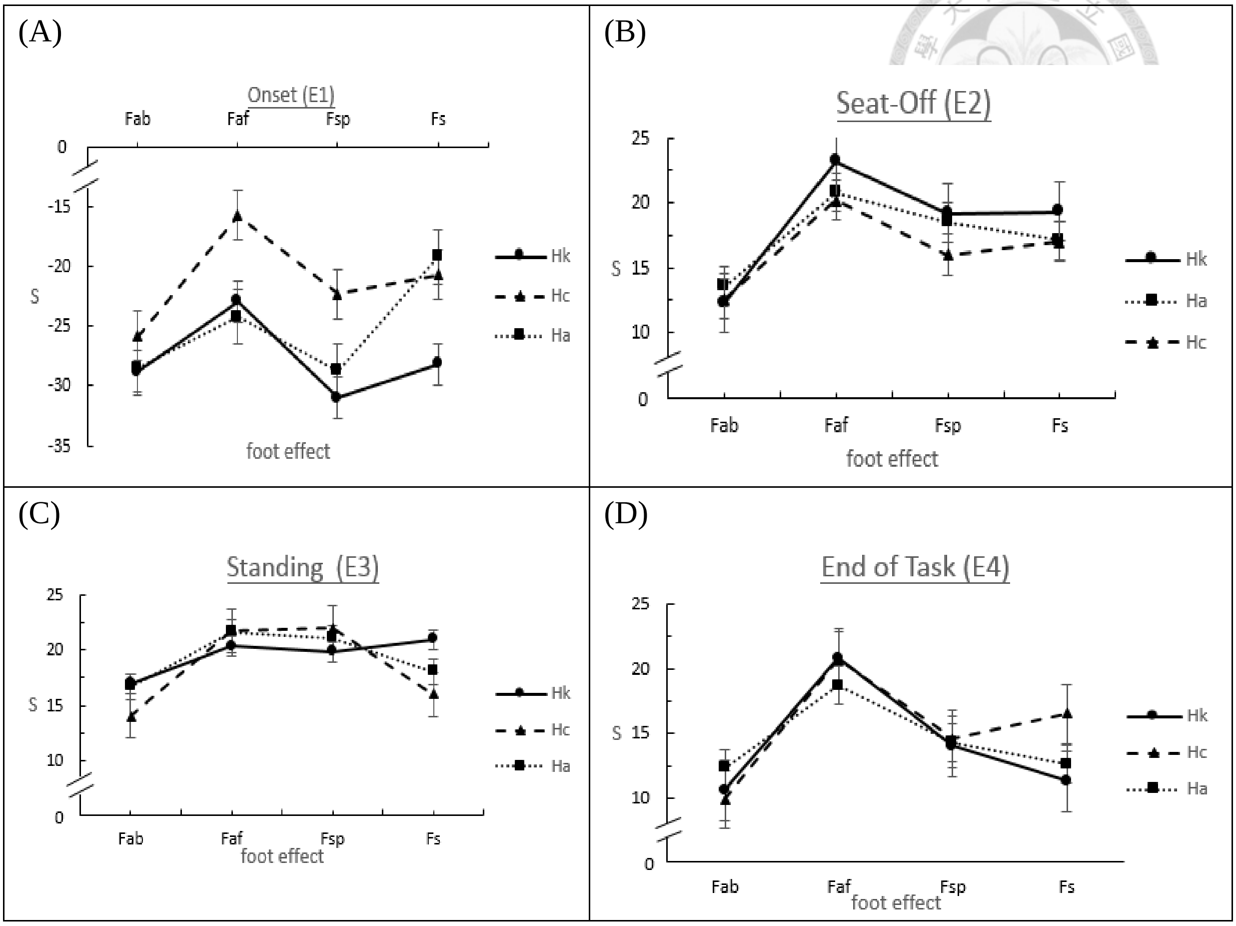

Figure 4-9 The asymmetry Index of events according to Foot and Hand Positions: (A) onset. (B) seat off. (C) standing. (D) end of task. All values are represented as mean (standard deviation).

Fab, Affected foot backward; Faf, Affected foot forward; Fsp, Foot spontaneous; Fs, Foot symmetry; Hk, Hands on knees; Hc, Hands clasped; Ha, Hands aside.

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The effect of hand and foot position on leg load discrepancy during the SitTS task (Figure 4-10). Leg load discrepancy was used as an index for the difference in leg load between the two sides during the task. Significant effects were found only for foot positions, in each phase, throughout the entire task duration, but no such effects were found for hand positions (Table 4-1). The results showed that Faf had the greatest LLD in each phase and total sitTS. Despite of hand position, the placement of affected foot backward (Fab) was less LLD than Fsp or Fs during the sitTS task. Figure 4-7 shows a visual presentation of the GRF percentages of each leg in the FspHk and FabHc positions during SitTS task.

