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原著

六週跑步機訓練對下肢燒燙傷傷患平衡能力及生活品質之影響：初探研究

陳生松[1]　陳福成[2,*]

摘要

背景：下肢燒燙傷會限制患者的肢體活動，並導致肌力和平衡能力下降，進而影響日常生活和工作能力。為改善這些問題，跑步機常用作復健工具，以提升患者的平衡能力與生活品質。

方法：研究對象為 10 名住院且已無需手術的下肢燒燙傷患者，隨機分為兩組。實驗組每日進行 30 分鐘常規復健，合併每週 3 次、每次 30 分鐘跑步機訓練；對照組僅接受每日 30 分鐘常規復健。所有參與者在前、中、後期分別接受燒燙傷健康量表台灣精簡版與伯格氏平衡量表的評估，並依自覺運動強度量表調整跑步機速度，統計採用無母數分析。

結果：實驗組與對照組在平衡能力皆有顯著進步，但兩組的進步幅度無顯著差異。

結論：下肢燒燙傷患者經由 6 週的常規復健訓練合併跑步機訓練後，於平衡能力有顯著進步；然此進步幅度與僅接受常規復健訓練者接近。建議未來增加樣本數以增加統計檢定力。

關鍵詞：燒燙傷、平衡、生活品質、跑步機訓練

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Original article

Effect of Six Weeks Treadmill Training on the Balance Function and Quality of Life in Patients With Lower Extremity Burn Injury: A Pilot Study

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Abstract

Background: Burns on lower extremity not only limit limb movements but also lead to decreases in muscle strength and balance function, which in turn affects daily life, work capabilities, and quality of life. Therefore, treadmills are often used as rehabilitation training tools to improve balance and quality of life.
Methods: 10 hospitalized patients with burns on lower extremity, who no longer required surgery, were randomly assigned into an experimental group (30-minute daily conventional rehabilitation activities plus 30-minute treadmill activity, three times a week for 6 weeks) or a control group (only 30-minute daily conventional rehabilitation activities). Outcome measures included the Taiwanese version of the Burn Specific Health Scale-Brief (BSHS-B-Taiwanese) and Berg's Balance Scale (BBS). Treadmill speed was adjusted based on the Rating of Perceived Exertion (RPE). Data were analyzed by nonparametric statistics.
Results: Both the experimental and control groups had significant improvement in balance and quality of life after the 6-week intervention period. However, there was no significant differences between the two groups.
Conclusions: After six weeks of conventional rehabilitation combined with treadmill training, patients with lower limb burns showed significant improvements in balance and quality of life; the extent of improvement was comparable to that of patients who received only conventional rehabilitation.

Keywords: Balance, Burn injury, Quality of life, Treadmill training

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前言

燒燙傷是日常生活中常發生的意外事件，凡是因火焰、熱液、高溫物體、電擊、化學物質或放射物質等對人體所造成的傷害就稱為燒燙傷 (Clark et al., 2018)。嚴重燒燙傷對於個案整體健康生理功能影響很大，包含：急性期的水腫、傷口疼痛及收縮、穩定期的關節活動受限、疤痕攣縮 (Scar Contracture)，都會造成生活品質低落 (Palackic et al., 2021; Schouten et al., 2021)。而下肢燒燙傷患者不只關節活動範圍減少，更會降低個案肌力、平衡能力，長期下來進而造成身體失能，乃至於日常生活活動功能、重返工作的能力以及生活品質都會受到損害。

運動對燒燙傷後體適能的改善及肌力的復原有極大的益處，尤其是有氧運動及阻力性運動，都能改善身體組成、預防疤痕攣縮以及提升生活品質 (de Lateur et al., 2007; Flores et al., 2020)。一般來說有氧運動的運動類型大概是跑步機、腳踏健力車 (Cycle Ergometers)、橢圓機 (Elliptical Machines)、手臂健力車 (Arm Ergometers)、划船機，甚至足球或籃球等運動都是適合燒燙傷患者的有氧運動；而以患者的安全為優先考量的因素之下，無論在醫院復健室、健身房或居家運動設備中，跑步機仍是最常見的訓練設備器材之一。

燒燙傷患者的存活率已隨著醫療的進步而逐漸提高，但是嚴重燒燙傷患者仍需要長期住院、多次外科手術或有其他併發症而限制活動，導致在很長時間無法輕鬆自主處理日常生活活動，因此這些患者在復能時，更應加強提升日常生活功能獨立和促進生活品質 (Disseldorp et al., 2011)。跑步機運動可訓練下肢肌耐力及維持軀幹平衡，在室內能避開雨天或炎熱不適合運動的氣候，因此對於燒燙傷後皮膚暫時無法照射陽光的個案而言，可以提供作為復健訓練方式。

從受傷第一天開始應立即執行燒燙傷職能治療復健計畫直到疤痕穩定成熟為止，主要目標為維持肢體功能、防止關節攣縮變形、預防疤痕增生及恢復最大的日常生活功能 (Stekelenburg et al., 2015)，一般來說燒燙傷病人職能治療復健計畫應包含以下原則：擺位 (Position)、副木 (Splinting)、運動 (Exercise)、壓

力治療 (Pressure Therapy) (Ahuja et al., 2016)。對於意識清楚的個案，從入院開始，即應鼓勵其執行四肢及軀幹的主動運動，例如儘早下床行走及獨立完成日常生活活動 (Cartotto et al., 2023)，以避免攣縮並達到真正的肌肉收縮，也可以促進血液循環、降低水腫，鼓勵個案主動參與日常活動，提升自我成就感，建立個案對復原的信心。

燒燙傷後最大的後遺症就是疤痕增生、關節攣縮與變形，這不僅影響外觀，更會造成肢體功能及活動上的障礙，一旦受傷位置發生在下肢並造成肌肉力量的下降，都將會造成肢體平衡功能表現的障礙，而影響個案之生活品質功能及返回職場的能力，透過早期設立復健計畫、確實執行復健活動、儘早下床活動行走 (Cambiaso-Daniel et al., 2018; Cartotto et al., 2023; Gawaziuk et al., 2018; Hardee et al., 2014)，以促進日常生活功能表現。

嚴重燒燙傷傷者，由於需經歷多次清創及植皮，而植皮區若是在關節處，術後仍必須以石膏或低溫副木固定至少一週，以確保移植皮膚吻合於傷口上，因而導致下肢植皮的傷者無法下床活動；長期躺床不活動會造成肌力的下降，固定處也會使關節產生僵直的情形；除此之外，更因為肌肉無負重而產生肌肉萎縮的情形，而且下肢會比上肢嚴重，以及膝部伸肌群比膝部屈肌群肌肉力氣流失更快（李水碧 , 2000），一旦脛前肌群、小腿肌群、股四頭肌群以及腿後肌群肌力下降，平衡能力就成為下肢燒燙傷患者常見到的失能問題。

平衡包括人體在各種活動中保持、獲得或恢復穩定狀態的能力。對燒燙傷個案來說都有可能部分或全部缺失，而無法維持平衡或行走的基本能力 (Ali et al., 2015)。Ali 等針對 30 位年齡 20 至 40 歲，二度燒燙傷在 20 至 40 % 全身體表面積的傷友進行研究時發現，即使已經受傷達三個月，但是他們的平衡能力仍較差，以伯格氏平衡量表 (Berg's Balance Scale, BBS) 進行評估後發現平均分數在滿分 56 分中只得到 27 分，雖然已經可以返家休養卻仍具有中度跌倒風險。

Kornhaber 等 (2014) 統整了 14 篇研究論文，在 184 名平均年齡為 41 歲，平均燒燙傷表面積為 34 % 總表面積 (Total Body Surface Area, TBSA)，住院時間從一天到 68 個月不等的研究參與者當中。發現到影響燒燙傷恢復的因素除了肢

體的傷害所造成的身體變化外，最重要的就是因為行動限制而使生活品質下降。

燒燙傷之後的健康相關生活品質 (Health-Related Quality of Life, HRQOL) 會明顯下降，Grisbrook 等學者在 2012 年時讓九名平均受傷面積 42 ± 18.38 % TBSA 的傷友進行 12 週有氧運動訓練，以燒燙傷健康量表精簡版 (Burn Specific Health Scale-Brief, BSHS-B) 及健康狀況量表 (Medical Outcomes Study 36-Item Short Form, SF-36) 評測 HRQOL， 並以 QuickDASH (Quick Disabilities of the Arm, Shoulder and Hand) 評估日常生活及工作對個案造成的困難程度，其結果與九名對照組相比下發現，燒燙傷傷者的 BSHS-B 與 SF-36，都低於對照組的評估分數呈現，以及由 QuickDASH 發現，實驗組的活動受限程度較高，但是經由有氧運動訓練後，實驗組的 SF-36 和 QuickDASH 進步到與對照組無差異 (Grisbrook et al., 2012)。由於燒燙傷的復能是多面向的，運動訓練似乎是一種成功的介入方式，可以協助個案因重大傷害而可能出現的生理、社會、心理障礙恢復功能。因此推論運動訓練不但可以改善因燒燙傷而導致長期功能障礙的成年人的活動限制並提高生活品質，甚至還能改善輕度燒燙傷或功能較弱的燒燙傷個案的生活品質。de Lateur 在 2007 年對於 35 位嚴重燒燙傷患者進行研究時，發現經過 12 週的有氧訓練，實驗參與者的最大有氧能力都有顯著改善；而且 Abdelbasset 與 Abdelhalimy (2020) 研究發現介入六週的個別化有氧運動訓練後，參與者的生活品質能顯著改善。

步行是燒燙傷患者最常用的運動類型，因為步行是可以持續進行、又安全也易於監控，並且涉及大肌肉群的活動，因此也可視為一個很好的開始。每週進行三次每次 30 分鐘的跑步機運動計畫，持續 12 週，可顯著改善燒燙傷患者有氧體適能，而只接受常規復健訓練者則無法維持體適能 (de Lateur et al., 2007)。Ali 等 (2015) 以跑步機進行有氧訓練研究，招募 15 位成年二度燒燙傷深度在 20 % 至 40 % 全身體表面積的傷友，每週三次、每次 60 分鐘的跑步機進行有氧訓練，三個月後發現他們在 BBS 評估分數由 27 分進步到 48 分。根據文獻回顧，本研究的目的為檢測跑步機訓練對下肢燒燙傷傷患平衡能力及生活品質之影響。

方法

研究對象

本研究依據臨床取樣方便性進行招募研究參與者，招募自 112 年 8 月 22 日至 113 年 3 月 1 日期間，於高雄市某區域醫院 10 位研究參與者，並將研究參與者隨機分為實驗組 5 人與對照組 5 人。研究參與者皆符合下列條件：(1) 下肢有燒燙傷且以 BBS 初次評估得分低於 40 分；(2) 年齡在 20 到 60 歲之間；(3) 燒燙傷傷口穩定已無開刀需求；(4) 可遵循並理解治療師的指示；(5) 有意願參與者除原本安排之復健活動外，每週需增加三次跑步機運動訓練，並持續六週，每次 30 分鐘，共 18 次的運動訓練課程。排除條件為：(1) 骨骼、肌肉、呼吸循環系統，或其它周邊與中樞神經系統病變等問題（例如：巴金森氏症、內耳疾患、前庭功能缺損、小腦失能）；(2) 膝關節及髖關節曾經更換人工關節；(3) 罹患心血管疾病、代謝疾病及腎臟疾病。本研究施測流程通過國軍高雄總醫院人體試驗委員會審查准許實施 (KAFGHIRB 112-008)。

研究介入及過程

本研究篩選符合條件且有意願參與研究之參與者，填寫知情同意書後，隨機分為實驗組及對照組，所有受試者每次均接受 30 分鐘一般職能治療，實驗組參與者在休息 10 分鐘後接著進行跑步機訓練介入 30 分鐘，每週 3 次，歷時 6 週，共 18 次的訓練。

跑步機步行訓練時研究者在旁全程觀察呼吸、排汗狀況並預防姿勢性低血壓的發生，並請參與者雙手握住跑步機握把以偵測心跳，預防心跳異常。研究流程分為四個階段：包含預備、熱身、訓練及緩和。首先，在預備階段，參與者需依照熱身影片進行 5 至 10 分鐘的伸展運動，包括伸展小腿肌肉、脛前肌群、腿後肌群、股四頭肌、髂腰肌，影片內容如網址 (https://reurl.cc/zlMx70)，接著讓參與者練習上下跑步機，並告知跑步機安全閥作用，以預防跌倒危險；然後

是熱身階段，參與者由時速 1.5 公里開始熱身，讓研究者瞭解參與者可接受的速度，進行 5 分鐘的跑步機行走熱身運動；其次是訓練階段，參與者接受 20 分鐘跑步機訓練，第一週的訓練速度從時速 1.5 公里開始，每週增加時速 0.5 公里，直至第 6 週剛好是時速 4 公里；最後，在緩和階段，參與者以時速 1.5 公里慢速行走 5 分鐘緩和運動並調整呼吸。

另外，進行每次的介入活動時，在監控的時間點（活動進行之第 3、第 8、第 13、第 18、第 23 及第 28 分鐘時）上以自覺運動強度量表 (Rating of Perceived Exertion, RPE) 示意圖，詢問個案自己感覺到的運動強度，研究人員並記載於紀錄表中。訓練期以時速 1.5 公里開始，若 RPE 介於 10 分至 14 分時則緩慢提升速度，訓練速度最高不超過時速 4 公里，第 1 週及第 2 週的訓練目標則設定在 50 % 最大心跳率，第 3 週及第 4 週則設定在 60 % 最大心跳率，第 5 週及第 6 週則設定在 70 % 最大心跳率；若研究參與者在 RPE 超過 14 分時，則當週就維持與前一週相同的速度；若研究參與者在 RPE 超過 17 分時則立即停止進行活動；研究活動過程中研究參與者有任何的不適，例如：噁心、嘔吐、頭暈、冒汗等，即刻停止訓練。

研究工具

個案在進行研究前會先進行前測評估，3 週訓練完成後進行中測評估，6 週研究完畢後再進行後測評估，並以 RPE 作為記錄每一次活動進行時之介入監控的方式。

Berg’s Balance Scale (BBS) 可用來評估個人平衡能力，也可用來評估在平衡障礙後的復健指標衡量，包含 14 項日常生活活動的功能性任務，從坐姿靜態平衡到單腳站立平衡，每個任務分數從 0 分到 4 分，總分 56 分，分數越高表示個案平衡功能越好，評估所需時間約 15 至 20 分鐘。

Taiwanese version of the Burn Specific Health Scale-Brief (BSHS-B-Taiwanese) 是針對燒燙傷患者所設計，用來評估個案燒燙傷後健康相關生活品質的量表，內容包含有生理功能、心理社會功能領域。由 Blades 等 (1982) 發表第一版的

燒燙傷健康量表，共有 114 題題目，因太過冗長，而發展出只有 40 題的精簡版。黃于芳等在 2016 年更進展成 BSHS-B-Taiwanese，以減少中西方文化差異，以符合台灣臨床及研究者所應用 (Hwang et al., 2016)。題目評分以 5 分法表示，4 分代表從來沒有或毫無什麼困難；0 分代表總是或極度困難，總分為 160 分，分數越高，表示生活品質越高（Gittings et al., 2016; 許國正 et al., 2017）。BSHS-B-Taiwanese 除了人際關係面向 (Interpersonal Relationships) 外，其內部一致性 Cronbach's $\alpha > .70$；其中，在工作 (Work)、對熱敏感 (Heat Sensitivity) 和身體形像 (Body Image) 這三個面向 Cronbach's $\alpha \geq .90$。另外，除了基本能力面向 (Simple Ability) 外，其餘面向的測試 - 再測試信度範圍從 0.74 到 0.93，顯示 BSHS-B-Taiwanese 有較高的測試 - 再測試信度。效標效度方面，BSHS-B-Taiwanese 與 36-item Short Form Health Survey-Taiwanese (SF-36-Taiwanese) 具有中度的相關性；而且在區別效度上，BSHS-B-Taiwanese 在判別住院時間和燒燙傷部位面積百分比的幾個領域之間具有顯著差異。因此，BSHS-B-Taiwanese 可用於測量臺灣燒燙傷患者的生活品質 (Hwang et al., 2016)。

