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生物迴饋站立平衡訓練儀之研發與臨床評估-初步報告

郭榮昆　黃美涓　李明義*　鄧復旦

對於半身偏癱(hemiplegia)的病人，站立對稱平衡(postural symmetry)和步長及偏癱的嚴重度有極大的相關性。傳統站立平衡訓練儀為腦傷病患如腦血管病變以及頭部外傷病患等患者在復健治療中極為重要且常用的一項訓練工具。其主要功能係在於訓練病患重建其站立靜態和動態平衡功能，以奠定日後學習步行及自立生活的能力。

在本研究中，設計製作一部具生物回饋的站立平衡訓練儀，這部儀器是以傳統站立平衡訓練桌加上迴饋系統（biofeedback）而成。兩腳底板均各有一踩重的儀器式感應計測器及一組可及時顯示之視覺/聽覺迴饋顯示器。並且將急性中風後及頭部外傷病患六十名隨機分成控制組及實驗組，經過四星期的訓練後，實驗組及控制組之姿勢對稱百分比由15.6±10.5%及16.8±10.3% 降至3.5±2.2%及10.1±6.4%（p=0.002）。左側及右側偏癱均無差異，結果顯示這部新型迴饋站立平衡訓練儀對中風患者在站立對稱有較好的訓練療效。

關鍵詞：生物迴饋(biofeedback)，站立訓練(standing training)，姿勢對稱性(postural symmetry)，復健(rehabilitation)

前　言

腦血管病變及頭部外傷（head injury）在發生後常會後遺半身偏癱（hemiplegia)或四肢運動障礙等。這些患者接受復健的過程，首重站立平衡（standing balance）的訓練，因為偏癱的病人均有站姿不平衡的問題，常以好腳來支撐大部份的體重[1,2]，國外研究發現許多中風病人步態對稱性（symmetry）與運動功能損傷的嚴重度及住院日的長短均有極強的相關性。

對於偏癱病患下肢的負重運動訓練，在傳統上是由物理治療師經各種徒手操作技巧來訓練。並加上職能治療師經由動態穩定站立活動來作姿勢調整，及經由不同的平衡控制做平衡訓練[6,11]。而站立平衡訓練過程都須治療師在一旁，依個人主觀判斷指導、修正病患的站姿，不但缺乏客觀評估標準，也造成治療人力的浪費。一般而言，大部份的治療師均不知道在訓練過程中有多少重量轉移至患側肢。而且對於患肢載重是否改善通常都是依治療師個人主觀的判定或是經由一些間接的測量方法來判定，例如視個人日常生活自理能力進步的情形等。

本研究將常用的站立平衡訓練桌加上自行設計的生物迴饋系統以電子式磅秤測得兩腳直立著地載重，經由視覺及聽覺警示訊號系統作迴饋訓練(圖1）。為了評估臨床使用療效，亦在病患復健訓練過程針對平衡訓練效果、姿勢作客觀評估。

材料與方法

新發展的生物迴饋站立平衡訓練儀

這部新型的生物迴饋站立平衡訓練儀，是經由傳統站立平衡訓練儀改良而來，包括每一腳踏板（force platform）有負重大小的測重感應器（pressure

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sensor）可以經桌前的鏡面（postural correction mirror）及時顯示出數字大小和燈號數目多寡（light emitting diodes, LEDs）。並且有一語言系統可以告訴患者靠左站或靠右站以訓練兩側平均載重（symmetry of upright stance）。病患可任選包括國語、台語、客語三種語言。此外，本訓練儀附有骨盆腰帶及上肢懸吊設施視需要加以選用固定良好站姿（圖2）。這些改良主要目的就是要讓病患在兩腳站立時透過載重以數值和燈號及時顯示，聽覺和視覺的警告系統來做站姿的調整，並且可以克服聽力或視力不良的問題，任選其中一種作迴饋方式。