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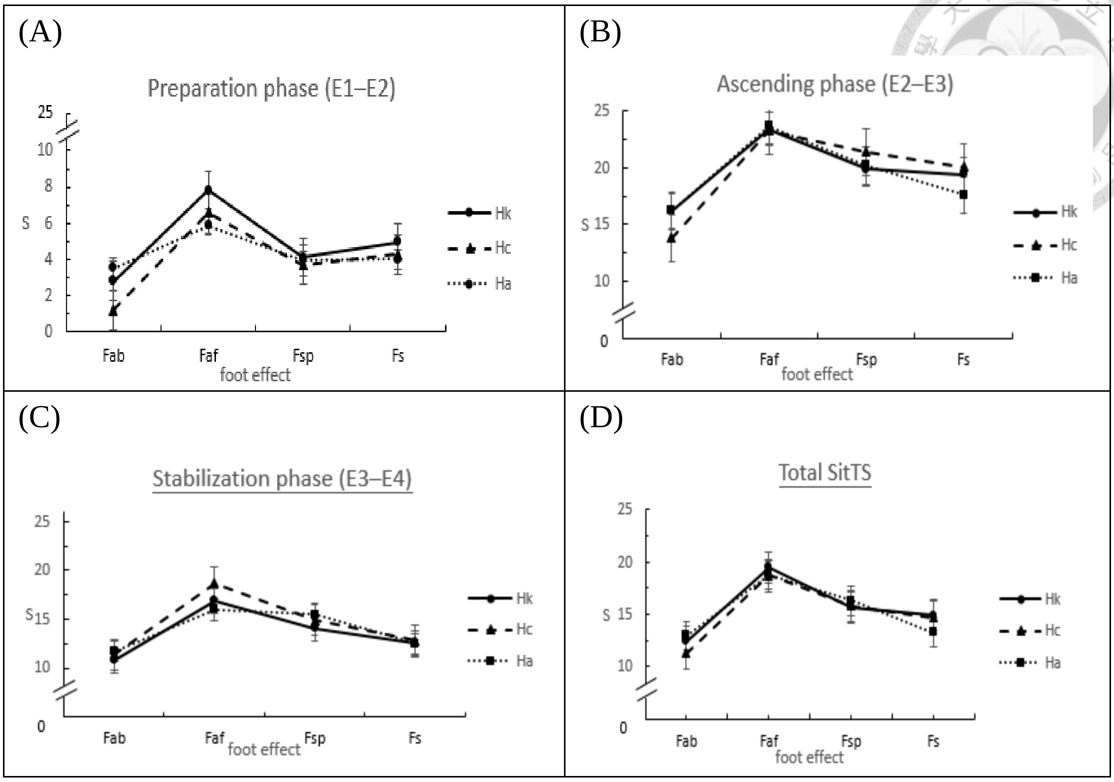

Figure 4-10 Leg Load Discrepancy of sit to stand by phase: (A) preparation phase. (B) ascending phase. (C) stabilization phase. (D) total sit to stand. All values are represented as mean (standard deviation).

Fab, Affected foot backward; Faf, Affected foot forward; Fsp, Foot spontaneous; Fs, Foot symmetry; Hk, Hands on knees; Hc, Hands clasped; Ha, Hands aside.

E1, Onset; E2, Seat-off; E3, Standing; and E4, End of Task.

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Table 4-1 Leg load discrepancy by phase.

Factors	Wald X^2	P value	Pairwise test
Preparation phase (E1–E2)			
Foot effect	13.36	0.004	Faf > Fs, Fsp, Fab Fs > Fab
Hand effect	2.95	0.229	
Foot x Hand interaction	5.11	0.530	
Ascending phase (E2–E3)			
Foot effect	25.05	0.003	Faf > Fsp, Fs, Fab Fs, Fsp > Fab
Hand effect	0.91	0.956	
Foot x Hand interaction	3.77	0.708	
Stabilization phase (E3–E4)			
Foot effect	13.87	<0.001	Faf > Fsp, Fs, Fab Fsp > Fs, Fab
Hand effect	0.38	0.826	
Foot x Hand interaction	2.47	0.872	
Total SitTS			
Foot effect	22.87	<0.001	Faf > Fsp, Fs, Fab Fsp > Fab
Hand effect	0.55	0.758	
Foot x Hand interaction	5.94	0.430	

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4.5 Discussion

Most studies of the SitTS movement have included constraints on the use of the hands to simplify experimental procedures. However, we believe the use of the hands in performing the SitTS task is common among elderly and hemiparetic patients and likely to significantly influence foot placement. Therefore, the effects of foot and hand placement during the SitTS task were the main foci of this study. Our results demonstrated that a number of events and phases during the SitTS process were influenced by foot and hand position configurations.

4.5.1 Durations in response to hand and foot placement

During the preparation and ascending phases, there was an interaction effect between foot and hand positions. After standing, only main effects of foot and hand position were found. The results imply that at each phase subjects might use their limbs differently to address the task according to external demands (foot or hand position) and internal ability (balance and muscle strength). Despite the fact subjects spent most of their time on the ascending phase, the stabilization phase was the main determinant of the total time expenditure and where no interaction between foot and hand positions and total time of SitTS task was observed.

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In past studies, the mean duration of sit to stand was 4.32 s for stroke fallers, between 2.31 and 3.89 s for stroke non-fallers, and between 1.88 and 2.42 s for healthy subjects [14,16,18]. In this study, durations ranged from 2.57 to 3.36 s, similar to previous studies. Hence, we believe no postural configurations examined in this study led to an increased SitTS duration in stroke patients, and that these postural configurations were commonly used in daily life.

4.5.2 The effect of foot position on the asymmetry of weight bearing

The symmetry of weight bearing at seat-off during SitTS has been extensively studied, as this event is a transition point at which the balance parameters change from a stable three-point base of support to a relatively unstable two-point base of support. Roy found asymmetry index values at seat-off range from 11.1 (20.2) to 25.6 (12.7) for four foot positions among stroke patients (spontaneous, symmetrical, and the 2 asymmetrical foot positions) [16]. By comparison, the average asymmetry index for SitTS at seat-off is 1.017 (0.979–1.054) among healthy subjects [19], and ranged from 12.8 (Fab) to 21.4 (Faf) in our study. This was much higher than in normal subjects even though subjects exhibited relatively high functional performance as measured by FIM.

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In terms of the effect of foot position on the asymmetry index, our results were consistent with previous studies in demonstrating the asymmetrical foot position with Fab facilitated more leg load on the affected leg and subsequently resulted in reduced asymmetry index during SitTS tasks [20,21]. The backward foot functioned as a main pivot at the initial phase. To rise up, the affected lower limb must generate sufficient joint moment from the ankle, knee, and hip joints. Thus, adopting this foot position may improve symmetrical leg loading and avoid non-use of the affected leg.