RPE 則用來測量及描述運動時自己感覺到的運動強度，分數從 6 分到 20 分，6 分代表休息，每分鐘心跳大約 60 下的運動強度，完全沒有用力的感覺；7 分代表很輕鬆；10 分代表中等強度，有一點點喘，但還能講話；20 分代表極強烈感覺，感到很喘、疲憊，已經盡最大的努力，每分鐘心跳大約 200 下的運動強度。Palackic 等 (2021) 建議中等強度運動 (RPE = 10) 是屬於安全的而且可以提高有氧能力。

資料處理及統計分析

本研究之依變項為執行 BBS 及 BSHS-B-Taiwanese 前測、中測和後測所得到的總分。以無母數分析法進行統計分析，Wilcoxon signed-rank test 檢驗介入前中後之差異，以及 Mann-Whitney U test 檢驗實驗組與對照組之表現差異，顯著水準 α 設為 0.05（雙尾檢定）。以 IBM SPSS 28.0 Statistics for Windows 套裝軟體 (IBM Corp., Armonk, NY)，進行相關統計分析。

結果

本研究共包含 10 位研究參與者，4 位女性與 6 位男性，平均年齡為 38.1 ± 11.85 歲，平均身高為 169.1 ± 7.77 公分，平均體重為 67.8 ± 10.05 公斤，平均燒燙傷面積為 15.0 ± 12.24 % TBSA，受傷住院天數平均為 33.6 ± 36.62 天。燒燙傷發生型態分析：火焰燒燙傷有 5 位，熱液燙傷有 5 位；10 位皆有進行燒燙傷植皮手術。Mann-Whitney U 分析結果顯示實驗組及對照組成員在年齡、身高、體重、受傷面積以及住院天數上無顯著差異。研究參與者基本資料如表 1 所示。

表 1　研究參與者基本資料

	參與者	性別	年齡	身高 (cm)	體重 (kg)	受傷面積 (%)	住院天數
實驗組 (n = 5)	E1	男	30	178	72	29	16
	E2	男	36	175	70	6	17
	E3	女	28	162	59	8	24
	E4	女	59	164	65	4	22
	E5	男	27	166	84	32	45
	Mean (*SD*)		36.0 (13.32)	169.0 (7.07)	70.0 (9.30)	15.8 (13.54)	24.8 (11.78)
對照組 (n =5)	C1	女	55	162	63	6	16
	C2	男	42	181	75	35	135
	C3	男	30	168	73	11	23
	C4	男	28	176	70	11	19
	C5	女	46	159	47	5	19
	Mean (*SD*)		40.2 (11.28)	169.2 (9.26)	65.6 (11.35)	13.6 (12.28)	42.4 (51.83)
組間差異							
p			0.46	1	0.83	0.83	1

經過 6 週跑步機訓練，所有實驗組參與者之 RPE 皆未超過 14，因此行走速度皆可達時速 4 公里。研究參與者 BBS 與 BSHS-B-Taiwanese 分數見表 2。Wilcoxon signed-rank test 分析結果顯示，實驗組與對照組，其 BBS 評估前、中、後測之組內比較皆具有顯著差異（表 3）。在 BSHS-B-Taiwanese，實驗組在中、後測之組內比較具有顯著差異；而對照組 BSHS-B-Taiwanese 評估前、中、後測之組內比較皆具有顯著差異。

表 2　研究參與者評估分數

		BBS			BSHS-B-Taiwanese		
		前測	中測	後測	前測	中測	後測
實驗組 (n = 5)	E1	17	35	50	114	91	110
	E2	9	29	45	62	113	128
	E3	3	17	37	30	59	79
	E4	4	21	35	36	76	90
	E5	20	40	51	65	85	98
	Mean (*SD*)	10.6 (7.64)	28.4 (9.53)	43.6 (7.33)	61.4 (33.21)	84.8 (19.85)	101.0 (18.87)
對照組 (n =5)	C1	12	37	51	64	98	121
	C2	3	21	39	36	57	68
	C3	11	36	48	42	48	122
	C4	15	34	51	51	66	85
	C5	25	44	52	38	89	110
	Mean (*SD*)	13.2 (7.95)	34.4 (8.38)	48.2 (5.36)	46.2 (11.50)	71.6 (21.22)	101.2 (23.81)
組間差異							
	Z	-0.419	-1.048	-1.375	-0.419	-0.94	0
	p	0.675	0.295	0.169	0.675	0.347	1

BBS: Berg's Balance Scale; BSHS-B-Taiwanese: Burn Specific Health Scale-Brief-Taiwanese version.

表 3　研究參與者評估分數之組內差異

		BBS			BSHS-B-Taiwanese		
		前測 vs. 中測	中測 vs. 後測	前測 vs. 後測	前測 vs. 中測	中測 vs. 後測	前測 vs. 後測
實驗組	*Z*	-2.032	-2.023	-2.032	-1.483	-2.023	-1.753
	p	.042	.043	.042	.138	.043	.080
對照組	*Z*	-2.041	-2.023	-2.032	-2.023	-2.023	-2.023
	p	.041	.043	.042	.043	.043	.043

BBS: Berg's Balance Scale; BSHS-B-Taiwanese: Burn Specific Health Scale-Brief-Taiwanese version.

在組間比較，Mann-Whitney U test 結果顯示兩組在 BBS 和 BSHS-B-Taiwanese 的前測、中測及後測中均未達顯著差異（表 2）。

討論

本研究結果發現，下肢燒燙傷傷患經 6 週常規復健訓練合併跑步機活動訓練後，在平衡能力與生活品質上皆有顯著的進步，但其進步幅度與僅接受常規復健訓練者無顯著差異。

本研究實驗組 BBS 平均分數由 10.6 分進步到 43.6 分，與 Ali 等 (2015) 進行以跑步機進行有氧訓練的研究結果相符。另外，在本研究中的參與者在住院期及再無後續手術需求的情況下即開始進行訓練，與 Cartotto 等 (2023) 於美國燒燙傷協會所提出的早期活動及復健臨床指引中的原則一致，亦即建議燒燙傷個案在受傷後若是情況許可，可早期進行運動復健計畫，以增進動作控制，避免平衡控制障礙。

本研究皆是在住院期，而且是在下肢最後手術日滿一週及無後續手術需求的情況下施行前測，至中測時仍有一位對照組參與者尚住院中，因此 BBS 評估分數在前測結果皆處於較低水準，這可能與下肢燒燙傷後的肌力不足、關節活

動受限、疼痛或感覺異常等因素有關。由於平衡能力的低下可能增加跌倒風險，影響患者的行動能力與日常生活自主性，因此即使最終統計結果未達顯著差異，這項評估資料仍然具備重要的臨床價值，即「低平衡能力所帶來的風險在臨床應用上不容忽視」。對於下肢燒燙傷患者而言，在復健初期進行跑步機運動時，若平衡能力尚未改善，可能會增加跌倒或再次受傷的風險。因此，未來在應用跑步機訓練作為復健介入時，可能需要更明確的評估，如額外測試患者的步態穩定性、姿勢控制能力，甚至採取輔助措施，如使用護欄、穿戴安全帶，或先以其他較低風險的訓練模式作為前導，待患者的平衡能力有所改善後，再逐步轉換到跑步機訓練。

經 6 週常規復健訓練合併跑步機訓練，實驗組參與者在 BSHS-B-Taiwanese 前測時平均分數為 61.4 分，進步至後測時平均分數 101.0 分，與 Grisbrook 等學者 (2012) 進行之研究的結果相符，顯示有氧運動訓練能有效改善燒燙傷個案的生活品質。

實驗組進行組內比較時，發現研究參與者在 BSHS-B-Taiwanese 的後測成績優於中測成績，這結果支持著下肢燒燙傷傷患經過一段時間的跑步機訓練後，逐漸習慣和適應新的運動模式，使生活品質有正面的調適和改善。然而生活品質是一個綜合性的概念，包括生理、心理、社會等多個層面，或許在六週短期的跑步機訓練，結果可能主要影響生理層面，而這些改變在短時間內並不會立即在整體生活品質評估中顯現出來；這可能也反映出生活品質的提升可能與身體功能、自主性以及心理狀態相關，但是對於自身生活品質改善的體會可能需要較長時間的累積，需要持續一段時間的努力和維持，而不是在短期內產生明顯的差異，使其在心理、社交、環境等方面的感受有所改善。

在組間比較方面，研究參與者在 BSHS-B-Taiwanese 前測並沒有差異，在加入跑步機訓練後，中測和後測的組間比較並未顯示生活品質的顯著差異。推測跑步機訓練對生活品質的影響可能是相對較緩慢，對於短期內生活品質的整體改善沒有帶來顯著效果，需要更長時間才能產生明顯的變化。另外，生活品質可能受到多種因素的影響，單一訓練可能無法立即改善所有方面，或許對於短期內生活品質的整體改善沒有帶來顯著效果。訓練難易度和時程安排上，六

週的訓練期間可能對於生活品質的整體改善來說時間較短，而生活品質可能需要更長的時間來反映在評估工具的分數上。而 BSHS-B-Taiwanese 可能較不敏感於短期內的變化，需要更長的時間來觀察生活品質的真實改變。

此外，在本研究的實驗組中，E1 個案的 BSHS-B-Taiwanese 分數在前測、中測、後測之間的變化幅度與其他個案存在較大差異，可能對組內比較的統計結果產生影響。進一步探討發現，該個案在前測至中測期間因出院後返家自行照護傷口時，造成傷口感染導致局部發炎與搔癢，不僅影響了其生理舒適度，也可能對心理狀態與日常生活活動造成負面影響。因此，在中測時該個案的 BSHS-B-Taiwanese 分數較前測更低，顯示出短期內因併發症影響導致生活品質下降的情形。然而，隨著傷口狀況的改善，該個案在後測時的 BSHS-B-Taiwanese 分數顯著提升，甚至接近前測水準，顯示其復原狀況對生活品質的正面影響。這樣的變化模式可能導致整體組內比較未達顯著差異，可能因為該個案的數據拉大了個體間的變異性。這也反映出個案在恢復過程中的多種可能變數，例如：傷口照護、併發症影響及個體對不適的主觀感受，皆可能影響短期內的生活品質評估結果。

整體來說，本研究結果顯示了常規復健訓練合併跑步機訓練對生活品質有正向的趨勢，，但這種改善可能需要長期而持續的努力才能在整體生活品質評估中產生明顯的變化。最佳的復健計畫應該根據個人的需求和能力進行設計，而訓練計畫是一個動態的過程，需要不斷進行評估和調整，透過定期評估以及患者的回饋來進行修正，醫療團隊可以及時調整康復計畫，以確保其符合患者當前的需求和進展，並可能需要更長時間的追蹤來全面評估復健介入的效果。

研究限制

本研究最後只招募到 10 位傷患，樣本數相對較少，因此施測之基準分數也不同，都會影響統計檢定的結果與效果量的判斷；而且本研究是在一家公立醫院進行，尚未到其他醫療場域；另外，由於我們只關注到有下肢燒燙傷的傷患，並未擴及到是否因為身體其他部位受傷而影響到平衡能力及生活品質表現；也

未考量到燒燙傷患者在運動時，由於燒燙傷的嚴重程度以及治療和復原的進展情況而可能會出現不同程度的疼痛反應，因此無法確定這運動訓練模式是否可以適用到全部傷患。

由本研究結果，可以推論下肢燒燙傷傷患在接受常規復健訓練合併跑步機訓練後，能改善平衡能力。回顧相關文獻發現可能是因為在跑步機上行走時會維持固定的時間和速度，重複練習跨步的動作，對於下肢燒燙傷傷患的下肢訓練能讓髖、膝和踝關節重複練習由彎曲到伸直的動作，可增加下肢肌力和關節活動度。因此本研究的一個研究限制是進行時間未提供下肢肌力和關節活動度的測量，所以無法確切了解是否因為下肢肌力或關節活動度關節活動度增加而導致進步的趨勢。

其次，本研究僅持續進行六週，研究報告提供了六週的跑步機訓練後的結果，但未提到長期追蹤效應。跑步機訓練後的長期效果，包括是否這些改善在訓練結束後持續存在，以及是否需要定期訓練維持這些效果。

最後，由於燒燙傷多是起因於意外，所以在收案時並無法預期收案量，期待將來可以持續增加收案量，以彰顯跑步機訓練計畫在下肢燒燙傷傷患之平衡能力及生活品質的助益影響。

結論

本研究結果發現，下肢燒燙傷傷患經 6 週常規復健訓練合併跑步機活動訓練後，在平衡能力與生活品質上皆有顯著的進步，但其進步幅度與僅接受常規復健訓練者無顯著差異。

本研究所有參與者在前測時的平衡能力皆處於低水準，突顯出此類患者在復健初期可能面臨較高的跌倒風險，進而影響行動能力與日常生活品質。雖然跑步機訓練的介入在統計上未達顯著差異，但個別案例的變異性顯示，患者的復原過程可能受到不同因素影響，例如傷口狀況、疼痛程度及運動適應能力。因此，未來在應用跑步機作為復健工具時，需考量患者的平衡能力狀況，適時提供輔助措施，以確保安全性並提升訓練效果。

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原著

學齡孩童遠距書寫介入方案之可行性研究

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摘要

目的：書寫對學齡孩童而言是重要的職能活動，然而書寫實體介入課程的執行模式容易受到疫情、上課地點、通勤時間的影響。若能發展適用於學齡孩童的遠距方案，將提升治療方案的普及性和適用性。因此，本研究旨在發展適用於學齡孩童的遠距版「字字不倦」介入方案，並探討其與實體版接受度的差異。

方法：本研究中進行書寫方案遠距版課程的開發，並探討介入方案的接受程度，共招募 8 位國小正常發展孩童作為受試者，其中 4 位進行遠距版之課程，另外 4 位孩童接受實體版課程，每次訓練後都會由孩童填寫兒童動機問卷，以評估方案的接受程度。使用曼－惠特尼 U 檢定來比較遠距版和實體版的接受度。

結果：遠距版書寫介入方案整合線上形式以符合學齡孩童需求，並於兒童動機問卷的量性題目中顯示中至高的接受度 (平均數 = 3.89, 標準差 = 0.72)，且與實體組 (平均數 = 4.33, 標準差 = 0.91) 於各項目分數及總分皆無顯著差異。質性結果顯示孩童對課程活動的設計反應正向，透過有趣的故事及動畫，提升參與動機與學習興趣。

結論：參加遠距版「字字不倦」方案課程的孩童顯示出良好的接受程度。本研究的結果將作為未來遠距書寫課程的參考。

關鍵詞：書寫、接受度、孩童

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Original article

Feasibility Study of a Tele-Version Handwriting Intervention Program for School-Aged Children

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Abstract

Purpose: Handwriting is an important occupational activity for school-age children. However, the execution of in-person handwriting intervention courses is easily affected by factors such as the pandemic, location of the classes, and commuting time. Developing a tele-based program suitable for school-age children would improve the accessibility and applicability of the intervention. Therefore, this study aimed to develop a tele-version of the Go-Go Handwriting intervention program and explore the differences in acceptance between the tele-version and the in-person version.