受測者

本研究中，選擇了第一次發生腦中風或頭部外傷併單側肢體偏癱病患共60名接受訓練。他們皆意識清醒，病況穩定且沒有任何併發症，預估經過復健訓練後有功能性行走能力者。我們將其隨機分成兩組各30名，兩組的偏癱嚴重度均相當，受試者的特性如表1及表2所示。兩組均接受同樣的物理治療及職能治療訓練。

實驗設計

實驗組和控制組在訓練前和訓練後都接受一連串的測試，每週測試一次，受測者經過3~4週的訓練和測試期間。整個實驗設計包含一混和式兩因素模式，也就是受測者自我重複測試的比較。病患接受物理治療和職能治療規畫的內容兩組都一樣包含每天60分鐘，每週訓練五天，共訓練3~4星期。在職能治療的部份控制組使用傳統站立平衡儀，實驗組用改良式生物迴饋站立平衡儀，每天訓練20分鐘。

資料分析

本研究評估病患站立能力進步程度以站姿對稱性

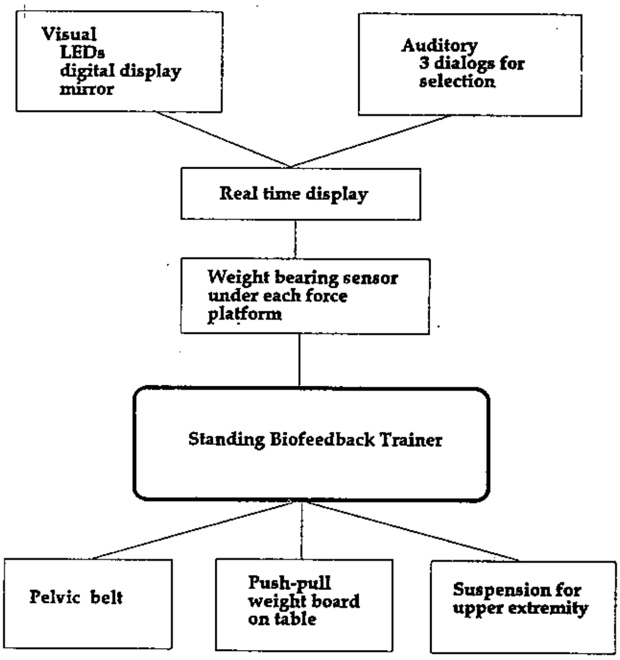

Fig 1. Functional Design of the New Standing Biofeedback Training Device

Table 1. Subject Data

Group	Experimental (n=30)	Control (n=30)	Total (n=60)
Age (y/o)	45.4 ±16.9	52.8 ±12.36	49.1 ±15.2
Sex M	20	22	42
F	10	8	18
Etiology			
CVA	22	28	50
Head injury	8	2	10

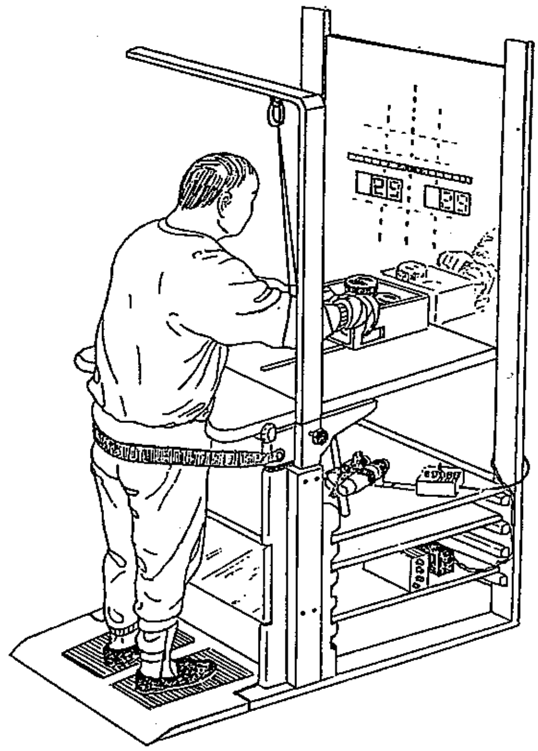

Fig 2. The Biofeedback standing trainer with visual and auditory display for keeping stance symmetry.