4.5.3 The effect of hand position on the asymmetry of weight bearing

In this study, the position of the hand was found to play an important role in adjusting motor control before the standing event, even when feet were placed asymmetrically. When feet were placed asymmetrically (Fab or Faf), the hands-clasped (Hc) position led to a shorter duration than other hand positions during preparation and ascending phases, but led to increased duration of the stabilization phase, which is the major determinant of the overall duration of the SitTS task. The increase time needed to stabilize the body might result from a lack of hand movement after standing. It may therefore be inferred that the overall duration of SitTS may be shortened when subjects stand up from the chair with hands clasped and then release their hands for further balance control with an asymmetrical foot position. Regarding

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the effect of hand position on the asymmetry index, the hands clasped position let to decreased asymmetry at the onset and seat-off events regardless of foot position.

When subjects reach forward in the hands clasped position, the basic kinematics of forward reach includes forward trunk flexion and hip flexion to bring the center of mass (COM) forward. Furthermore, the retraction of scapula and associated reactions in arm is prevented during SitTS with hands held forward. In simulated studies of the whole-body forward reach task, COM has been shown to be the primary stabilizing reference for posture and movement coordination [22, 23]. Forward trunk inclination has been shown in hemiparetic patients to improve stability at seat-off and during the standing process [18]. As the head-arm-trunk (HAT) segment represents about 70% of the body mass, a change in trunk position leads to altered weight bearing during the SitTS task. Their results may indicate the hands clasped position influences COM and lead to symmetrical alignment of the upper body before standing and during the ascending phase [21]. Thus, the effect of hand position appears to act as the initiating events of a kinematic chain-reaction. Correct hand placement before standing up from the chair usually results in a shorter duration of SitTS and greater symmetry of weight bearing. Torso-limb coupling is a complex neural circuit pathway [24–26], and a fundamental concept, often used in clinical practice to train hemiparetic patients.

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Torso-limb coupling also enhances activity through alignment of limbs and body segments.

4.5.4 The effect of foot and hand positions on leg load discrepancy

This whole section is unclear and disorganized. There are some good points but none are fully developed or linked to results. Although the asymmetry index has been studied for various events (such as seat-off), this may not have been sufficient in representing the actual muscle activity after each event. Throughout the SitTS task, the Fab position led the lowest degree of leg load discrepancy.

The stroke patients in this study, with mild functional impairment, compensate for increased difficulty in rising from a chair by attempting to increase body momentum. While increasing their momentum, they also need to maintain postural stability. Thus, the subjects in this study were likely presented with two conflicting situations: the biomechanical result of projecting the COM onto the posterior foot (affected lower extremity); and the natural tendency to put more weight on the unaffected side. The large leg load discrepancy observed asymmetrical foot placement is most likely a compromise in this difficult situation. The findings in this study, regarding reduced weight-bearing asymmetry, are consistent in terms of leg load discrepancy.

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4.6 **Limitations**

First, due to the high demands of this study in terms of participant effort and time, only 21 subjects with relatively high functional performance completed all trials. Though study subjects had only mild impairments, significant differences were observed among postural configurations in this study. It could be inferred that asymmetry of weight bearing may be even more marked in subjects with moderate and severe functional impairments. Second, the kinematic data of the upper extremities and trunk are not included in this study. Understanding the interaction of the limbs and trunk and changes in COM would be helpful in determining strategies used by, in, hemiparetic patients performing the SitTS task. Further studies utilizing full body markers and electromyographic recordings during SitTS are required to elucidate the neural control of interactions between the trunk and limbs.

4.7 **Conclusions**

The FabHc position leads to shorter movement durations before rising up and increased leg load symmetry during SitTS. Using the FabHc position for rising up and releasing clasped hands for more stability after standing is a useful strategy for stroke patients performing the SitTS task. Using this strategy, to train stroke patients

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according to the purpose of training, clinicians can provide more effective therapeutic interventions for specific underlying impairments.

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Suppliers

a. Optotrak Certus, Northern Digital Inc, Waterloo, Ontario, Canada

b. AMTI, Advanced Mechanical Technology, Inc., Watertown, MA, USA

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Chapter 5. Multidisciplinary interventions for fall prevention related to the stroke

We had presented the research results that the previous stroke was one of risk factor of fall and fall related injury (OR=2.9, 95% CI. 1.6~6.3).[1] A high sensitivity and specificity multivariate regression model was built to predict risks of fall for community-dwelling stroke patients, and asymmetrical gait pattern [adjusted odds ratio, aOR = 2.2, 95% CI (1.2–3.8)], spasticity of gastrocnemius [aOR = 3.2 (1.4–7.3)], and depression [aOR = 1.4 (1.2–1.8)]; the accuracy of model is 0.856; Model two: low score of functional independent measure [aOR = 0.9 (0.9–1.0)], asymmetrical gait pattern [aOR = 3.6 (1.4–9.2)] and postural sway in mediolateral direction [aOR = 1.7 (1.0–2.7)] were identified as independent risk factors. Furthermore, the leg and hand strategies during the sit-to-stand and stand-to-sit task, which is related to fall risk during the transfer, were investigated. All these information were useful for making strategies of multidisciplinary interventions for fall prevention related to the stroke. Recently, the ways of intervention for stroke patients is changing toward a biopsychosocial care model, instead of traditional biological model which only focused on physical condition. The International Classification of Functioning, Disability and Health (ICF) model is based on the interactions of body functions, body structures, activities and participation, the

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environment, and personal factors. This model can be used to gather information from biological, psychological, and social perspectives. Therefore, the ICF model is an appropriate model for comprehensive fall prevention to organize fall-related risk factors in stroke patients.