Methods: This study developed the tele-version handwriting intervention program and investigated the acceptance of the intervention. Eight typically developing elementary school children were recruited, with four receiving the tele-version training and four receiving the in-person version. After the training session, children completed the Pediatric Motivation Questionnaire (PMQ) to evaluate the program's acceptance level. The Mann-Whitney U test was used to compare acceptance levels between the tele-version and the in-person version.

Results: The tele-version handwriting program successfully integrated an online format to meet the needs of school-age children, demonstrating a moderate to high level of acceptance on the PMQ scale (M = 3.89, SD = 0.72), with no significant differences in scores across items or total scores compared to the in-person group (M = 4.33, SD = 0.91). Qualitative results indicated that children responded positively to the course, with engaging stories and animations enhancing their motivation and interest in participation.

Conclusion: Children participating in the tele-version of the handwriting program exhibited good acceptance levels. The findings of this study will serve as a reference for future tele-handwriting courses.

Keywords: Handwriting, Acceptance, Children

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前言

書寫對學齡孩童而言是一項極為重要的職能活動 (Feder & Majnemer, 2007)。在學生時期，孩童於上學日約有 37% 至 60% 的時間會進行精細動作任務，其中約 18% 的時間會進行書寫任務 (Caramia et al., 2020)。書寫的易讀性 (legibility) 為學校老師評估孩童書寫能力的主要依據 (Feder & Majnemer, 2007; Hammerschmidt & Sudsawad, 2004)，易讀性涵蓋字體的排列、空間分佈、筆畫結構、部件比例、大小等因子 (曾美惠 , 1993)。由於易讀性常作為辨認孩童書寫成果的指標 (Chang & Yu, 2005; Hammerschmidt & Sudsawad, 2004; Klein et al., 2011; Lee et al., 2016)，若書寫易讀性不佳，孩童在學業上可能難以取得良好成績，並且可能影響自尊心和自我效能 (Engel-Yeger et al., 2009; Feder & Majnemer, 2007)。然而，若能提供適當的訓練方案，不僅可以提升孩童的書寫表現，更可進一步減少孩童因書寫能力不足所引起的學業和自尊問題 (Chang & Yu, 2005; Feder & Majnemer, 2007)，因此，發展針對學齡孩童的中文書寫表現之介入方案將有助於增進其書寫能力，並改善孩童因書寫表現造成的負面影響。

在中文書寫表現的研究中，視知覺 (visual perception)、動作協調 (motor coordination) 和視覺動作整合 (visual-motor integration) 被認為是關鍵因子。這些技巧幫助孩子辨識字體結構，並協調手眼動作完成流暢書寫 (Chang & Yu, 2005; Feder & Majnemer, 2007; Lee et al., 2016; Tse et al., 2019; Tseng & Chow, 2000)。孩童若有較佳的視知覺、動作協調及視動整合表現，則可以藉此預測有較佳的書寫表現 (Lee et al., 2016; Tse et al., 2019; Tseng & Chow, 2000)。李冠儀等 (2021) 提出「字字不倦」中文字書寫介入方案，訓練內容聚焦於視知覺、動作協調及視覺動作整合技巧，並根據高尚仁 (2000) 所提出之中文字書寫之心理幾何理論，結合中文字體結構特徵於視知覺、動作協調及視覺動作整合活動中。例如，視知覺活動訓練孩童學習區辨中文字的差異；動作協調活動訓練孩童描繪幾何圖形與文字；視覺動作整合活動則訓練孩童抄寫與書寫練習。此外，研究中以兒童中文書寫易讀性測驗 (Chinese Handwriting Legibility Assessment for Children,

CHLAC) 之易讀性分數作為介入成效的指標（王姝婷等，2024）。該測驗提供全面性的書寫易讀性評估，涵蓋文字的大小、位置、旋轉、部件比例及部件間距五大面向。「字字不倦」可行性研究結果顯示，在接受訓練後孩童的書寫易讀性表現有所進步，此外，依照兒童動機問卷之填寫結果，孩童們對此方案也具高度的參與動機及接受度，顯示此方案除了具有增進孩童書寫表現之潛能外，於學齡孩童使用上的可行度也相當高。

「字字不倦」雖已初步證實有助於孩童書寫易讀性的表現，但實體介入方案設計為治療師與孩童一對一面對面進行，對於許多生活在偏遠地區或資源缺乏的孩童而言，介入方案的可及性不足，可能導致部份孩童無法獲得適當的治療服務。而在過去新冠肺炎疫情期間，為了避免接觸，實體方案的執行也受到諸多限制，遠距醫療 (telehealth) 的發展為這些問題提供了可行的解決方案。隨著科技進步，醫療介入形式日益多元，透過資訊和通訊科技 (information and communication technologies, ICT)，治療師能夠使用攝影機、電腦、電話進行通訊或線上遊戲進行遠距訓練，可於家中、學校或其他場所進行 (Florea et al., 2021; Hung Kn & Fong, 2019)，不僅提升醫療服務的可及性，也減少照顧者和參與者的通勤時間與交通成本 (Chung et al., 2016; Florea et al., 2021; Prodhan et al., 2017)，並降低治療效果受到時間與空間限制的影響 (Hung Kn & Fong, 2019)。同時，遠距醫療也有助於減少接觸傳染的風險 (Nulle & Nelson, 2020)。過去文獻支持遠距方案具有一定的治療效果及接受度 (Ashfaq et al., 2020; Florea et al., 2021; Hung Kn & Fong, 2019)， Criss (2013) 的研究顯示遠距方式進行的書寫介入方案能夠顯著提升孩童於英文的書寫成效，並且在家長及孩童都具有良好的接受度。除此之外，利用多媒體素材如動畫和聲音等進行遠距介入，相較於傳統書面素材，能夠更靈活、多樣地呈現內容，有助於提升孩童的參與度與學習成效 (Hsu, 2016; Qaddumi et al., 2021; Rajabalee & Santally, 2021)。因此，透過遠距版「字字不倦」方案的發展，能夠使孩童即使在資源有限或具防疫需求的情況下，仍然能夠於安全、舒適的環境下參與訓練，不受到時空的限制 (Dostie et al., 2022; Hung Kn & Fong, 2019; Nulle & Nelson, 2020)。

遠距方案具有諸多優勢，然而目前仍然面臨一些挑戰，如器材設備的設置困難、訊號的穩定性要求，以及訓練成效的疑慮 (Dostie et al., 2022; Peters et al., 2021)，但綜合上述觀點，若能將「字字不倦」方案發展為遠距版，將使孩童能在超越時空限制的情況下接受書寫技巧的訓練，這樣不僅減少疾病傳染的風險，還能提高治療師、孩童及家長的時間運用效率及便利性，並有助於偏鄉及離島地區孩童獲得平等的訓練機會。這符合現代社會的需求，兼具實用性和可行性。因此，本研究旨在發展以「字字不倦」方案為基礎的學齡孩童遠距中文字書寫促進方案，並與實體版進行比較，以探討遠距版與實體版的訓練差異，並提出修改方向，作為日後執行訓練的參考。

研究方法

受試者

本研究目的為發展學齡孩童中文字書寫表現之遠距版介入方案，並探討此方案於孩童之可行性。於接受度驗證研究招募 8 位具有書寫易讀性訓練需求之孩童，並將其分配至實體組與遠距組進行對照研究。納入條件為：(1) 就讀於國小之學齡孩童；(2) 無智能障礙；(3) 無肌肉骨骼、感覺或皮膚等影響書寫之損傷；(4) 家長或學校教師反映孩童具有書寫易讀性問題，包括字體大小、排列、部件比例等。

研究流程

本方案之發展為改良「字字不倦」方案，進行三個單元課程（視知覺、動作協調和視動整合）的遠距版課程開發；方案可行性驗證階段共招募 8 位受試者，4 位進行遠距版之介入課程，4 位接受實體版方案，兩組受試者皆分別進行視知覺、動作協調或視動整合其中一單元之方案訓練，課程時長均為 2 小時，訓練過程中根據孩童狀況彈性提供休息時間，並透過兒童動機問卷 (Pediatric

Motivation Questionnaire, PMQ) 之填寫結果探討孩童於方案的接受度。於測驗完成後，將問卷的分數進行分析，以驗證遠距版方案於學齡孩童之接受度，並進一步探討如何進行修正以增進遠距方案的完整度，提升孩童參與動機。

遠距版「字字不倦」方案發展

「字字不倦」方案內依中文字型結構分為四個單元（左右型、上下型、兩面包圍型、三面及四面包圍型），每單元皆含視知覺、動作協調、視動整合等三個訓練面向 (李冠儀等，2021)。而遠距版「字字不倦」方案依遠距需求調整實體版「字字不倦」，方案內容分為三單元：視知覺、動作協調、視動整合（表 1），每單元約需 2 小時完成。課程中出現的文字皆涵蓋左右型、上下型、兩面包圍型、三面及四面包圍型之四種字型，文字選自同時收錄於教育部 (2000)《國小學童常用字詞調查報告書》及教育部 (民 71)《常用國字標準字體表（甲表）》使用頻率前 1500 的常用文字。在課程開始前，會給予孩童一本上課教材，以利遠距時進行紙筆部分之訓練（包括動作協調、視動整合）。訓練順序照單元依序進行。

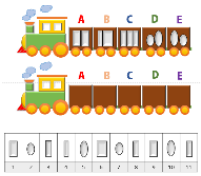
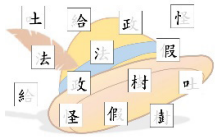
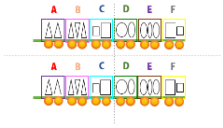
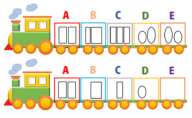
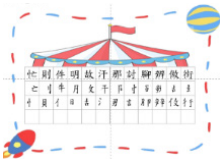
表 1　遠距版「字字不倦」方案架構及設計概念簡要整理表

基本技巧訓練元素		設計概念
視知覺	視知覺 I	幾何圖形及字符之空間分割及配置之區辨
	視知覺 II	筆畫形體區辨，於背景中視覺搜尋及區辨出指定之筆畫；於字符中搜尋出指定之筆畫
動作協調	動作協調 I	幾何圖形及線條描繪，圖形設計中結合字形結構、空間比例以及字樣
	動作協調 II	描寫字符，分別描繪不同空間分割之部件
視動整合	視動整合 I	幾何圖形之抄畫，圖形設計中結合字形結構、空間比例以及字樣，著重於相對空間位置及大小安排
	視動整合 II	抄寫部件及字符，著重於相對空間位置及大小安排

為了符合遠距教學的操作需求，遠距版方案基於實體版的基礎上，進行一些調整與改變（表 2），目的是確保介入過程的順暢性，並使孩童能夠在線上情境中保持專注與參與。在故事包裝方面，遠距版以蒐集寶石的冒險故事為主軸，強化趣味性和情境設定，吸引孩童的注意力並提升參與動機。這樣的設計不僅增添了學習的樂趣，也有助於孩童在每個步驟中保持專注。在視知覺課程中 （表 2 － a, b, c, d），實體版活動是由孩童直接操作透明片進行圖形排列，而遠距版則改為將圖形標記上數字，並讓孩童通過視訊指揮治療師進行圖形的排列，透過這種方式不僅保留了原本的教學目標，也確保孩童能主動的參與並獲得練習。動作協調課程的改變包括故事情節和動畫的輔助（表 2 － e, f, g, h），通過鮮明的視覺引導，幫助孩童理解當前需要描繪的部件，其中，動畫的使用幫助孩童更加直觀地理解任務要求，避免因單調的描繪過程而失去興趣。在視動整合課程中（表 2 － i, j, k, l），由動畫引導孩童按照順序完成圖形和部件的抄畫及抄寫，使孩童能夠在遠距環境中順利完成複雜的書寫任務。

整個遠距版方案皆由同一位治療師在電腦視訊軟體的輔助下進行，確保課程的連續性與一致性。所有課程的教材均以 PowerPoint 形式呈現，並透過螢幕分享進行講解，為了更有效地觀察孩童的學習狀況，治療師使用雙螢幕，其中一個螢幕用於教學內容展示，另一個則用於觀察孩童的動作與表情，以根據需要提供即時回饋與指導。孩童則在家長的協助下開啟鏡頭與麥克風，以維持與治療師的互動，確保遠距方案的順利運行並達成教學目標。

表 2　遠距版「字字不倦」方案範例（左右型字體為例）

遠距版修改策略	實體版圖示	遠距版圖示
視知覺		
I：將圖案編號，並在孩童指揮下以滑鼠拖曳放置的位置並調整空間排列	 (e)	 (f)
II：將筆劃編號，孩童需先選擇題目中筆畫的編號，之後會透過動畫呈現正確的筆畫	 (g)	 (h)
動作協調		
I：以動畫依序框選需要描繪的內容，並引導孩童於紙本教材上進行描繪以完成任務	 (a)	 (b)
II：以動畫依序框選需要描繪的字符，並引導孩童於紙本教材上進行描寫，完成後需自行檢查並修正，最後給介入者檢查，若有明顯錯誤則須修正	 (c)	 (d)
視動整合		
I：以動畫依序呈現要抄畫的內容，並引導孩童於紙本教材上進行抄畫以完成任務	 (i)	 (j)
II：在孩童抄寫的過程中，需在每個字開始前引導使用策略，抄寫完畢後需要自行檢查並修正，最後給介入者檢查，若有明顯錯誤則須修正	 (k)	 (l)

評估工具

本研究以兒童動機問卷評估孩童於訓練課程的接受度，於每堂課程結束後使用，此問卷由本研究團隊自行設計，問卷包含 9 個量性與 4 個質性的題目，量性題目包含：「你參加活動時快樂嗎？」、「你喜歡這個課程活動嗎？」、「你覺得自己做得好不好？」、「我覺得這個活動很有趣」、「活動中老師很關心我」、「這個活動對我來說有幫助」、「我在過程中感覺很累」、「我覺得這個活動很困難」及「你會期待下一次上課嗎？」，採用臉譜量表進行評分，共包含五種不同表情，分別對應 1 至 5 分，1 分表示最負向的回應，5 分則表示最正向的回應。質性題目包括：「今天最喜歡的活動是什麼？為什麼？」、「哪些活動不喜歡？」、「要如何改造會更喜歡？」、「其他想說的話？」，孩童需以敘述回答，藉此了解孩童對活動的參與動機及接受度，作為未來課程調整方向及臨床應用的參考。

資料分析

本研究參與者的人口學資料呈現每位個案的年級、性別及其參與的課程單元類型。方案接受度問卷以描述性統計分析各題項的評分數值，並以曼－惠特尼檢定 (Mann-Whitney U test) 比較遠距版方案與實體版方案之接受度，開放式問題的評估結果則以質性描述呈現。

結果

參與者人口學特徵

本研究共有 8 位國小一般班級孩童參與訓練課程並完成問卷評估。其中，4 位接受遠距版課程（包含 2 位二年級及 2 位五年級孩童），另 4 位則參與原版課程（包括 1 位一年級、2 位五年級 及 1 位六年級孩童）。受試者的人口學特徵詳列於表 3。

表 3　參與者人口學特徵及參與課程 ($N = 8$)

參與者編號	年級	性別	訓練模式	參與課程單元
1	二	男	遠距	動作協調
2	二	男	遠距	視動整合
3	五	男	遠距	視知覺
4	五	男	遠距	動作協調
5	一	男	實體	視知覺
6	五	男	實體	視知覺
7	五	男	實體	動作協調
8	六	男	實體	視動整合

方案接受度評估結果

本研究共招募 8 位受試者，其中 4 位受試者進行 2 小時之簡版之遠距版方案訓練，訓練者以電腦開啟視訊，並以平板確認孩童情況，而參與者則運用視訊設備進行課程，並於課程後完成兒童動機問卷以探討孩童於方案的接受度。