Table 2. The severity of hemiplegia according to Brunnstrom's stage in both groups.

Group / Br. stage	Experimental	Control	Total
II	7	10	17
III	4	8	12
IV	7	7	14
V	12	5	17
Total	30	30	60

(postural symmetry)為主。

$$\text{站姿對稱性指數} = \left| \frac{\text{患側載重量}}{\text{重量}} - 0.5 \right| \times 100\%$$

由以上計算程式，若兩側載重均等則站姿對稱性數值等於零，數值愈大表示兩腳載重相差愈多。實驗組及控制組訓練的效果及訓練前後都使用本站立平衡儀之視、聽迴饋系統作測試。測試結果之個人數值連續變化均以paired t-test和變異數分析（ANOVA）作比較。所有分析均取$p < 0.05$為顯著差異。

Table 3. Effect of Balance Training in both Groups.

	Experimental Group		Control Group		
	No.	Mean±SD (%)	No.	Mean ±SD (%)	P
Pre-training	30	△15.6 ± 10.5	30	□16.8±10.3	0.666
Post-training					
Day 1	30	△9.6 ± 9.4	30	□15.4 ±9.6	0.020*
Week1	30	7.9 ±5.9	30	12.7 ±7.6	0.010*
Week2	30	5.7 ±4.9	30	10.2 ±5.9	0.002*
Week3	19	5.3 ±4.7	21	9.2 ±5.7	0.024*
Week4	14	3.5 ±2.2	11	10.1 ±6.4	0.002*

* P< 0.05

△P=0.020* □P=0.590

結　果

姿勢對稱性百分比顯示病患維持站立平衡改善的情形，以paired t-test 的統計比較分析如表3所示實驗組在第一天就有立即學習效果，姿勢對稱性指數由15.6±10.5 % 降至9.6±9.4% (p=0.02)。控制組則僅由16.8±10.3% 降低至15.4±9.6% (p=0.59)。經過3~4週的訓練，實驗組和控制組的姿勢對稱性指數百分比分別降至3.5±2.2% 和 10.1±6.4% ，顯示實驗組效果較控制組為佳。兩組的訓練效果，若以每日平均值畫出的曲線（圖 3)，實驗組及控制組兩組病患均有趨向平衡點的趨勢。但仍以使用生物迴饋訓練比用傳統方式可更早更有效接近平衡點。若將患者按訓練前兩腿載重程度不等分成四組（0~10%，10~20%，20~30%，30~50%)(表4)或按下肢運動功能Brunnstrom stage (stage II,III,IV,V)分組(表5)，所得結果均以實驗組略優於控制組。

討　論

對稱性（symmetry)、穩定性（steadiness)及動態穩定性（dynamic stability)是姿勢控制的三大要素，對稱性是站立時使身體重量均勻分佈在兩腳的能力，穩定度是讓一個人保持身體儘量不晃動的一種能力，動態的穩定度則是在將重心垂直轉移到支持面的能力，在直立時姿勢控制均十分重要[12]。對於腦中風或頭部外傷併偏癱的病患，動態姿勢和移位的不對稱是在行動中最常見的缺失。在步態過程中的站立期，典型的情形是患側相對於非患側受到相當大的限制，無法將重量轉移到患側。