5.1 Fall prevention and management related to the stroke

Among the interventions studied in our publications and conference papers, a multifactorial falls risk assessment and management were list below in Table 5-1. It includes that exercise program (Yuanji-dance), physical therapy (electrical acupuncture), and Botulinum Toxin Type-A for spasticity reduction. Although multifactorial fall prevention interventions might be effective for individual patients. However, for community programs for stroke populations still have risks, targeted single intervention is as effective as multifactorial interventions in the beginning of intervention, may be more acceptable and cost effective.

Table 5-1 Publications and conferences related to fall prevention for the stroke.

Items	Publications and Conferences	Method
Spasticity reduction	1. Early Injection of Botulinum Toxin Type-A and Electrical Stimulation Improve Upper Extremity Motor	Botulinum Toxin Type-A

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	Function in Stroke Patients(2016 ISPRM) 2. Effect of Electro-acupuncture on Decreasing Spasticity of Lower Limbs in Stroke Patients. Journal of Chinese Medical Association of Acupuncture, 2004	Electrical acupuncture
Improvement of Balance & Gait (Asymmetric-al gait)	1. Application of Electroacupuncture for Improving Gait Performance of Stroke Patient. Journal of Rehabilitation Medicine Association, 1992 2. The Immediate Effect of Electro-acupuncture on Gait in Stroke Patients with Spastic Hemiplegia. Journal of Chinese Medical Association of Acupuncture, 2011 3. The effect of Chinese Yuanji-dance on Dynamic Balance and the Associated Attentional Demands in Elderly Adults. J Sport Sci Med, 2010	Electrical acupuncture Yuanji-dance
Depression	1. The Influence of Nasogastric Tube to Post-Stroke Depressive Tendency and Functional Outcome. Journal of Rehabilitation Medicine Association, 2006	Nasogastric Tube
Biopsychosocial assessment & intervention	1. Delphi-Based Assessment of Fall-Related Risk Factors in Acute Rehabilitation Settings According to the ICF. Archives of Physical Medicine and Rehabilitation,2014 2. Geriatric health promotion Ch 9: Fall prevention in the elderly. Farseeing publisher, 2012	ICF model (Core set) Comprehensive management

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5.2 Treatments of spasticity improves gait asymmetry

Spasticity is an upper motor neuron syndrome. It may cause a variety of symptoms that interfere with function. Interventions effects of spasticity management in stroke patients are affected by the length of onset, severity, and distribution of the spasticity; the locations of injury; the presence and severity of co-morbidities; the family support; and the goals of treatment (Figure 5-1). In stroke patients, inadequate motor unit recruitment and co-contraction attributable to impaired antagonist inhibition play in the movement disorder of the hemiplegic limbs. Electromyographic data could record muscle activities from agonist and antagonist muscles while subjects attempted to do specified tasks. Inadequate recruitment of agonists, not increased activity in the antagonists, was often seen in patients who were unable to carry out the movement tasks. A case study with co-activation of leg muscles in a patient with stroke was shown in Figure 5-2.

Abnormal muscle tone reduction is indicated if spasticity interferes with some level of function, positioning, care, or comfort. Treatment goals should be well defined before treatment. Botulinum toxin may be used to treat focal spasticity as part of an overall treatment plan [4] and early intervention is suggested [5].

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Accurate injection is a fundamental prerequisite for the effective and safe treatment of focal spasticity with botulinum toxin type A (Figure 5-3), and the excellent outcome after botulinum toxin injection was shown in Figure 5-4.

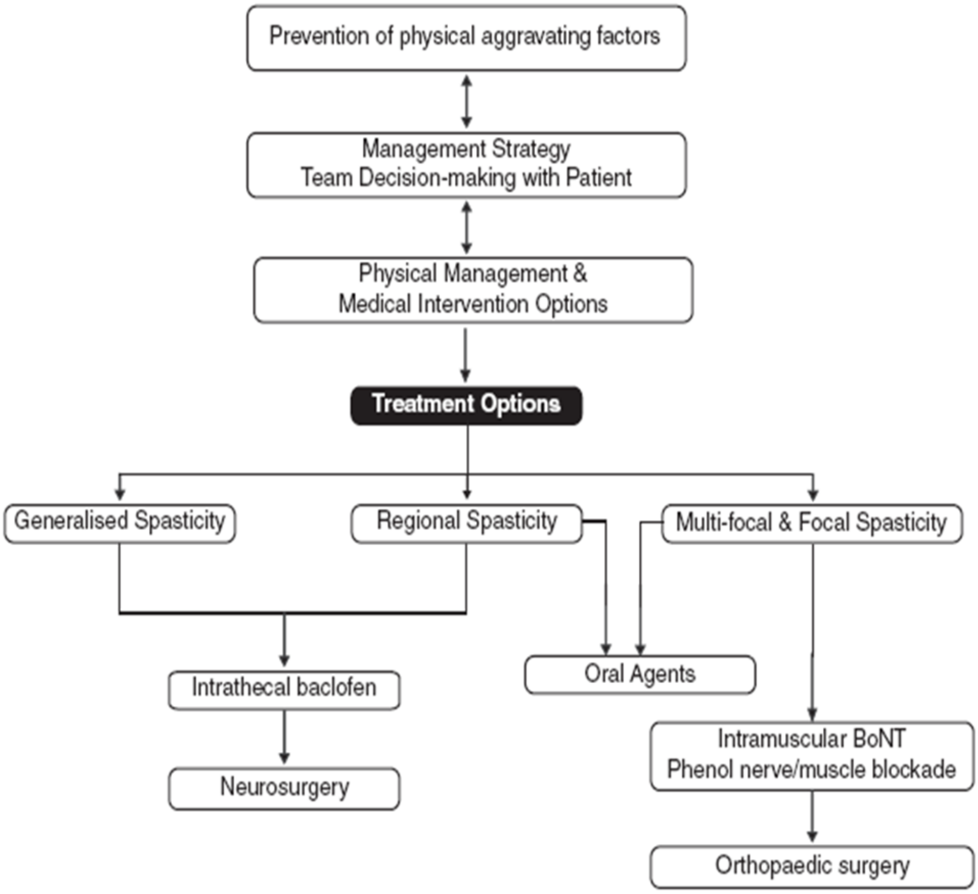

Figure 5-1 Management of spasticity algorithm.