表 4 呈現實驗組與對照組孩童填寫遠距版兒童動機問卷的平均分數。研究結果顯示，孩童對於本研究開發的遠距版課程具有中至高度的滿意度 ($M = 3.89$, $SD = 0.72$)。在問題 4「我覺得這個活動很有趣」($M = 5.00$, $SD = 0.00$)、問題 6「這個活動對我來說有幫助」($M = 4.75$, $SD = 0.50$)，顯示孩童對於此遠距方案的呈現方式及自我效能滿意度高，然而問題 7「我在過程中感覺很累」($M = 2.00$, $SD = 1.15$) 顯示課程長短及內容仍需做些微調整。實體版課程具有中高度滿意度 ($M = 4.14$, $SD = 0.15$)，遠距版與實體版課程間的分數經統計檢驗顯示於每個題目並無顯著差異。

表 4　接受度問卷評估結果

	遠距組 (n = 4)		實體組 (n = 4)		
題目	*Mean*	*SD*	*Mean*	*SD*	*p*
量表平均分數	3.89	0.72	4.33	0.91	0.20
1 你參與活動時快樂嗎？	3.50	1.73	4.25	0.96	0.69
2 你喜歡這個課程活動嗎？	3.75	0.96	4.50	1.00	0.34
3 你覺得自己做得好不好？	4.25	0.50	4.5	1.00	0.49
4 我覺得這個活動很有趣	5.00	0.00	4.25	0.96	0.34
5 活動中老師很關心我	4.25	0.50	4.50	1.00	0.49
6 這個活動對我來說有幫助	4.75	0.50	4.25	0.96	0.49
7 我在過程中感覺很累	2.00	1.16	4.00	1.16	0.11
8 我覺得這個活動很困難	4.00	2.00	4.50	1.00	1.00
9 你會期待下一次上課嗎？	3.50	1.92	4.25	0.96	0.69

本研究也以開放式問題詢問孩童對於此課程的觀點。遠距組的四位孩童皆認為課程活動十分新奇有趣，而當詢問孩童「今天喜歡哪些活動？為什麼？」，參加視知覺課程的孩童表示都還好，而參與動作協調課程的孩童表示受到「文字甜甜圈－上下型字動作協調Ⅱ」的圖樣設計吸引，因為自己喜歡甜甜圈；另一位同樣參與動作協調課程的孩童則表示整個活動設計以蒐集寶石的主題作為包裝十分有趣；參與視動整合的孩童亦認為蒐集寶石的過程提升課程趣味，會因期待看到下個寶石而更願意認真參與，另外，簡報動畫也十分吸引人，而在揮揮魔法棒的活動因覺得自己表現好所以也特別喜歡，該個案更表示自己在課程中越寫品質越好，感受到進步。針對「其他想說的話？」，參與動作協調課程的孩童表示整體活動都覺得很有趣，尤其喜歡簡報的轉換，設計的動畫也很

好看、很喜歡，也不會覺得需要寫字並拿給老師檢查很無聊。對於「有什麼不喜歡的活動？」，部分參與視知覺和動作協調單元的孩童提到會因為進行紙筆任務而感到疲累。當詢問「如何改進會讓你更喜歡？」時，所有參與的孩童皆表示沒有任何改進的建議。實體組的部份，孩童普遍表示課程內容令人喜愛，無特別不喜歡的活動，僅有一名參與實體視知覺課程的孩童表示希望減少訓練任務，但仍認為課程有趣，並希望在家中也能持續參與相關活動。

討論

本研究發展遠距版「字字不倦」方案，並探討其於學齡孩童之接受度。量性結果顯示，儘管遠距組分數整體略低於實體組，但兩者在接受度上無顯著差異，均顯示中至高度的接受度。質性結果則表明，孩童對課程活動的設計反應良好，透過有趣的故事和動畫，能有效提升他們的參與動機和學習興趣，顯示遠距版「字字不倦」方案具備成為有效介入方案之潛力。

遠距組與實體組在各項接受度表現相當，顯示遠距版方案具有一定之可行性。在 PMQ 問卷的 9 個問題中，有 2 題的表現優於實體組，然而其餘 7 題的分數皆較低，顯示遠距版方案可再進一步調整以更好的滿孩童的需求。其中有兩題分數高於實體組，首先，在問題 4「我覺得這個活動很有趣」中，四位參與孩童皆給出滿分，根據質性回饋，推測原因可能是遠距課程中使用較多動畫，進一步引起孩童的興趣，從而提升該課程的接受度。先前研究顯示，相較於靜態圖片，動畫能夠更具體地呈現動態的過程與變化，幫助學習者更直觀地理解知識，進而提高學習動機 (Barut Tugtekin & Dursun, 2022; Höffler & Leutner, 2007; Lin & Li, 2018)。在遠距版「字字不倦」方案中，動畫有效解決了單調紙筆練習的問題，透過生動的情境和視覺刺激，引起孩童興趣，並增強孩童的參與度和專注度，進而提升學習成效。此外，也有部分孩童表示喜愛寶石蒐集的故事情節，因此未來版本或可增加動畫的使用，並結合趣味性元素，例如聲音回饋和故事發展，進一步提高孩童的參與動機。另一高分項目為問題 6「這個

活動對我來說有幫助」，遠距組得分稍高於實體組，這可能是因為課程強調自我覺察，介入者透過螢幕引導孩童自行檢查書寫是否正確、筆跡是否超出描線範圍。由於介入者無法在身邊直接指導孩童，需引導其自我檢視，這種過程可能有效地提升孩童的自我效能感。

儘管遠距方案整體接受度佳，但數值顯示遠距組在部分題目得分仍低於實體組，這可能有以下三個原因：設備、方案設計及課程流程。首先，設備方面，介入者端需提前確認網路連線的穩定性，並檢查視訊平台是否有維修狀況，以避免技術問題中斷課程進行。此外，也應仔細檢查視訊鏡頭是否出現鏡像問題，避免孩童在書寫時混淆筆畫方向，特別是撇捺等動作。在參與者端，應增設額外鏡頭專門拍攝紙張和手部，以更精確地觀察孩童的書寫姿勢，還能避免孩童直接將作業展示到鏡頭前時出現作弊或隨意書寫的問題。同時，照護者可在旁協助，並將孩童完成的書寫圖片傳給治療師做確認，以便即時訂正錯誤。第二，於方案設計層面，實體版課程中，視知覺單元使用透明片進行排列，遠距版則改為滑鼠拖曳操作，這樣的變更雖然符合遠距教學的需求，但操作相對繁瑣且費時，對介入者來說也增加了難度。建議可以善用簡報的動畫功能來減少操作上的不便，或嘗試使用不同的數位媒介來替代，如將視知覺部分設計為線上遊戲，不僅能提升操作效率，還能增加孩童的參與感。最後，於流程層面，遠距組研究中發現於問題 7「我在過程中感覺很累」，部分孩童給出最低分，並於質性回饋中反應書寫內容較多而導致疲累的狀況，由於課程全程未設休息時間，與原版實體課程應有的 10 至 15 分鐘休息時間不同，這可能導致孩童較疲憊並影響參與動機。此外，部分孩童表示對活動的目的並不清楚。因此，為了提高其參與度，建議在課程開始前，加強對故事情境的引導，使孩童更容易進入學習情境中。透過更明確的故事背景及情境設計，不僅可以提升孩童對課程的理解，還能增強其對活動的投入度，有助於他們保持專注，更能讓孩童有動力完成課程中的各項任務。相較於實體版方案，遠距版方案雖能提供即時回饋，但由於表情與肢體引導的減少，可能影響孩童的理解與參與。因此，建議進一步強化與照護者的溝通，使其能在課程中適時提供額外的引導與回饋，以提升孩

童的參與度，並幫助他們更清楚理解活動內容，從而確保介入效果的最大化。

比較遠距組於視知覺、動作協調及視動整合三個單元之間的接受度，結果顯示動作協調單元的分數高於其他兩個單元，而視動整合單元的分數最低。先前研究指出，視知覺課程中的「筆畫練習」因為較少運用到精細動作，成為孩童最喜歡的活動之一 (李冠儀等，2021)，但在本研究中，動作協調單元的接受度反而更高，推測是因遠距課程中動作協調單元的動畫設計引發孩童更高的興趣，而視知覺課程中的滑鼠拖曳操作相對單調，缺乏動畫互動元素，導致其吸引力較低。至於視動整合單元，顯示出較低的接受度分數，研究結果與實體方式一致，推測是因為該單元要求孩童直接進行抄寫，不僅增加了挑戰性，也需要進行較多次的訂正。這些原因可能導致孩童容易感到疲倦，進而降低了他們對此單元的喜好。總體而言，課程設計上可增加互動性元素，並適時提供休息以避免過度疲勞影響參與動機 (Lemyre et al., 2007)。本研究是針對遠距版「字字不倦」方案的初步探討，儘管結果顯示遠距方案具有可行性與潛力，但仍存在一些限制：(1) 本研究採用方便樣本，僅收入 8 位個案，樣本代表性不足。(2) 由於考量臨床可行性，每位孩童僅接受 2 小時的視知覺、動作協調及視動整合簡版課程，未能全面呈現完整方案的效果。因此，下一步應根據本研究發現的問題進行修正，並增加參與者數量和課程次數，以提供更完整的遠距課程訓練，進一步檢驗視知覺、動作協調、視動整合及書寫易讀性等方面的成效，未來也應納入具有書寫障礙特徵的孩童，進行更深入的成效評估。

本研究首次嘗試遠距進行中文字書寫介入，採用線上視訊的方式進行，透過故事情節包裝介入內容，引發孩童興趣，並藉由完成任務的成就感來提升其參與動機。此外，透過動畫製作、現有素材之調整及內容設計，讓畫面更加生動活潑，避免孩童因重複執行單調的紙筆練習而感到厭煩。整體而言，遠距版「字字不倦」方案在孩童中展現出良好的接受度，並顯示出成為書寫介入的有效替代方案的潛力。雖然技術層面和流程仍需改進，但本研究的初步結果為臨床及研究提供了重要參考，未來可根據這些發現修改方案，並進一步發展遠距書寫介入方案。

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原著

探索密集性的照顧者參與之自然發展行為團體介入模式在自閉症幼兒之可行性及效果

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摘要

目的：本研究旨在透過評估一個密集型、以自然發展行為介入法 (NDBI) 為基礎、家長參與、團體模式的方案，在台灣的臨床環境中對自閉症學齡前幼兒的效果，來填補目前相關研究的不足。

方法：我們回顧 2 至 6 歲的自閉症學齡前幼兒的病歷，這些幼兒參與為期 8 至 12 個月的密集型、以家長參與為基礎的 NDBI 團體介入。NDBI 策略包括利用自然情境與學習機會、遵循發展原則，以及透過行為方法促進新技能學習。結果指標包含自閉症症狀、發展商數、團體適應及參與行為。我們使用配對樣本 *t* 檢定及重複測量共變數分析來分析介入前後的結果。

結果：共有 11 名自閉症學齡前幼兒（8 名男孩、3 名女孩）參與，年齡介於 26 至 50 個月（平均 34.3 個月，標準差 7.7），平均參與療程時長為 309 天。自閉症治療評估量表在語言 / 溝通以及總分上顯示顯著進步 ($t = 5.37$，$p < 0.001$；$t = 2.43$，$p = 0.035$)。團體適應功能指標的所有子量表均顯示顯著改善（團體規範：$t = –4.65$，$p < 0.001$；學習反應：$t = –4.97$，$p < 0.001$；溝通行為：$t = –3.56$，$p = 0.005$；社交行為：$t = –3.89$，$p = 0.003$）。然而，我們意外發現粗大動作子量表的分數在介入前與介入後之間有顯著下降 ($t = 3.66$，$p = 0.004$)。

結論：研究結果支持該介入方案的有效性，其整合了有效早期介入的核心要素，同時也考量了健保早療系統中的持續性與家庭的可負擔性。本研究為自閉症學齡前幼兒的早期介入臨床實務提供了重要參考。

關鍵詞：自閉症、自然發展行為介入、團體、可行性、療效

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Original article

Exploring Preliminary Feasibility and Effectiveness of Intensive Parent-Involved NDBI-Based Group Intervention on Autistic Preschoolers in a Daycare Setting

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Abstract

Purpose: This study aimed to evaluate the effectiveness of an intensive, Naturalistic Developmental Behaviors Intervention (NDBI)-based, parent-involved, group-based program for autistic preschoolers in a clinical setting in Taiwan.
Methods: We retrospectively reviewed the charts of autistic preschoolers aged 2 to 6 years old who received an intensive parent-involved NDBI-based group intervention for 8-12 months. The strategies of NDBIs included using naturalistic settings and learning opportunities, following developmental principles, and facilitating new skills through behavioral approaches. Outcome measures included autistic symptoms, development quotient, and group adaptive and participative behaviors. Paired sampled *t* tests and repeated measure Analysis of Covariance were utilized to analyze pre- and post-intervention outcomes.
Results: Charts of 11 autistic preschoolers (8 boys and 3 girls) aged 26 to 50 months (M = 34.3 months, SD = 7.7) was reviewed and analyzed. The average therapy duration was 309 days. Autism Treatment Evaluation Checklist scores showed significant improvements in Speech/Language/Communication subscale and the total score ($t = 5.37$, $p < 0.001$; $t = 2.43$, $p = 0.035$). All subscales of the Group Adaptation Function Index showed significant improvements ($t = –4.65$, $p < 0.001$ in group regulation; $t = –4.97$, $p < 0.001$ in learning response; $t = –3.56$, $p = 0.005$ in communicating behaviors; $t = –3.89$, $p = 0.003$ in social behaviors). Unexpectedly, we found a significant decrease in the gross motor subscale of Chinese Children Developmental Inventory between baseline and postintervention ($t = 3.66$, $p = 0.004$).
Conclusion: The results support the effectiveness of the program, which integrates key elements of effective early intervention while also addressing sustainability within the public early intervention system and affordability for families. This study provides valuable insights into early intervention practices for autistic preschoolers.

Keywords: Autism, Naturalistic developmental behavioral intervention, Group-based, Feasibility, Effectiveness

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Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by impaired social communication and restricted and repetitive behaviors and interests, which hinders autistic individuals' daily participation (American Psychiatric Association, 2022). The prevalence of ASD is approximately 1% globally and in Taiwan, which leads to more than 16000 autistic individuals in Taiwan requiring diverse clinical services (Chen et al., 2020; Zeidan et al., 2022). Early intervention is pivotal to support young autistic children's development including cognition, communication, and adaptive function (Fuller & Kaiser, 2020; Warren et al., 2011).

Naturalistic Developmental Behavioral Interventions (NDBIs) are one of the most evidence-supported interventions for autistic preschoolers (Sandbank et al., 2023; Schreibman et al., 2015). The strategies of NDBIs include using naturalistic settings and learning opportunities, following developmental principles, and facilitating new skills through behavioral approaches (Schreibman et al., 2015). The common elements across different NDBIs models are (1) face-to-face and on the child's level; (2) following the child's lead; (3) positive affect and animation; (4) modeling appropriate language; (5) responding to attempts to communicate; (6) using communicative temptations; (7) pace and frequency of direct teaching opportunities; (8) quality of direct teaching opportunities (Frost et al., 2020).

A meta-analysis of NDBIs found significant positive effects of naturalistic developmental behavioral intervention on expressive language, autism symptom reduction, play skills, social engagement, and overall cognitive development, with marginal effects on joint attention and receptive language (Tiede & Walton, 2019).