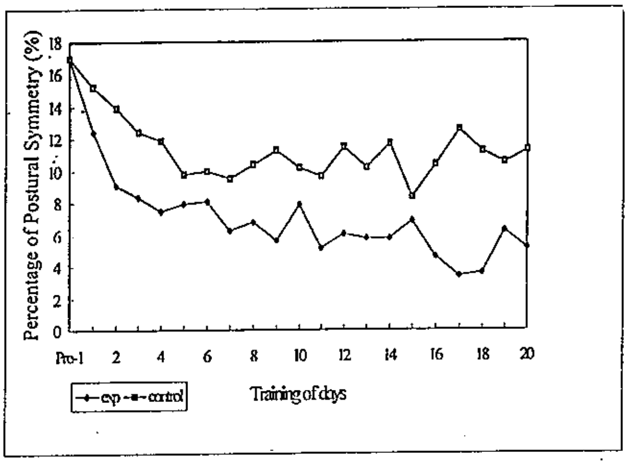

Fig 3. The effect of standing training of both groups by percentage of postural symmetry in different days.

Sackleg發現腦中風病患其站立期的對稱性和住院日數長短有關[13]，而且也顯示出其嚴重度和其他功能例如運動功能，日常生活自理能力的缺失有關。Winestein曾經證實偏癱病患以視覺迴饋比沒有視覺迴饋的訓練獲得較佳的對稱性。

在本研究中，我們證實這一部具有視覺和聽覺迴饋訊號的新型生物迴饋站立平衡儀，用在偏癱病患站姿平衡對稱性訓練有較佳的療效。利用這部非常經濟的站立平衡訓練儀，治療師和病患均可了解量化兩腳載重的情形並加以改善，可得到較好的訓練療效及縮短療程。在療程中也具有能節省治療師時間的能力。我們的研究結論為（1）偏癱患者的訓練，以生物迴饋比傳統方式具有較明顯的效果。（2）用生物迴饋方式訓練，第一天便有明顯的立即訓練效果，而傳統的訓練方式則沒有。（3）使用生物迴饋的平衡訓練儀在訓練過程中，病患表示利用視覺或聽覺生物迴饋站立平衡儀因訓練時可直接看到瞬間兩腿載重差異，可自行立刻調整站姿的平衡，使學習更容易，也較能在訓練中維持注意力的集中。而傳統的治療方式則需靠治療師的調整，較耗費人力。（4）對於中等程度偏癱者，例如Brunnstrom's stage III或距離兩腳平衡重量差百分比在10%~30%，特別適合用生物迴饋的站立平衡儀作自我訓練。

由於偏癱病患的選擇須脫離急性期後才評估可否加入做為測試對象，且部份病患後遺運動功能較佳，

或受併發症之影響，致未達測試四星期。本篇為一初步報告，未來本研究尚須改進之處有：病患為隨機分配，卻仍有實驗組較多頭部外傷之情形，以及病患包含腦中風及頭部外傷患者，可能影響評估的結果。目前已針對這些問題改進並對不同中風部位加以分組做訓練評估中，待有結論再進一步報告。

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Table 4. The effect of balance training in both groups according to levels of weight bearing differences at bilateral legs.

	Experiment Group		Control Group		
	No.	Mean±SD (%)	No.	Mean±SD (%)	P
Group 1 (X=0~10%)					
Pre-training	13	6.8±2.7	8	5.8±2.8	0.382
Post-training					
Week1	13	5.2±5.5	8	5.5±3.2	0.876
Week 2	13	3.9±3.2	8	4.1±2.0	0.887
Week 3	7	3.8±4.6	6	4.3±1.4	0.904
Week 4	6	4.1±2.2	2	4.7±3.8	0.704
Group 2(X=10~20%)					
Pre-training	10	15.8±2.9	14	15.3±2.8	0.848
Post-training					
Week 1	10	7.8±3.9	14	11.1±5.2	0.052
Week 2	10	4.6±3.3	14	10.2±5.4	0.002*
Week 3	7	4.9±5.3	9	8.9±4.8	0.140
Week 4	3	3.0±3.2	6	9.2±3.7	0.044*
Group 3(X=20~30%)					
Pre-training	4	27.5±2.1	5	24.6±2.9	0.136
Post-training					
Week 1	4	10.7±4.7	5	19.4±2.4	0.008*
Week 2	4	8.0±6.4	5	16.5±4.4	0.050*
Week 3	2	7.9±6.1	3	14.5±6.0	0.320
Week 4	2	3.2±1.1	2	10.7±1.6	0.034*
Group 4(X=30~50%)					
Pre-training	4	37.3±4.0	3	39.0±6.9	0.753
Post-training					
Week 1	4	17.8±5.3	3	25.4±7.5	0.217
Week 2	4	14.7±5.9	3	13.5±5.3	1.000
Week 3	4	11.9±9.5	3	14.5±5.6	0.169
Week 4	4	5.5±4.4	1	-	-