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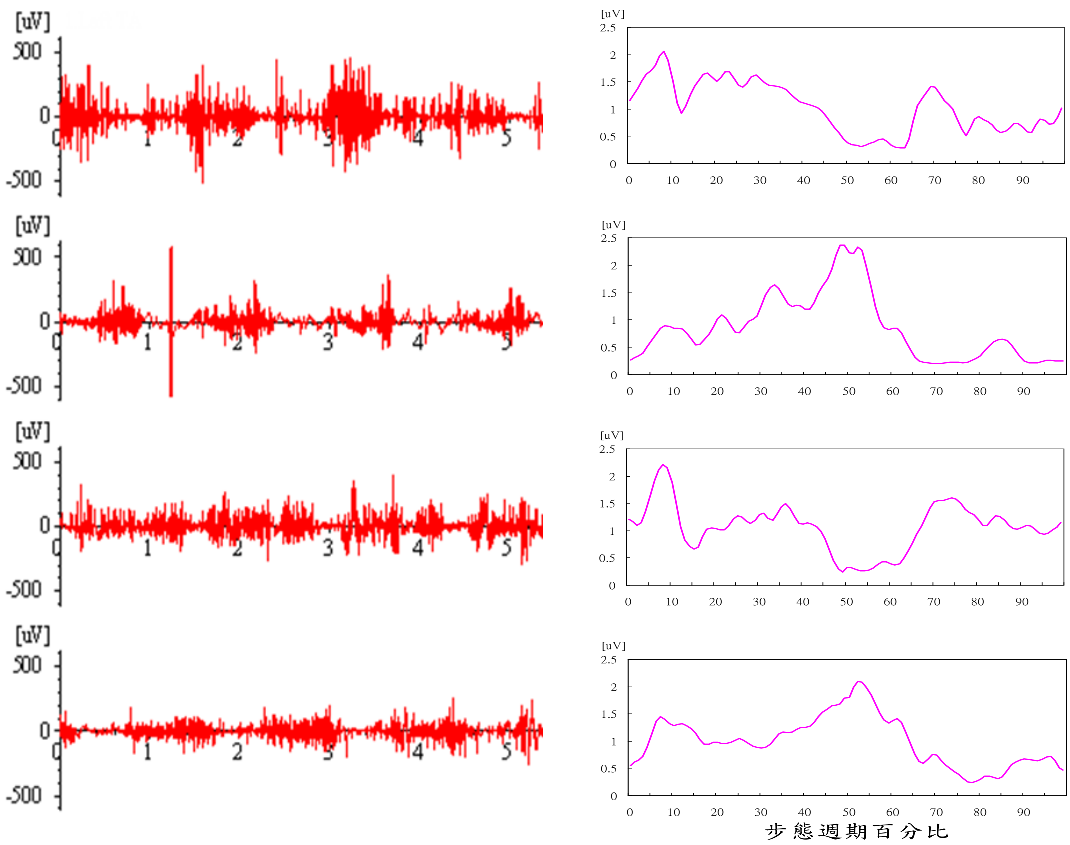

Figure 5-2 Muscle co-contraction pattern on upper and lower limbs.

Agonist-antagonist muscle co-contraction in a 70-year-old Right Hemiplegic patient.

Left: raw EMG signal at lower legs.

Right: RMS of EMG signal.

(A)L anterior tibialis (B)L gastrocnemius

(C)R anterior tibialis (D)R gastrocnemius

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Figure 5-3 Ultrasound guided Botox injection for spasticity reduction.