A large-scale meta-analysis of non-pharmacological autism interventions found that NDBIs showed higher empirical support quality than other interventions. These results from randomized controlled trial (RCT) studies excluding caregiver reports

demonstrated significant positive effects on play and social communication (Crank et al., 2021; Sandbank et al., 2020). NDBI is an interdisciplinary model that integrates principles from various fields (Ingersoll et al., 2024), providing occupational therapists with effective strategies to engage with autistic children while working toward occupational therapy goals. Additionally, occupational therapists represent the second or third largest group of professionals implementing specific NDBI models, highlighting its widespread use within the field of occupational therapy (Pickard et al., 2024; Seng et al., 2022).

However, while rigorously studied and established through repeated experiments and showing robust evidence of manualized NDBIs, families often find it difficult to access equivalent services in real-world contexts (Bent et al., 2023), suggesting the needs to explore NDBIs implementation in the community-based or clinical-based settings (Jobin et al., 2023; Kasari & Smith, 2016; Nahmias et al., 2019). Moreover, while NDBIs were originally developed for one-on-one interactions, there has been limited research investigating their adaptation and utilization in group-based settings. Group settings are prevalent in real-world service provision due to their potential for achieving cost-effectiveness and sustainability. In addition, learning and participating in group settings are crucial abilities for autistic preschoolers, as most educational contexts are group-based. Therefore, facilitating their understanding of group rules, improving their learning responsiveness, and enhancing social behaviors in group settings should be important goals of early intervention.

One of the most evidence-supported group-based NDBIs model is Group-Early Start Denver Model (G-ESDM), which showed benefits to autistic preschoolers in social communication, cognition, adaptive function, and overall developmental rate (Vivanti et al., 2019; Vivanti et al., 2014). This model expanded more fidelity dimensions in NDBIs that are specific to group settings, including promoting peer interactions, arrange seats according to individual children's characteristics, choosing activities based on the

motivation of the ‘group’, and considering the adult-child ratio to ensure the quality (Vivanti et al., 2017). However, this model is required a comprehensive teamwork and manpower (e.g., many accredited G-ESDM therapists) to meet the adult-child ratio (i.e., 1:2~4), and basically are not direct-parent-involved.

Only few studies investigated the group-based NDBIs delivered in the community or integrated into the routine care (Swain et al., 2020). One feasibility study of community based NDBIs delivered in group settings showed positive effects on adaptative function and social skills in autistic preschoolers, showing that broad NDBIs strategies could be incorporated into group-based services in communities, in spite of lacking detailed fidelity criteria (Jobin et al., 2023). No studies have explored the improvement in required behaviors to adapt in group learning contexts, including following the group rules, responding to learning activities, and social communication abilities in group settings. Furthermore, the cross-culture perspectives regarding the feasibility, adaptations, and effectiveness of implementing NDBIs are warranted given the majority of NDBIs was established in western contexts (Lee et al., 2023; Seng et al., 2022; Sengupta et al., 2020).

Moreover, parent involvement plays a crucial role in interventions for autistic children (Martinez-Torres et al., 2021). Parent-mediated intervention (PMI) emphasizes on teaching parent strategies and parent serve as treatment providers. The majority of PMI formats involve parent training delivered either individually or in group settings, often supplemented with short sessions of direct coaching for parent-child dyads (coaching one parent-child dyad at a time) (Nevill et al., 2018). For instance, World Health Organization Caregiver Skills Training (WHO CST), Parent-ESDM, and Project ImPACT (Improving Parents as Communication Teachers) are well-known models utilized this format to coach parents, and showed promising effectiveness (Ingersoll & Wainer, 2013; Rogers et al., 2012; Salomone et al., 2021). Only very few studies reported the format of involving multiple parent-child dyads at a time. Anan et al.

reported a program called Group Intensive Family Training (GIFT), which involved six parent-child dyads in a group aimed at teaching behavior analytic techniques (Anan et al., 2008). However, this program did not implement NDBIs strategies. Project ImPACT proposes an alternative format for delivering ImPACT strategies: a toddler group involving multiple parent-child dyads participating in group activities with separate individual coaching sessions outside the group (Ingersoll & Dvortcsak, 2019). However, there have been no reports on its effectiveness. Although the effect sizes of PMI reported in meta-analyses were small, previous studies have shown positive impacts on children's social communication and parent-child interaction (Nevill et al., 2018; Oono et al., 2013), suggesting that involving parents into the intervention is beneficial for the effectiveness.

The daycare for autistic preschoolers at National Taiwan University Hospital (NTUH), established in 1970 and continuously serving as routine care for autistic preschoolers in Northern Taiwan, provides an intensive, caregiver-engaged, and group-based intervention, with good coordination with the diagnosis and transfer system in the community. As a clinical service with a long history, the daycare at NTUH service has maintained its unique model of parent-child dyads in group settings, while implemented Discrete Trial Training (DTT) in the beginning of the program's establishment (Shyu et al., 2010), and gradually incorporated NDBI strategies in the past decade along with the development and dissemination of NDBIs in Taiwan. Within this program, the parents are required to actively participate and facilitate their children's participation in group activities according to the therapists' instruction, which is a good opportunity of practice for them to learn and implement NDBI strategies. This model integrates key elements of effective and feasible early intervention, including evidence-based practices, parental involvement, and a group setting. Given its alignment with real-world clinical care (Vivanti, 2022) and the integration of NDBI strategies, evaluating the effectiveness of this program is crucial to determine whether evidence-based interventions remain

feasible, generalizable, and effective outside of research contexts.

This study aimed to evaluate the effectiveness of an intensive parent-involved NDBI-based group intervention on autistic preschoolers in a clinical-based and real-world setting (i.e., the daycare program in NTUH) in Taiwan. We hypothesized that autistic preschoolers would show improvements in global development, autistic symptoms, and adaptative performance in group settings after receiving the program in the NTUH daycare.

Methods

Study Design and Participants

We retrospectively reviewed the charts of autistic preschoolers who received autism-specific intervention in clinics of NTUH from December 2021 to September 2023. The institutional review board (IRB) approval number of this study is 202504032RIN. The inclusion criteria for the program were: (1) a clinical diagnosis of Autism and with a major illness certificate; (2) age between 2 and 6 years; (3) at least one parents available to attend intervention sessions. There were no exclusion criteria, and no limitations regarding cognitive function or general development for participating children. Since the duration of the intervention varied due to both treatment considerations and practical constraints, we included children who attended the program for 8 to 12 months in order to evaluate its effectiveness. This duration reflects the typical length of participation in our setting and aligns with common research practices in daycare settings (Vivanti et al., 2014; Makrygianni et al., 2017; Vivanti et al., 2019).

Procedure

All patients were referred by child psychiatrists at NTUH, who introduced the

program and invited families to participate. The therapist then contacted the family to confirm their interest in attending and to determine which parent would accompany the child. As part of hospital regulations, families were required to sign a consent form for admission to the program, which was administered by the hospital's administrative department. However, the participants did not sign an IRB-informed consent form, as this study utilized a retrospective chart review design in which informed consent was waived.

The pre-test was conducted one week prior to admission, while the post-test was administered on the last day of the program. Parents completed the Autism Treatment Evaluation Checklist (ATEC) and Chinese Child Developmental Inventory (CCDI) questionnaires, while the therapist rated the Group Adaptation Function Index (GAFI). Evaluators (i.e., parents and the therapist) were not blinded to the study.

Intervention

The intervention took place at the daycare facility of NTUH, occurring four times a week for 2 hours per session and involving 8-10 parent-child dyads. One therapist, who is a master trainer of an NDBI program (WHO CST), led the group, while parents acted as facilitators to support their children’s participation. The therapy room was designed as a preschool classroom, with a large white board, children’s tables and chairs, cabinet with doors for material storage, and open shelves that were not reachable by children. The space was sufficient to accommodate 10 parent-child dyads to do both table tasks and physical activities. Activities included table tasks (e.g., playing with toys or painting), sensory social routine activities (e.g., singing songs, dancing), storybook reading, and games with simple rules (e.g., music chair or London Bridge). In this group setting, preschoolers engaged in shared play and learning activities, creating a naturalistic context similar to preschools or playgroups.

The therapist employed NDBIs strategies to facilitate shared engagement and support the individual development of social communication, play, group adaptative and participative behaviors, and emotional regulation. For example, the therapist, acting as the group leader, might initiate a LEGO-building activity with all the children. During the play, the therapist would implement NDBI strategies, such as creating opportunities for communication by waiting for the children to request more LEGO pieces using words or gestures. The therapist might also imitate how the children build their structures to capture their attention and then demonstrate new ways to assemble the LEGO pieces to expand their play skills. Parents served as facilitators, providing prompts to help children achieve specific behavioral goals (e.g., pointing to request or engaging in new play actions) while also supporting their engagement by offering encouragement and comfort.

The goals for each child were set in collaborate with their parents and primarily focused on social communication, emotional regulation, and group adaptive and participative behaviors. The decision to discharge (i.e., end of the program) was made collaboratively by the medical team and the family. Discharge reasons included goal achievement, successful placement, and family expectations or family issues. The program was fully covered by National Health Insurance (NHI), so families did not incur any costs for participating in the intervention.

Measures

・*Chinese version Clancy Behavior Rating Scale (CBRS)*

The Chinese version of the CBRS is a parent-rated questionnaire used to evaluate autistic characteristics (Shiech, 1983). This version was translated from the original CBRS (Clancy et al., 1969), with the rating scale modified from 2 points to 3 points. As a screening tool for ASD, Li et al. suggested that a cutoff score of 6 for positivity is

optimal, with a specificity of 0.91 and a sensitivity of 0.82 (Li et al., 2005). It consists of 14 items rated from 0 (never, to 1 (occasional), to 2 (frequent), with higher scores indicating greater severity of autistic characteristics. In this study, the CBRS was used to support the diagnosis of ASD and to present the baseline severity of symptoms in the children.

・*Taiwanese version Screening Tool for Autism in Toddlers and Young Children (T-STAT ™)*

The T-STAT™ is a screening tool designed for autism spectrum disorder, comprising 12 interactive items that evaluate behaviors across Play, Requesting, Directing Attention, and Motor Imitation domains. Scores on the T-STAT scale range from 0 to 4, with lower scores indicating milder impairment (Chiang et al., 2013; Stone et al., 2004). A specific cutoff point is utilized for screening toddlers aged 24 to 36 months. As not all children in our study fall within this age range, we opted to use the raw scores from the T-STAT™ to gauge the baseline severity of autistic symptoms. In this study, the T-STAT was used as an observational measure to complement the parent-reported CBRS.

・*Autism Treatment Evaluation Checklist (ATEC)*

The ATEC is a parent-reported questionnaire suggested as a comprehensive tool to monitor the treatment effect and progress of children with ASD. As a caregiver-reported measure, it has been validated against professionally rated tools (Geier et al., 2013; Magiati et al., 2011). Four subscales assess child outcomes: speech/language/communication (14 items, 3-point scale), sociability (20 items, 3-point scale), sensory/cognitive awareness (18 items, 3-point scale), and health/physical behavior (25 items, 4-point scale). The scores for the speech/language/communication subscale and sensory/

cognitive awareness subscales were reversed to match the other two subscales. Higher scores represented more severe autistic symptoms; therefore, a decrease in scores reflects an improvement. We utilized the Chinese version of ATEC, as used in Seng's study in 2022, which reported a good reliability of the Chinese version, with Cronbach's alpha coefficients higher than 0.9 for the first three subscales, and higher than 0.8 for the fourth subscale (Seng et al., 2022).

・*Chinese Child Developmental Inventory (CCDI)*

The CCDI was modified from the Minnesota Child Development Inventory. Taiwanese norms were established, and the tool has demonstrated adequate reliability and validity (Hsu, 1978; Wu et al., 2013). In Wu et al.'s study, Cronbach's alpha coefficients for internal consistency across dimensions were generally higher than or near 0.7 (Wu et al., 2013). The CCDI assesses children aged 6 to 78 months. It consists of eight developmental dimensions, including gross motor, fine motor, expressive language, comprehension conceptual, situation comprehension, self-help, personal-social, and general development. It contains 320 items with specific behavioral descriptions. Parents are required to indicate whether they have observed these behaviors in their child (i.e., yes or no). The raw scores are converted into developmental quotients based on age. The developmental quotient (DQ) is calculated using the following formula: [developmental age / chronological age] × 100.

・*Group Adaptation Function Index (GAFI)*

The GAFI is a therapist-rated index for assessing the group adaptive and participative behaviors. It has demonstrated sufficient psychometric properties, with the Cronbach's alpha of 0.94 for internal consistency (Lin et al, in preparation). The index includes four categories: group regulation, learning response, communication behavior,

and social behavior. Each category comprises 6-9 expected and well-adapted behaviors, which the therapist rates on a scale from 0 (never occurring) to 4 (fully accomplished), based on the children's performance in daycare activities.

Statistical Analysis

The outcome measures, including ATEC scores, developmental quotients of CCDI, and GAFI scores, are analyzed using paired t tests. We also conducted repeated measure Analysis of Covariance (ANCOVA) to adjust for hypothesis-driven potential confounding factors affecting effectiveness, including the child's age and the number of days in the program. We used JOMAVI version 2.3 to analyze the data.

Results

Eleven autistic preschoolers (8 boys and 3 girls), aged 26 to 50 months (M = 34.3 months, SD = 10.0), participated. The baseline autistic characteristic, as assessed by CBRS, ranged from 8 to 21 (M = 14.6, SD = 4.34). Three preschoolers attended preschools concurrently while receiving the daycare program. All preschoolers also received other intervention (e.g., occupational therapy, speech therapy, and physiotherapy) as usual care. Ten preschoolers were accompanied by their mothers while only one preschooler was accompanied by the father. Most of the parents had education levels of college or higher, with only one mother having a high school diploma. The demographic data are shown in Table 1. The average duration attending daycare program was 309 days, ranging from 262 to 368 days (SD = 37.3). After discharge from the program, 6 preschoolers transitioned to general preschool, while 5 transitioned to special education preschool.

Table 1 Participants' demographics ($N = 11$)

Characteristics	Range	*M* (*SD*)	*n* (%)
Age in months	26-50	34.3 (7.7)	
Sex			
Boy			8 (72.7%)
Girl			3 (27.3%)
Baseline general developmental quotient	33-110	65.2 (20.3)	
Baseline CBRS	8-21	14.6 (4.34)	
Baseline T-STAT™ ($n = 9$)	0.50-3.50	2.25 (1.07)	
Attended preschools while receiving daycare service			2 (18.2%)
Caregivers who engaged in the treatment			
Mother			10 (90.9%)
Father			1 (9.1%)
Parents' education levels [*n*, (%)]			
High school			1 (9.1%)
College			7 (63.6%)
Graduate			3 (27.3%)

CBRS: Chinese version Clancy Behavior Rating Scale; T-STAT: Taiwanese version Screening Tool for Autism in Toddlers and Young Children

Baseline and Postintervention Differences

We found significant reductions in the ATEC speech/language/communication subscale and the total score ($t = –5.37$, $p < 0.001$; $t = –2.43$, $p = 0.035$), with large (Cohen's $d = –1.62$) and medium effect sizes (Cohen's $d = –0.73$), respectively. No significant difference was found in the developmental quotient, except for a significant decrease in gross motor ($t = –3.66$, $p = 0.004$, Cohen's $d = 1.10$). Significant improvements were also found in the GAFI in group regulation, learning response,

communicating behavior, and social behavior ($t = 4.65$, $p < 0.001$; $t = 4.99$, $p < 0.001$; $t = 3.56$, $p = 0.005$; $t = 3.89$, $p = 0.003$), with large effect sizes (d ranged from 1.07 to 1.51). However, after controlling for children's age and the number of days in the program in the repeated measure ANCOVA analyses, only the speech/language/communication subscale in ATEC showed a significant difference between baseline and postintervention ($F = 5.37$, $p = 0.049$, $\eta 2_p = 0.402$). The baseline and postintervention differences are shown in Table 2.