X=% of weight bearing difference at bilateral legs.
*P<0.05

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Table 5. The effect of balance training in both groups according to differences Brunnstrom's stage of the patients.

	Experiment Group		Control Group		
	No.	Mean±SD (%)	No.	Mean±SD (%)	P
Br.stage II					
Pre-training	7	25.0±13.7	10	23.1±13.5	0.781
Post-training					
Week1	7	12.7±6.9	10	14.9±10.0	0.627
Week 2	7	11.0±6.3	10	10.6±5.1	0.900
Week 3	6	9.0±4.8	8	8.7±5.9	0.920
Week 4	5	3.9±1.9	3	13.8±11.4	0.094
Br.stage III					
Pre-training	4	14.8±4.0	8	16.1±7.4	0.125
Post-training					
Week 1	4	7.1±2.7	8	13.6±6.8	0.004*
Week 2	4	2.6±1.1	8	11.1±5.4	0.0003*
Week 3	3	2.2±0.9	4	11.0±5.2	0.0002*
Week 4	1	-	3	9.6±2.6	-
Br.stage IV					
Pre-training	7	14.4±9.4	7	10.9±6.0	0.414
Post-training					
Week 1	7	7.0±5.1	7	11.6±4.4	0.196
Week 2	7	4.6±3.3	7	9.2±6.5	0.120
Week 3	4	3.8±4.2	6	8.5±5.6	0.200
Week 4	3	3.2±3.1	5	8.3±4.3	0.125
Br.stage V					
Pre-training	12	11.2±4.0	5	13.6±5.6	0.529
Post-training					
Week 1	12	6.1±7.6	5	8.4±6.7	0.480
Week 2	12	4.2±5.7	5	13.5±8.9	0.089
Week 3	6	4.3±3.1	3	14.5±8.4	0.242
Week 4	4	3.5±2.5	0	-	-

*P<0.05

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Clinical Investigation of A New Design Standing Balance Training Device with Biofeeedback-A Preliminary Report

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For the patient with neurological damage of central nervous system, such as CVA or head injury, standing balance training is very important before walking and self-care training. Stance symmetry in hemiplegic patients had been reported to be significantly related to measurement of severity and length of stay.

The present equipment for standing balance training in occupational therapy is too simple in design and with limited function, lack of self-feedback system, unable to adjust the slope of the training table. A newly standing biofeedback training device including instrumented sensors of weight bearing under dual force platform and a real time visual/auditory feedback system had been developed for postural training.

Sixty patients with hemiplegia after acute stroke or traumatic brain injury were randomly divided into an experimental and a control groups. They were either trained by the new designed standing balance equipment or the conventional equipment for 5 times per week, 20 minutes at each section. After training for a period of four weeks, the percentage of postural symmetry in experimental and control groups were reduce from 15.6 ± 10.5 % and 16.8 ± 10.3 % to 3.5 ± 2.2 % and 10.1 ± 6.4 % respectively (p=0.002). There was no significant difference between right and left hemiplegia patients. The results indicated that this newly designed standing biofeedback device had good training effect on stance symmetry in hemiplegic patients.

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