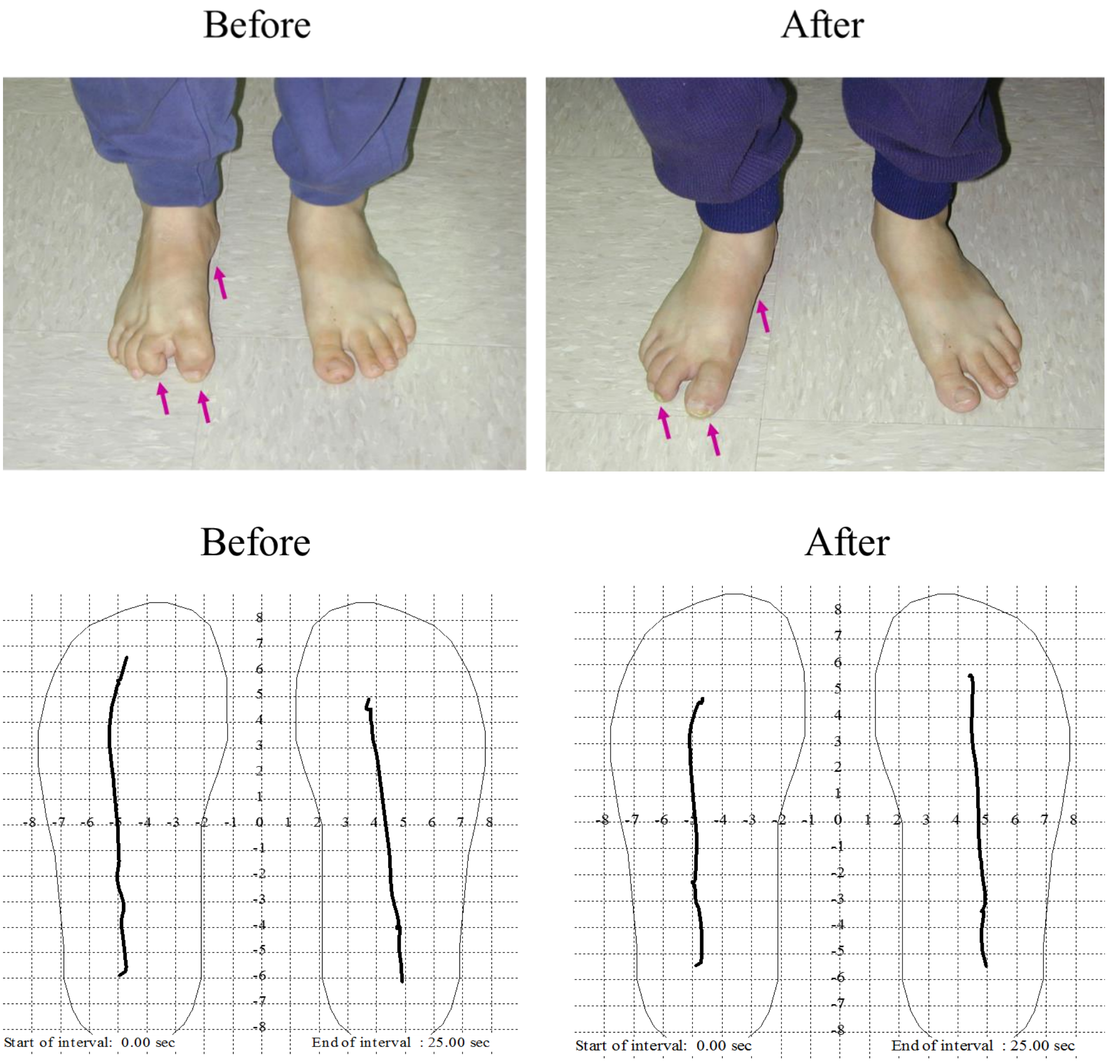

Figure 5-4 Improvement of equino-varus foot and claw toes after Botox injection.

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5.3 ICF model for fall prevention

In the past, specialists approach fall-related risk assessment and the development of prevention strategies from their own experience. Currently, the International Classification of Functioning, Disability and Health (ICF) provides a model that systematically organizes fall related risk factors into a comprehensive framework to elucidate the multiple domains of items linked to risk and their interrelations provides a holistic framework for describing and classifying diseases and health conditions.[2]

The ICF model is based on the interactions of body functions, body structures, activities and participation, the environment, and personal factors. It can be used to gather information from biological, psychological, and social perspectives. [2] Therefore, the ICF model is an appropriate model for comprehensively organizing fall-related risk factors. The advantage of an ICF core set of fall-related risk factors is that multiple fall-related risk factors can be systematically organized based on the ICF framework. A total of 88 fall-related risk factors were identified from relevant articles published between March 1987 and July 2012 were identified from the MEDLINE, PubMed, and SCOPUS databases. Among them, 86 were derived from the systematic literature review and 2 were derived from expert opinion, namely, brain structure defects and ankle spasticity (Appendix 1). This model focused on interactions

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between falls and functioning, personal attributes, and environmental influences (Figure 5-5). Table 5-2 showed that the ICF core set for falls by Delphi round in acute rehabilitation settings. A total of 34 categories achieved threshold values of importance after the third round: 18 categories in body functions (53%), 2 categories in body structures (6%), 8 categories in activities and participation (23%), and 4 categories in environmental factors (12%). Two categories in personal factors (6%) were also identified. For the stroke patients, an example for evaluation of a Stroke patient by ICF healthcare model was shown in Table 5-3.

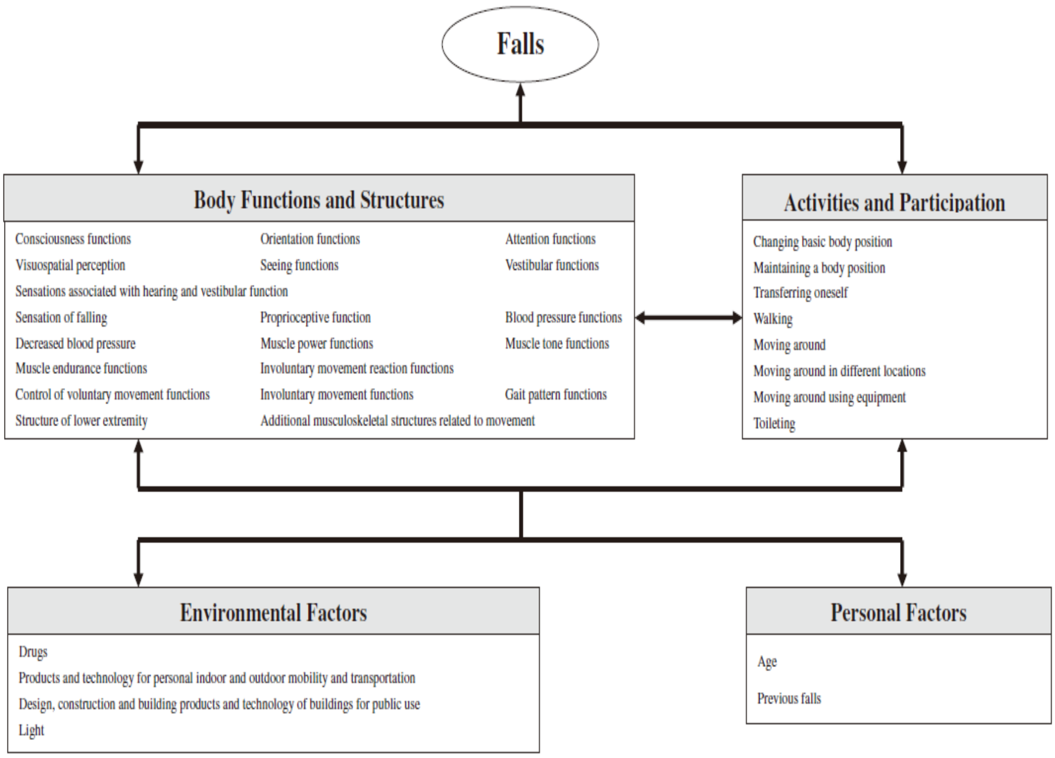

Figure 5-5 ICF core set of risk factors for falls in acute rehabilitation settings.