Table 2　Baseline and post-intervention differences ($N = 11$)

	Baseline	Post-intervention	Paired *t* test			Repeated measure ANCOVA§		
	M (*SD*)	*M* (*SD*)	*t*	*p*-value	Effect size (*d*)	*F*	*p*-value	Effect size ($\eta 2_p$)
Autism Symptoms-ATEC								
Speech/language/ communication	18.9 (5.7)	12.2 (6.2)	–5.37	<0.001***	–1.62	5.37	0.049*	0.402
Sociability	15.4 (5.5)	12.8 (6.1)	–1.99	0.75	–0.60	0.03	0.869	0.004
Sensory/cognitive awareness	14.5 (5.6)	11.1 (5.7)	–2.05	0.068	–0.62	0.22	0.654	0.026
Health/physical behaviors	24.2 (10.0)	24.5 (8.5)	0.10	0.920	0.03	0.93	0.363	0.104
Total	72.9 (18.7)	60.9 (25.2)	–2.43	0.035*	–0.73	0.01	0.910	0.002
Development-CCDI (DQ)								
Gross motor	84.8 (16.6)	72.8 (17.8)	–3.66	0.004**	–1.10	0.39	0.550	0.046
Fine motor	76.2 (18.4)	83.2 (27.0)	1.54	0.155	0.46	1.38	0.274	0.147
Expressive language	47.5 (17.6)	58.5 (29.3)	1.95	0.079	0.59	0.23	0.642	0.028

Concept comprehension	50.5 (22.1)	63.0 (35.8)	1.61	0.138	0.49	0.29	0.604	0.035
Situation comprehension	67.7 (20.9)	69.8 (25.5)	0.37	0.718	0.11	1.38	0.274	0.147
Self-help	48.5 (15.0)	50.8 (21.3)	0.62	0.551	0.19	0.58	0.468	0.068
Personal-social	62.4 (19.0)	62.6 (26.5)	0.04	0.966	0.01	4.95	0.057	0.382
General development	65.2 (20.3)	69.7 (31.9)	0.79	0.449	0.24	2.09	0.187	0.207
Group adaptation-GAFI								
Group regulation	3.3 (3.3)	12.5 (6.7)	4.65	<0.001***	1.40	1.02	0.343	0.113
Learning response	1.6 (2.1)	14.0 (9.0)	4.99	<0.001***	1.51	0.26	0.621	0.032
Communicating behavior	3.1 (4.7)	10.5 (7.9)	3.56	0.005**	1.07	1.37	0.275	0.147
Social behavior	0.5 (1.3)	8.9 (7.4)	3.89	0.003**	1.17	0.16	0.703	0.019

ATEC: Autism Treatment and Evaluation Checklist; CCDI, Chinese Child Development Inventory; DQ: developmental quotients; GAFI: Group Adaptation Function Index.

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

§Repeated measure ANCOVA controlled for the child's age and the number of days in the daycare program.

In repeated-measure ANCOVA analyses, significant age-by-time interactions were found in speech/language/communication subscale of the ATEC ($F = 6.81$, $p = 0.031$, $\eta 2_p = 0.460$), group regulation in GAFI ($F = 5.57$, $p = 0.046$, $\eta 2_p = 0.411$), learning response in GAFI ($F = 6.57$, $p = 0.033$, $\eta 2_p = 0.451$), social behavior in GAFI ($F = 5.54$, $p = 0.046$, $\eta 2p = 0.409$), and total score in GAFI ($F = 5.62$, $p = 0.045$, $\eta 2_p = 0.413$). Significant time-by-days in the program interactions were found in general development in the CCDI ($F = 5.53$, $p = 0.047$, $\eta 2_p = 0.409$).

Discussion

This study reported the significant effectiveness of an intensive, parent-involved NDBI-based group intervention for autistic preschoolers in mitigating autistic symptoms in communication, and improving adaptative performance in group contexts, consistent with our hypothesis. However, we did not find a significant improvement in general development, which contradicted our hypothesis. This study demonstrates the effectiveness of a clinically-based intervention program in a real-world setting, which is valuable given the limited research on the effectiveness of early interventions implemented as part of routine care. Moreover, to our knowledge, this is the first study exploring the effectiveness of a group-based NDBI program that involves the multiple parent-child dyads in the intervention.

Aligning with our hypothesis, we found significant improvements in autistic symptoms, especially in language and communication, as indicated by the reduction in ATEC scores. Sandbank and colleagues reported two meta-analyses studies of early intervention for autistic children in 2020 and 2023, indicating small to medium effect sizes of NDBIs on language, social communication, and cognition when only including RCT studies that did not derive from caregiver reports (Sandbank et al., 2020; Sandbank et al., 2023). Although we used parent-report information as the outcome measure of autistic symptoms, our findings align with these meta-analyses, suggesting that NDBI strategies, even when delivered in a group format, are beneficial to autistic preschoolers' communication. The significant difference in language and communication remained even after controlling for age and days in the program, demonstrating the robust effectiveness of this program on communication.

However, we did not find significant improvements in developmental quotients from this program and observed significant regression in the gross motor developmental quotient at postintervention. As developmental quotients are compared with their

typically developing peers of the same age, the lack of significant improvement suggests that while not significantly improved to catch up with their peers' developmental level, the intervention is able to sustain ongoing progress in autistic toddlers, preventing the widening gap of developmental delays. Additionally, the reduction in gross motor developmental quotient may be attributed to the fact that gross motor skills were not prioritized as a primary target within the NDBI activities (Sandbank et al., 2020; Sandbank et al., 2023; Tiede & Walton, 2019).

Moreover, we observed a significant increase in group adaptive and participative behaviors, which is not surprising considering the participants received training in a group-based context over an extended period. Although group adaptation is not typically a primary focus of NDBI programs, the strategies employed in NDBIs are utilized to develop new skills (Frost et al., 2020). Therefore, our results offer preliminary evidence that implementing NDBI strategies in group settings may facilitate the acquisition of skills necessary for group contexts, such as adhering to group regulations, enhancing learning responsiveness, and increasing communication and social behaviors towards adults and peers.

However, the significance in group adaptive and participative behaviors disappeared once we controlled for children's age and days in the program. Some previous studies have reported that younger children may be more responsive to the intervention, suggesting that age may be associated with the outcomes (Vivanti et al., 2014). The dosage effect (i.e., the intensity and duration of the treatment) was also suggested to be positively correlated with the improvement in outcomes in behavioral interventions for autism (Linstead et al., 2017). In our study, we did find significant time-by-age effect in communication and group behaviors, and significant time-by-days-in-the-program effect in general development. Hence, it is not surprising that the significance diminished once these factors were included, particularly in a small-sample-size study. These findings suggest that these two factors should be considered when

interpreting the effectiveness of early interventions.

The program is unique in several dimensions. Firstly, it is relatively intensive, with sessions occurring four times a week, which is uncommon in Taiwan's current early intervention system. Since most interventions in Taiwan's early intervention system are relatively low intensity, typically consisting of only 30 minutes per week, a program that provides more treatment hours with consistent goal-setting and strategy implementation is crucial for enhancing the effectiveness of early intervention. Secondly, it is a group-based intervention of NDBIs involving multiple parent-child dyads. The group-based format provided a naturalistic context, as typically developing preschoolers learn in a group-based context (e.g., preschools). Although NDBIs are supported by empirical evidence, the effectiveness of group-based interventions for autistic preschoolers is still limited. Our results support the feasibility of implementing NDBIs strategies within a group context as well as its promising effectiveness on social communication.

Moreover, involving multiple parent-child dyads in the group is novel and under-investigated in previous research. This model creates rich opportunities for social interaction among children, among parents, and between children and parents, which may lead to enhanced social communication in children and improved parent-child interaction. Additionally, parents can learn from each other and feel supported within the group dynamic. Therefore, the current study demonstrated the feasibility and benefits of integrating important elements of early intervention addressed in previous research of early intervention. Lastly, this program is fully covered by NHI and integrated into Taiwan’s public system, showing a balance of sustainability and affordability. Concerns about meeting recommended fidelity of the NDBIs while maintaining cost-effectiveness in service systems have been raised (Vivanti et al., 2017). The current study demonstrated that implementing a program that utilizes NDBI strategies in a group-based format to achieve cost-effectiveness, while remaining affordable for families, is feasible.

The participants in this study were considered representative due to a sex ratio of autism similar to that reported in a global prevalence study (Zeidan et al., 2022), a high heterogeneity of symptoms, and the fact that all were receiving usual care within Taiwan's early intervention system. Thus, the results of the current study may be applicable to autistic preschoolers in Taiwan, suggesting this program is beneficial and the dissemination and promotion of it should be encouraged. However, the majority of participants were accompanied by their mothers when attending the intervention, indicating that mothers undertake the primary responsibility for bringing autistic preschoolers to early intervention sessions. Increasing the involvement of fathers in early intervention may be an important consideration, and further investigation into whether program adaptations are needed to accommodate fathers' needs and increase acceptability among fathers is warranted.

There are several limitations in this study. First, it is a nonexperimental study with a small sample size and lacks a control group, which weakens the results. Second, although the group was led by a therapist with abundant NDBI implementation experience, the fidelity of the implementation of this program was not meticulously reviewed and checked. Implementing NDBI strategies may require adaptations to suit the group context (Eapen et al., 2013). Therefore, future research should investigate how therapists adapt NDBI strategies for group contexts and how these adaptations affect effectiveness. Furthermore, it remains unclear how parents learn and utilize NDBI strategies in this parent-child dyads group to facilitate children's participation. Third, due to the small sample size, we could only include two potential factors in the repeated measures ANCOVA analyses. However, additional factors may have contributed to the results and should be considered in future analyses. Lastly, the outcome measures, which rely on parent-reported and therapist-reported data, may introduce detection bias. Employing objective measures and a blind design in future studies is warranted to ensure more robust results.

Conclusions

This study evaluated the effectiveness of an intensive, group-based NDBI program for autistic preschoolers, demonstrating significant improvements in autistic symptoms and group adaptive behaviors, but not in developmental quotients. The program employs a unique approach involving multiple parent-child dyads and implements NDBI strategies, demonstrating effectiveness in real-world settings, which emphasize the need for both sustainability and affordability. The results of this study offer insights into early intervention practices.

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文獻評論

數位化與沉浸式虛擬實境鏡像治療運用於中風後上肢動作與日常生活功能探討：系統性文獻回顧與統合分析

謝妤葳[1,2,*] 陳雅婷[1] 李孟達[1] 徐富琳[3] 陳芝琪[2,4]

摘要

新形態的鏡像治療使用數位影像處理或虛擬實境的技術，以促進上肢動作功能，並展現了作為中風復健策略的潛能。然而，其效果尚未被全面地評估。此系統性回顧旨在評估新形態的鏡像治療對於中風病人上肢動作和日常功能的效果。研究使用 PubMed, Scopus, Cochrane Library, EBSCOhost, 和 Airiti Library 等資料庫搜尋 2023 年 7 月之前的文獻。此回顧納入了檢驗對於中風病人新型態的上肢鏡像治療效果的隨機控制試驗。在回顧結果方面，此回顧採用了九個隨機控制試驗，包含 304 位中風病人。相較於控制組，新形態的鏡像治療對於上肢動作功能有顯著的中度至高度效果值 (SMD = 0.621 和 0.544，$p < .001$ 和 $p = .022$ 分別對應於傅格梅爾評估和操作功能評估測驗)。新形態的鏡像治療也顯示了在生活品質的顯著中度效果 (SMD = 0.501, $p = .043$)，以及在手部操作精細度 (SMD = 0.475, $p = .003$)、肌肉張力 (SMD = —0.380, $p = .005$) 和日常功能 (SMD = 0.468, $p < .001$) 的輕度至中度效果。總結而言，新形態的鏡像治療在促進中風病人的上肢功能上優於傳統的介入。建議未來運用高品質的隨機控制試驗檢驗新形態的鏡像治療的適合治療劑量和可能的不良反應。

關鍵詞：鏡像治療，數位科技，虛擬實境，中風復健，系統性回顧

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Review article

Digital-Based and Immersive Virtual Reality Mirror Therapy for Upper Limb Motor and Daily Functions After Stroke: A Systematic Review and Meta-Analysis

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Abstract

Novel forms of mirror therapy (MT) using digital image processing or virtual reality technology for facilitating upper limb motor function have demonstrated potential as stroke rehabilitation strategies; however, their efficacy has not been comprehensively evaluated. This systematic review aimed to evaluate the effects of novel forms of MT on upper limb motor and daily functions in patients with stroke. PubMed, Scopus, Cochrane Library, EBSCOhost, and Airiti Library were searched for articles published up to July 2023. Randomized controlled trial (RCT) studies examining the effects of novel forms of upper limb MT in patients with stroke were included. For the results of review, nine RCT studies with 304 participants with stroke were included. The novel forms of MT had a significantly moderate to large effect size on upper limb motor function (standardized mean difference [SMD] = 0.621 and 0.544, $p < .001$ and $p = .022$ for the Fugl-Meyer Assessment and Manual Function Test, respectively). Novel MT also showed a significantly moderate effect on quality of life (SMD = 0.501, $p = .043$) and a significantly small to moderate effect on manual dexterity (SMD = 0.475, $p = .003$), muscle tone (SMD = −0.380, $p = .005$), and daily function (SMD = 0.468, $p < .001$) as compared with the control groups. In conclusion, the review findings suggest that the novel forms of MT are superior to control interventions in improving upper limb motor function in patients with stroke. Further high-quality RCTs are recommended to examine optimal treatment dosages and potential adverse effects of novel MT.

Keywords: Mirror therapy, Digital technology, Virtual reality, Stroke rehabilitation, Systematic review

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Introduction

Stroke is a major cause of adult long-term disability worldwide (Collaborators, 2021; Hankey et al., 2002; Ovbiagele et al., 2013). About 65% of patients with stroke suffer from hemiplegia (Bindawas et al., 2017), and only 50% regain partial motor function (Gandhi et al., 2020). Limited motor function diminishes their participation in daily activities and overall quality of life. Hence, there has been an emphasis on improving the motor and functional recovery of individuals with stroke (Hatem et al., 2016; Winstein et al., 2016). Classic mirror therapy (MT) has been recognized as an effective therapeutic intervention (Morkisch et al., 2019; Thieme et al., 2018; Yang et al., 2018). Classic MT used a physical mirror or mirror box to provide mirror visual feedback, allowing patients to observe the reflected images of their nonaffected limb's movement as if it were the affected limb's movement (Wu et al., 2013).

In recent years, novel forms of MT have emerged as prominent interventions in stroke rehabilitation to overcome certain technical limitations associated with classic MT (Choi et al., 2019; Ding et al., 2019; Ding et al., 2018; Hsu et al., 2022; Kim et al., 2023; Mekbib et al., 2020; Weber et al., 2019). According to the equipment and technology used in individual studies, novel forms of MT can be generally classified into two categories: digital-based MT and immersive virtual reality MT. Digital-based MT commonly involves using cameras or webcams to capture the movements of the patient's unaffected hand, which are then instantly transformed into the movements of the affected hand through digital image processing software. Immersive virtual reality MT, on the other hand, requires the use of an immersive VR headset that displays 3D graphics and virtual hands, typically showcasing the movements of the affected hand within the virtual environment. Subsequently, the mirror visual feedback of the affected hand is presented either as a mirrored image of the unaffected hand on a computer monitor or tablet computer (Ding et al., 2019; Ding et al., 2018; In et al., 2012; Kim et

al., 2023; Lee et al., 2014) (i.e., digital-based MT) or via a generated virtual hand in a 3D virtual reality environment (i.e., immersive virtual reality MT) (Choi et al., 2019; Hsu et al., 2022; Lin et al., 2021; Mekbib et al., 2020; Sip et al., 2023; Weber et al., 2019; Wei et al., 2022).

The studies of novel forms of MT have revealed that patients with stroke gained significant improvements in motor function compared to those receiving conventional rehabilitation (Choi et al., 2019; Ding et al., 2019; Ding et al., 2018; Kim et al., 2023). Moreover, novel forms of MT provide more immersive mirror visual feedback (Hsu et al., 2022; Lin et al., 2021; Sip et al., 2023) and better perception of limb ownership (Ding et al., 2018; In et al., 2012), and they reduce the head and neck discomfort and postural pressure during rehabilitation (Choi et al., 2019; Ding et al., 2019; Ding et al., 2018; Mekbib et al., 2020; Weber et al., 2019). The advantages of novel forms of MT and those positive preliminary study findings make them promising approaches for further rehabilitation applications.

Recent reviews evaluated virtual reality MT for post-stroke upper limb rehabilitation. A scoping review concluded that immersive virtual reality MT is safe, feasible, and capable of improving upper limb motor function (Gebreheat et al., 2024). Moreover, a systematic review reported moderate to large effect sizes for motor outcomes and suggested potential benefits when combined with conventional rehabilitation (Okamura et al., 2023).

Although previous reviews and studies have demonstrated positive effects of novel forms of MT, some important research gaps remain. For example, some novel MT devices are still in the development stage, with certain studies lacking control groups (Hoermann et al., 2017; Mekbib et al., 2020; Weber et al., 2019) or involving small sample sizes (fewer than 20 participants) (Ding et al., 2019; In et al., 2012; Lin et al., 2021; Sip et al., 2023). The effects of interventions are often limited to specific subpopulations due to narrow inclusion and exclusion criteria (Ding et al., 2019; Kim

et al., 2023; Lee et al., 2014; Sip et al., 2023). Moreover, some studies focused on motor function improvement without addressing daily functional outcomes, which are critical for assessing the overall impact on quality of life. Additionally, while some studies utilized digital imaging technology to provide mirror visual feedback (Choi et al., 2019; Ding et al., 2019; Ding et al., 2018; Hoermann et al., 2017; Hsieh et al., 2022; In et al., 2012; Kim et al., 2023; Lee et al., 2014), others employed immersive virtual reality environments (Hsu et al., 2022; Lin et al., 2021; Mekbib et al., 2020; Sip et al., 2023; Weber et al., 2019). These variations complicate efforts to assess treatment effectiveness comprehensively. Finally, while the two recent reviews (Gebreheat et al., 2024; Okamura et al., 2023) provided valuable insights, their scope was restricted. Both reviews concentrated on virtual reality MT and did not included studies involving digital-based MT. Additionally, one review did not conduct a meta-analysis, restricting its ability to quantitatively synthesize findings. To address these issues, this study aims to evaluate whether the novel forms of MT have greater improvements in upper limb motor function and daily function for patients with stroke compared with control intervention, by synthesizing the study results of both types of the novel forms of MT.

Methods

Inclusion and Exclusion Criteria of the Studies

All articles found on the electronic databases were screened with the following criteria: (1) a study sample of people with stroke, (2) a randomized controlled trial (RCT) study design, (3) one intervention group implementing a novel form of upper limb MT (e.g., digital-based MT or immersive virtual reality MT), (4) at least one outcome measure assessing upper limb motor function and/or daily function, and (5) publication entirely in either English or Traditional Chinese. If the study intervention combined novel forms of MT and other rehabilitation therapy (e.g., robot-assisted rehabilitation,

brain-machine interface, or action observation), the study was excluded. However, the studies included regular or conventional rehabilitation were not excluded. The protocol of the systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO, registration number: CRD42023441037).

Search Strategy

Articles written in English were searched for on the following electronic databases: PubMed, Scopus, Cochrane Library, and EBSCOhost. Airiti Library was searched for articles in Traditional Chinese. The search strategy used on PubMed is reported in Table 1. All the potential articles published before July 19, 2023, were included.

Table 1　The searching keywords used on PubMed

Search	Query	Items found
#8	#6 AND #7	50
#7	#3 AND #4 AND #5	75
#6	#1 OR #2	602,058
#5	“upper limb*” OR “upper extremit*” OR arm* OR shoulder* OR hand* OR axilla* OR elbow* OR forearm* OR finger* OR wrist*	1,480,913
#4	“mirror* therapy” OR “mirror* visual feedback” OR “mirror* illusion” OR “visual illusion“OR “mirror* box” OR “mirror* reflection”	1,337
#3	computerized OR computerised OR camera-based OR “virtual reality” OR virtual OR digital OR game-based OR “video games” OR augmented	652,016
#2	hemipleg* OR hemipar* OR paresis OR paretic OR paretical	50,101
#1	stroke OR poststroke OR cerebrovasc* OR cva OR “cerebrovascular disease” OR “cerebrovascular accident” OR “brain infarct*” OR “brain ischemi*” OR “brain hemorrhag*” OR post-stroke OR apoplexy	568,862

Data Collection and Extraction

All articles found on the databases were imported into EndNote X9, and duplicate articles were removed. The titles and abstracts of the articles were first screened and evaluated according to the inclusion and exclusion criteria. The full texts of selected or possible relevant articles were accessed and reviewed.

After the selection of the relevant articles, the following data were extracted: sample size, demographic characteristics of the subjects (e.g., age, gender, lesion site of stroke, and time since stroke onset), the details of the intervention, outcome measures (e.g., the mean and standard deviation scores of outcomes in each intervention group), and main study findings. If there were missing data in the selected article, the corresponding author of the article was contacted by email.

Methodological Quality Assessment

To evaluate the methodological quality of the included articles, two independent reviewers appraised the articles with the Physiotherapy Evidence Database (PEDro) scale (Blobaum, 2006; Maher et al., 2003; Physiotherapy Evidence Database, 1999) and the Cochrane risk-of-bias tool (RoB 2.0) (Sterne et al., 2019). The maximum score on the PEDro scale is 10. Based on the PEDro score, each study was classified into excellent (9 to 10 points), good (6 to 8 points), fair (4 to 5 points), or poor quality (3 points or less) (Cashin & McAuley, 2020). The Cochrane risk-of-bias tool was used to assess 5 domains of bias: (1) randomization process, (2) deviations from the intended intervention, (3) missing outcome data, (4) measurement of the outcome, and (5) selection of the reported result. In case of the disagreement between the two reviewers, a third independent reviewer was consulted for the final decision.

Statistical Analysis

Comprehensive Meta-Analysis Version 2.0 (Biostat Inc., Englewood, NJ, USA) was used to analyze the data. The treatment effects of RCT studies with novel forms of MT on the outcomes were evaluated, and if a single study had 2 control groups, the effect sizes were assessed separately in comparison with the experimental group. In addition, the random effects model was used for each comparison due to differences in sample sizes, intervention dosages, and subject characteristics across each study. Moreover, subgroup analyses were conducted to evaluate the effect sizes of different types of novel MT (i.e., digital-based versus immersive virtual reality MT) and the impact of stroke phase based on the average onset time of more or less than 6 months (i.e., chronic versus subacute phase) on the most commonly used outcome, the Fugl-Meyer Assessment (FMA).

For the outcome measures, the standardized mean difference (SMD) and 95% confidence interval were utilized to assess the effect sizes of the studies. SMD values of 0.2, 0.5, and 0.8 are respectively considered to indicate small, moderate, and large effect sizes (Cohen, 1988; Faraone, 2008). All outcome measures included in the analyses were assessed at two time points: before and after the intervention period.

The Cochran Q test and I^2 statistics were used to examine the presence of heterogeneity among the studies. I^2 statistics of 25%, 50%, and 75% indicate that there is low, moderate, and high heterogeneity, respectively (Higgins et al., 2003). Furthermore, the Egger's regression test was used to evaluate the publication bias in these studies.

Results

Study Selection and Characteristics

The selection process of the articles in this review is depicted in Figure 1. Initially, 195 articles were found on the databases. After screening with the selection criteria, 9

eligible full-text RCT articles with 304 subjects were included in this review (Choi et al., 2019; Ding et al., 2019; Ding et al., 2018; Hsu et al., 2022; In et al., 2012; Kim et al., 2023; Lee et al., 2014; Lin et al., 2021; Sip et al., 2023). All 9 RCT articles were written in English and published between 2012 and 2023.

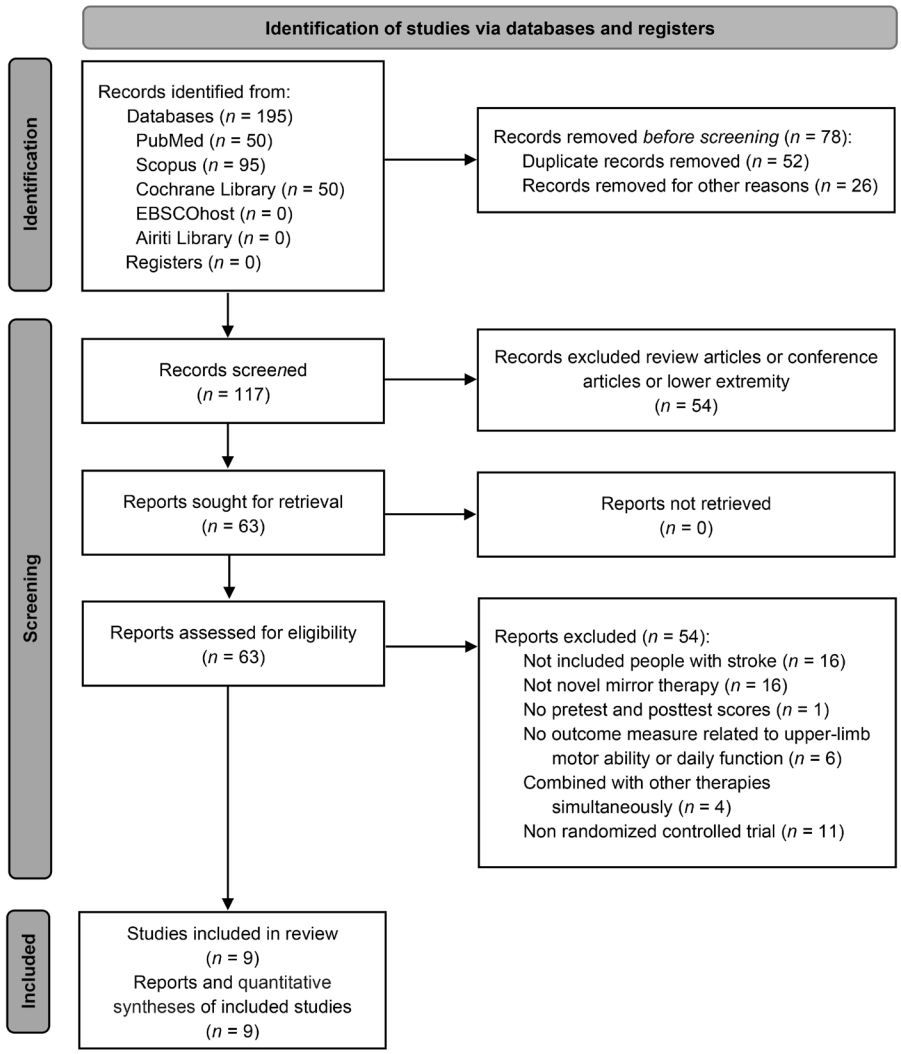


Figure 1 Flowchart of study selection.

There were 6 RCTs of digital-based MT (Choi et al., 2019; Ding et al., 2019; Ding et al., 2018; In et al., 2012; Kim et al., 2023; Lee et al., 2014) and 3 RCTs of immersive virtual reality MT (all involved using a head-mounted display) (Hsu et al., 2022; Lin et al., 2021; Sip et al., 2023). The control groups used in the included studies were sham MT (Choi et al., 2019; In et al., 2012), traditional MT (Choi et al., 2019; Hsu et al., 2022; Kim et al., 2023; Lin et al., 2021; Sip et al., 2023), conventional rehabilitation (Ding et al., 2019; Ding et al., 2018; Hsu et al., 2022; Kim et al., 2023), or digital MT with symmetric training (Lee et al., 2014). The sham MT was conducted in the same environment as the traditional MT, but the mirror was typically covered with black paper to prevent the affected hand from being seen. Moreover, only 2 studies of digital-based MT (Ding et al., 2019; Ding et al., 2018) and 2 studies of immersive virtual reality MT (Hsu et al., 2022; Lin et al., 2021) had reported that there was no adverse event in the study.

The mean ages of the participants in the RCT studies ranged from 54.25 to 63.89 years old, and the mean onset times of stroke varied from 72.45 days to 45.2 months, calculated based on the data provided by the authors of each included study. The total sample sizes of the studies ranged from 18 to 79 subjects. The treatment frequencies of novel forms of MT provided in the studies varied from 30 to 90 minutes per day, 2 to 6 days per week, for 3 to 9 weeks. In addition, the most commonly used outcome measure was the FMA. If the outcome measures applied in at least 2 included studies, the data were included in the meta-analysis. The outcomes used in one individual study were excluded from the meta-analysis, except for the 3 outcomes that all measure daily function (i.e., Barthel Index [BI], Functional Independence Measure [FIM], and Motor Activity Log [MAL]) and 2 outcomes that all assess quality of life (i.e., Short Form-8 [SF-8] and Short Form-36 [SF-36]).

Methodological Quality

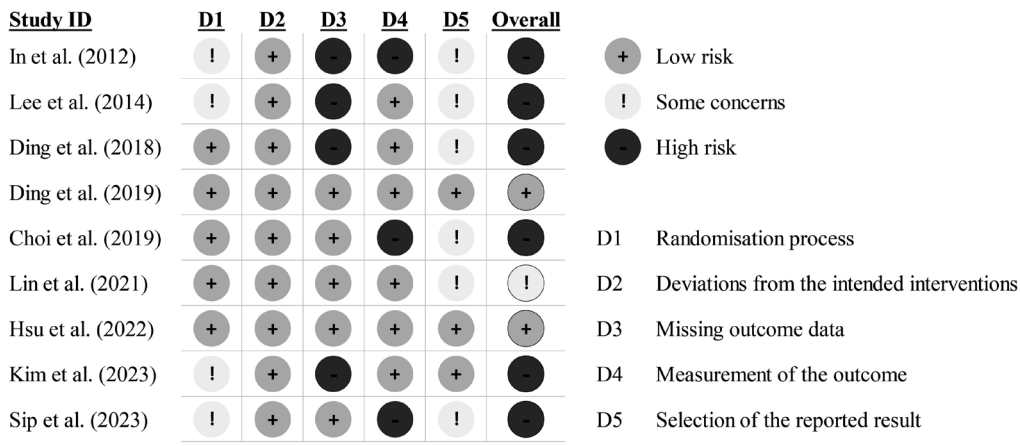
Table 2 presents the PEDro score of each RCT study; the scores ranged from 4 to

8. In all, 6 studies were rated as having good study quality (Choi et al., 2019; Ding et al., 2019; Ding et al., 2018; Hsu et al., 2022; Kim et al., 2023; Lin et al., 2021), while the remaining 3 studies had fair study quality (In et al., 2012; Lee et al., 2014; Sip et al., 2023). Furthermore, the methodological quality of each included study and across all studies using Cochrane risk-of bias tool 2 (RoB 2) is shown in Figure 2A and 2B. Among the included studies, 6 were rated as having a high risk of bias, 1 study was classified as having some concerns, and 2 studies were judged to have a low risk of bias. In terms of specific domains, 5 studies (55.6%) demonstrated a low risk of bias in the randomization process, and all studies (100%) had a low risk of bias regarding deviations from the intended interventions. Additionally, 5 studies (55.6%) exhibited a low risk of bias in reporting outcome data, while 6 studies (66.7%) showed a low risk of bias in outcome assessment. Furthermore, 3 studies (33.3%) appropriately mitigated bias in the selection of reported results.