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Table 5-2 ICF categories included in the ICF core set for falls in acute rehabilitation settings.

ICF Code	ICF Category Title	Round1	Round2	Round3
Body functions				
b110	Consciousness functions	4.7±0.4	4.9±0.2	4.9±0.2
b114	Orientation functions	4.2±0.9	4.2±0.9	4.4±0.6
b140	Attention functions	4.2±1.2	4.1±0.9	4.2±0.7
b1565	Visuospatial perception	4.6±0.6	4.8±0.4	4.8±0.4
b210	Seeing functions	4.6±0.6	4.6±0.5	4.7±0.4
b235	Vestibular functions	4.8±0.3	4.8±0.4	4.8±0.3
b240	Sensations associated with hearing and vestibular function	4.5±0.6	4.8±0.4	4.9±0.3
b2402	Sensation of falling	4.4±0.8	4.7±0.4	4.8±0.4
b260	Proprioceptive function	4.2±1.0	4.3±0.7	4.2±0.6
b420	Blood pressure functions	4.2±1.0	4.3±0.7	4.3±0.5
b4201	Decreased blood pressure	4.5±0.8	4.7±0.5	4.7±0.4
b730	Muscle power functions	4.8±0.3	5.0±0.0	5.0±0.0
b735	Muscle tone functions	4.6±0.5	4.7±0.5	4.8±0.3
b740	Muscle endurance functions	4.4±0.7	4.6±0.5	4.7±0.4
b755	Involuntary movement reaction functions	4.5±0.6	4.5±0.7	4.6±0.6
b760	Control of voluntary movement functions	4.6±0.5	4.8±0.4	4.8±0.3
b765	Involuntary movement functions	4.1±0.9	4.2±0.7	4.1±0.4
b770	Gait pattern functions	4.8±0.3	4.9±0.2	4.9±0.2
Body structures				
s750	Structure of lower extremity	4.5±0.6	4.6±0.5	4.7±0.4
s770	Additional musculoskeletal structures related to movement	4.1±0.9	4.0±0.7	4.0±0.7
Activities and participation				
d410	Changing basic body position	4.4±0.7	4.5±0.6	4.6±0.6
d415	Maintaining a body position	4.3±0.8	4.2±0.5	4.2±0.4
d420	Transferring oneself	4.4±0.6	4.5±0.5	4.5±0.5
d450	Walking	4.7±0.9	4.9±0.3	4.9±0.3
d455	Moving around	4.0±1.2	4.1±0.8	4.1±0.7

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d460	Moving around in different locations	4.3±1.0	4.4±0.6	4.3±0.6
d465	Moving around using equipment	4.0±1.0	3.9±0.7*	4.0±0.7
d530	Toileting	4.2±1.1	4.2±0.6	4.2±0.6
Environmental factors				
e1101	Drugs	3.9±1.1	4.1±0.7	4.0±0.6
e120	Products and technology for personal indoor and outdoor mobility and transportation	4.1±1.1	4.1±0.7	4.1±0.4
e150	Design, construction, building products, and technology of buildings for public use	4.4±0.8	4.4±0.6	4.4±0.5
e240	Light	4±1.0	4.0±0.9	4.0±0.7
Personal factors				
Age		4.7±0.5	4.8±0.5	4.8±0.3
Previous falls		4.9±0.2	4.9±0.2	4.9±0.2

NOTE. Values shown are the group's (20 experts) mean scores ±SD from a 5-point Likert scale.

* Categories with a mean score <4 in each round.

* The ICD codes with gray mark are consistent with the our findings in chapter 1

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Table 5-3 Evaluation of a stroke patient by ICF model.

<table>
<tr><td></td><td>Name:
Mr. Chuang
Age: 80</td><td>Medical diagnosis:
Ischemic stroke (I 63) with left hemiplegia and aphasia</td><td>Primary goal of rehabilitation:
Enhance independence of daily activity (FIM reach 80)
Prevent fall, reduce shoulder pain (VAS=2)
Inside walking with cane</td></tr>
<tr><td>Patient's perspective</td><td colspan="2">L't hemiplegia
Marked L't shoulder pain after assisted flexion (VAS=5)</td><td>Sitting independently
Standing for more than 10 minutes under minimal assistance
Slow walking with assistance of quad-cane for 10 meters
Favor to take a walk in the park, but refuse it after stroke event
Disability for engaging the farmer's work
Poor expression which lead to communication disturbance</td></tr>
<tr><td></td><td colspan="2">Body structures/ Functions</td><td>Activities/ Participation</td></tr>
<tr><td rowspan="2">Health professional's perspective</td><td colspan="2">L't shoulder ROM limited, (ER-60°, Abducted-160°)
Loss of muscle strength (MMT: 1-2)
Increased muscle tone (MAS:1-2)
Poor coordination
Abnormal gait pattern (drop foot in swing phase)</td><td>Moderate assisted in ADLs (FIM=68)
Transfer from wheelchair to bed (moderate support)
No active arm movement
Movement around using wheelchair need others assisted</td></tr>
<tr><td>Contextual factors:</td><td colspan="2">Environmental: Lives in a second floor flat, no elevator; good family support; had cane, wheelchair and AFO's, no other assistive products
Personal: a farmer, depression after stroke, lives with son; comorbidity- HTN, DM</td></tr>
</table>

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Appendix 1 Eighty-eight fall-related parameters and their linked 66 ICF categories and 5 personal factors.

	Fall-Related Parameters	Linked ICF Categories
Personal		
1. Age		Personal factors
2. Sex		Personal factors
3. Previous fall		Personal factors
4. Level of education		Personal factors
5. Marital status (single)		Personal factors
Disease		
6. Stroke		Health condition
7. Parkinson's disease		Health condition
8. Dementia		Health condition
9. Amputation		s750 Structure of lower extremity
		s770 Additional musculoskeletal structures related to movement
10. Knee osteoarthritis		Health condition
11. Ischemic heart disease		Health condition
12. Brain structural defect*		s110 Structure of brain
Nutrition and electrolyte		
13. Vitamin D supplementation		b520 Assimilation functions
		b540 General metabolic functions
14. Electrolyte abnormalities		b545 Water, mineral, and electrolyte balance functions
Physical		
Balance and posture stability	15. Berg Balance Scale	b235 Vestibular functions
	16. Tinetti balance scale	b755 Involuntary movement reaction functions
	17. Timed Up &Go test	b760 Control of voluntary movement functions
	18. Posturography	b765 Involuntary movement functions
		d410 Changing basic body position

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		d415 Maintaining a body position
Gait stability	19. Functionalambulation categories	b770 Gait pattern functions
	20. Use of walking aids	d465 Moving around using equipment
Motor status related to stroke	21. Grip strength on affected/unaffected side	b730 Muscle power functions
	22. Quadriceps strength	b735 Muscle tone functions
	23. Left side motor deficit	b740 Muscle endurance functions
	24. Bilateral motor impairment	d445 Hand and arm use
	25. Motricity index	
	26. Chedoke-McMaster Stroke Impairment Inventory-arm, leg, foot	
	27. Brunnstrom stage	
	28. Fugl-Meyer Assessment Scale	
	29. Modified Ashworth Scale-ankle spasticity*	
30. Aphasia		b167 Mental functions of language
31. Vision impairment		b210 Seeing functions
32. Hearing impairment		b230 Hearing functions
33. Proprioceptive impairment		b260 Proprioceptive function
34. Perceptual deficit		b156 Perceptual functions
35. Urinary incontinence		b620 Urination functions
		d530 Toileting
36. Foot problem/pain		b28015 Pain in lower limb
37. Chronic musculoskeletal pain		b280 Sensation of pain
		b840 Sensation related to the skin
38. Hemineglect	Star Cancellation Test	b1565 Visuospatial functions
39. Attention		b140 Attention functions

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Cognition	40. Mini-Mental State Examination 41. Abbreviated Mental Test	d160 Focusing attention b164 Higher-level cognitive functions
42. Impulse control		b1304 Impulse control
43. Agitation		b1263 Psychic stability
44. Confusion/disorientation		b110 Consciousness functions b114 Orientation functions
Fear of falling	45. Falls Efficacy Scale 46. Activities-specific Balance Confidence Scale	b2402 Sensation of falling
47. Depression	Geriatric Depression Scale	b152 Emotional functions
48. Executive function	Stroop test	b164 Higher-level cognitive functions d155 Acquiring skills
49. Sleep function		b134 Sleep functions
50. Postural hypotension		b420 Blood pressure functions b4201 Decreased blood pressure
51. Dizziness/vertigo		b240 Sensations associated with hearing and vestibular function
Stroke disease severity		
52. National Institutes of Health Stroke Scale		Not definable
53. Scandinavian Stroke Scale		
54. Stroke Impairment Scale		
55. Bilateral lesions		
Level of functional independence		
Barthel Index Katz Index FIM	56. Eating/feeding 57. Grooming 58. Bathing 59. Dressing upper body/lower body 60. Toileting	d230 Carrying out daily routine d420 Transferring oneself d450 Walking d455 Moving around d460 Moving around in different locations

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	61. Bowel management	d469Walkingand moving, other specified and unspecified
	62. Bladder management	d520Caringfor bodyparts
	63. Transfer	d510 Washing oneself
	64. Walking	d540Dressing
	65. Up/down stairs	d530Toileting
		d550 Eating
		d560Drinking
		d570Lookingafter one's health
Medications		
66. Antidepressant		e1101 Drugs
67. Diuretics		
68. Sedatives		
69. Antihypertensive medication		
70. Anti-Parkinsonism		
71. Antiepileptics		
72. Neuroleptics		
73. Polypharmacy (>4 medications)		
Time of falling	74. Daytime	e245 Time-related changes
Location of falling	75. Patient's room	Not covered by ICF
	76. Bathroom	d530 Toileting
Activities when falling	77. Transferring from sit to stand	e120 Products and technology of personal indoor and outdoor mobility and transportation
	78. Wheelchair activity	
	79. Walking	d420 Transferring oneself
		d450 Walking
80. Time after admission to rehabilitation facilities		Not definable
81. Efficiency of rehabilitation	Gains in Barthel Index after rehabilitation	Not definable
Environmental and home hazards		
82. Improper foot wear		e1150 General products and technologyfor personal use in daily
83. Loose rugs		living

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84. Lack of hand rails	e120 Products and technology of personal indoor and outdoor mobility and transportation e150 Design, construction, building products, and technology of buildings for public use
85. Light	e240 Light
86. Unobserved/living alone	e310 Immediate family e340 Personal care providers and personal assistants
87. Health education/nursing staff adequacy	e355 Health professionals
88. Health policy	e515 Architecture and construction services, systems, and policies e580 Health services, systems, and policies

* Fall-related parameters derived from expert opinion.

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