Table 2 Quality assessment of the included randomized controlled trial (RCT) studies with the PEDro scale

First author (year)	In (2012)	Lee (2014)	Ding (2018)	Ding (2019)	Choi (2019)	Lin (2021)	Hsu (2022)	Kim (2023)	Sip (2023)
Eligibility criteria	Y	Y	Y	Y	Y	Y	Y	Y	Y
Random allocation	1	1	1	1	1	1	1	1	1
Concealed allocation	0	0	1	1	1	1	1	0	0
Baseline comparability	1	1	1	1	1	1	1	1	0
Blind subjects	0	0	0	0	0	0	0	0	0
Blind therapists	0	0	0	0	0	0	0	0	0
Blind assessors	0	1	1	1	0	1	1	1	0
Adequate follow-up	0	0	1	1	1	1	1	1	1

Intention-to-treat analysis	0	0	0	0	1	1	0	0	1
Between group comparisons	1	1	1	1	1	1	1	1	1
Point estimates and variability	1	1	1	1	1	1	1	1	1
Total score	4	5	7	7	7	8	7	6	5



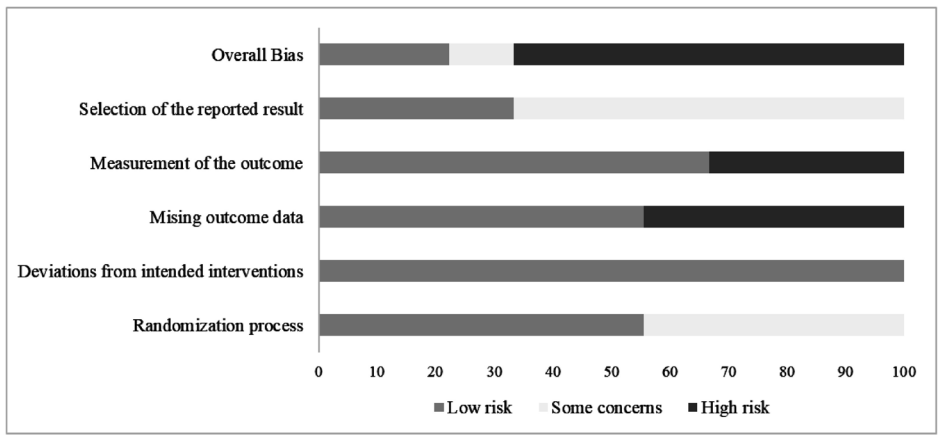


Figure 2　(A) Summary of risk of bias for each included study and (B) Percentage of risk of bias across all items for included studies.

Effect Size on Upper limb Motor Function

As for the treatment effects, the meta-analysis results of novel forms of MT on upper limb motor function measuring by the FMA and Manual Function Test (MFT) in patients with stroke are demonstrated in Figure 3A and 3B, respectively. A total of 8 studies involved 268 patients with stroke (Ding et al., 2019; Ding et al., 2018; Hsu et al., 2022; In et al., 2012; Kim et al., 2023; Lee et al., 2014; Lin et al., 2021; Sip et al., 2023) and assessed the effects of new forms of MT on the FMA. The studies of Hsu et al. (2022) and Kim et al. (2023) had 2 control groups, so 2 comparisons of effect sizes in these 2 studies were calculated. Figure 3A shows that the novel forms of MT had moderate to large treatment effects on upper limb motor function measured by the FMA as compared with the control intervention (SMD = 0.621, $p < .001$). In addition, there was no significant heterogeneity among these studies (Q = 6.307, $p = .709$, $I^2 < 0.001\%$).

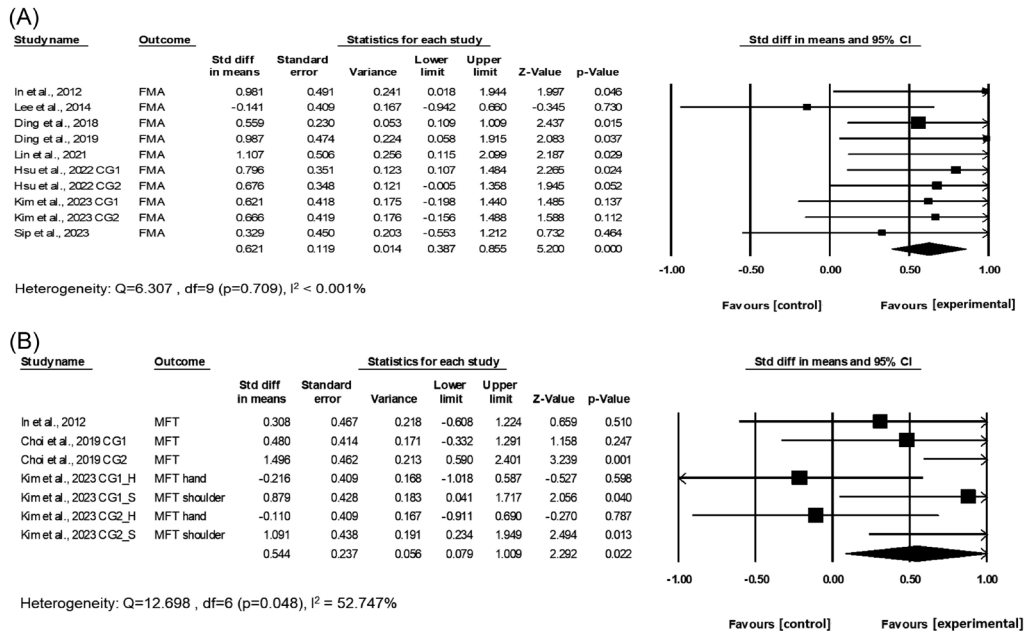


Figure 3 Forest plots of the meta-analysis of novel forms of mirror therapy compared with the control treatment on the (A) Fugl-Meyer Assessment and (B) Manual Function Test.

Furthermore, 3 studies involved 91 subjects (Choi et al., 2019; In et al., 2012; Kim et al., 2023) and evaluated the treatment effects on another outcome of upper limb motor function, the MFT. In the study of Kim et al. (2023), 2 control groups and 2 sub-scores of the MFT were used, necessitating the calculation of 4 comparisons of effect sizes. The forest plot of the 3 studies using the MFT demonstrated a moderate effect (SMD = 0.544, p = .022), and moderate heterogeneity was found (Q = 12.698, p = .048, I^2 = 52.75%) (Fig. 3B).

The Egger's regression tests of the 8 studies employing the FMA and the 3 studies using the MFT indicated that there was no significant publication bias (FMA: p = .524; MFT: p = .131).

Effect Size on Manual Dexterity

Figure 4A shows the meta-analysis results of 4 studies with 131 stroke participants (Hsu et al., 2022; In et al., 2012; Kim et al., 2023; Lee et al., 2014) assessing the treatment effects of novel MT on manual dexterity assessed by the Box and Block Test (BBT). Two comparisons of effect sizes were performed in the studies of Hsieh et al. (2022) and Kim et al. (2023) due to the 2 control groups applied in these studies. The forest plot showed a small to moderate effect (SMD = 0.475, p = .003) on manual dexterity, and no heterogeneity was found (Q = 2.258, p = .812, I^2 < 0.001%) (Fig. 4A). In addition, the Egger's regression test f the 4 studies with the BBT showed no significant publication bias (p = .411).

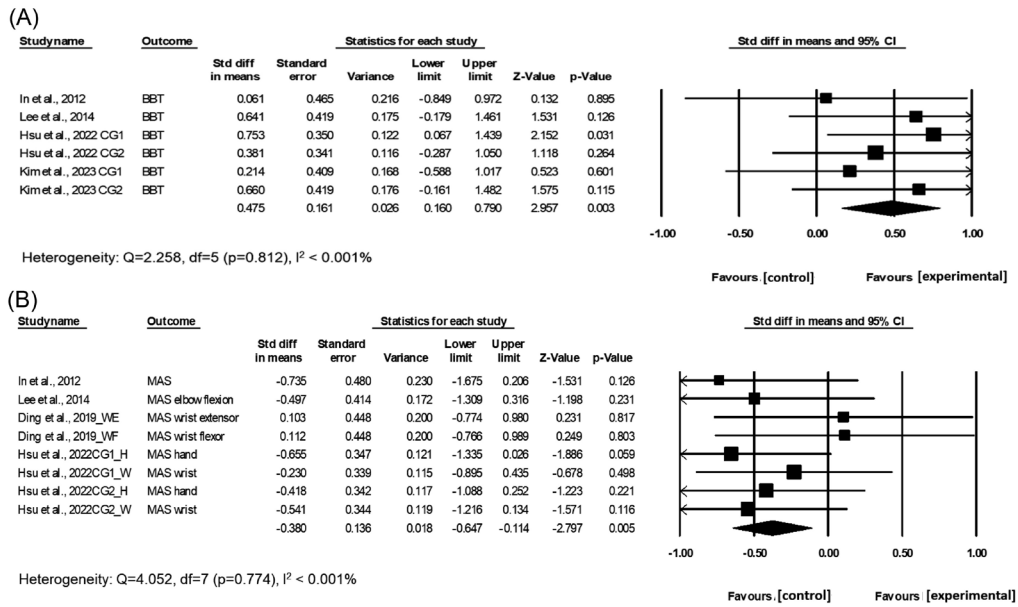


Figure 4 Forest plots of the meta-analysis of novel forms of mirror therapy compared with the control treatment on the (A) Box and Block Test and (B) Modified Ashworth Scale.

Effect Size on Muscle Tone

A group of 4 studies with 115 participants (Ding et al., 2019; Hsu et al., 2022; In et al., 2012; Lee et al., 2014) evaluated the effects of novel MT on muscle tone measured by the Modified Ashworth Scale (MAS). In the study of Hsu et al. (2022), 2 control groups and 2 subparts of the MAS (i.e., hand and wrist scores) were used, necessitating the calculation of a total of 4 comparisons of effect sizes. Figure 4B presents the meta-analysis results showing a small to moderate effect size (SMD = −0.380, p = .005), without heterogeneity among these studies (Q = 4.052, p = .774, $I^2 < 0.001\%$). A negative value for an effect size indicates that the muscle tone of the patients with stroke decreased after receiving the novel MT, and a lower MAS score represents less spasticity. Moreover, the non-significant Egger's regression test confirmed the absence

of publication bias (p = .456).

Effect Size on Daily Function

Three studies involving 151 patients with stroke (Ding et al., 2019; Ding et al., 2018; Hsu et al., 2022) discussed the effects of novel MT on improving daily function, respectively measured by the BI (Ding et al., 2018), FIM (Ding et al., 2019) and MAL (2 subscales of amount of use and quality of movement) (Hsu et al., 2022). Four comparisons of effect sizes were performed in the studies of Hsu et al. (2022) due to the 2 control groups and 2 subscales of MAL applied in this study. Figure 5A demonstrates that the novel forms of MT had a small to moderate treatment effect on daily function as compared with control treatments (SMD = 0.468, p < .001). There was no heterogeneity in the three studies (Q = 2.104, p = .835, I^2 < 0.001%). Additionally, the non-significant Egger's regression test confirmed the absence of publication bias (p = .962).

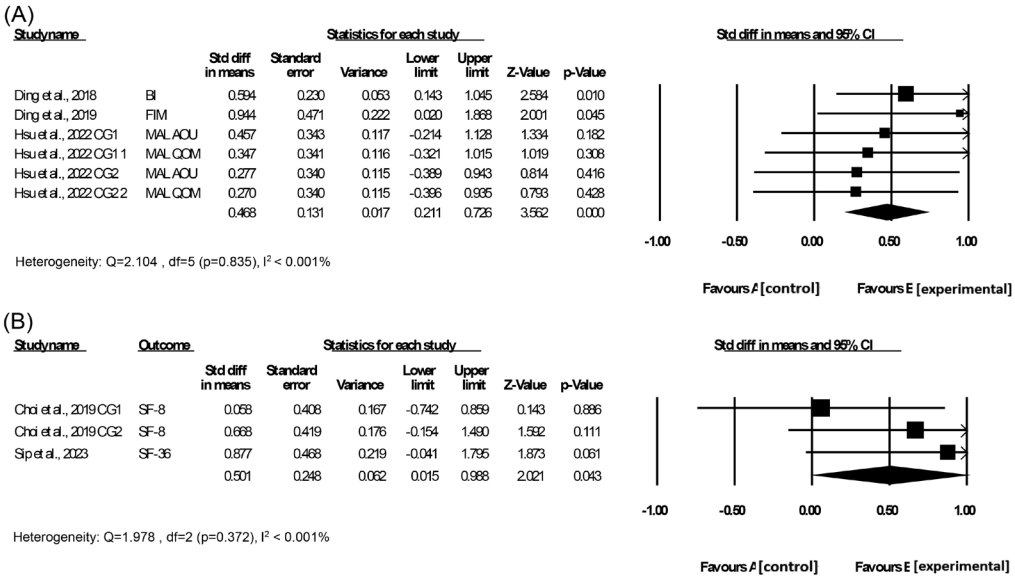


Figure 5　Forest plots of the meta-analysis of novel forms of mirror therapy compared with the control treatment on the (A) daily function and (B) quality of life.

Effect Size on Quality of Life

Two studies involved 56 subjects (Choi et al., 2019; Sip et al., 2023) and evaluated the treatment effects on quality of life measured by the SF-8 and SF-36. Two comparisons of effect sizes were performed in the study of Choi et al. (2019) due to the 2 control groups applied. The forest plot showed a moderate effect (SMD = 0.501, p = .043) on quality of life, and no heterogeneity was found (Q = 1.978, p = .372, I^2 < 0.001%) (Fig. 5B). In addition, the Egger's regression test showed no significant publication bias (p = .410).

Subgroup Analyses

For the subgroup analyses of different types of novel MT, 5 studies utilized digital-based MT (Ding et al., 2019; Ding et al., 2018; In et al., 2012; Kim et al., 2023; Lee et al., 2014) and 3 studies applied immersive virtual reality MT (Hsu et al., 2022; Lin et al., 2021; Sip et al., 2023). For the subgroup analysis of different stroke phases, 5 studies recruited patients with chronic stroke (Hsu et al., 2022; In et al., 2012; Kim et al., 2023; Lee et al., 2014; Lin et al., 2021) and 3 studies recruited patients with subacute stroke (Ding et al., 2019; Ding et al., 2018; Sip et al., 2023). These subgroup analyses excluded the study of Choi et al. (2019) because the FMA was not used as an outcome measure.

Digital-based MT showed a moderate effect (SMD = 0.569, p < .001; Fig. 6A) and immersive virtual reality MT had a moderate to large effect (SMD = 0.714, p < .001; Fig. 6B) on the FMA as compared with the control intervention. In addition, the novel forms of MT demonstrated moderate effects on the FMA in both patients with chronic stroke (SMD = 0.644, p < .001; Fig. 6C) and those with subacute stroke (SMD = 0.587, p = .002; Fig. 6D). There was no heterogeneity among the studies (all I^2 < 0.001%) and no publication bias according to the non-significant Egger's regression test (all p > .05) in the subgroup analyses.

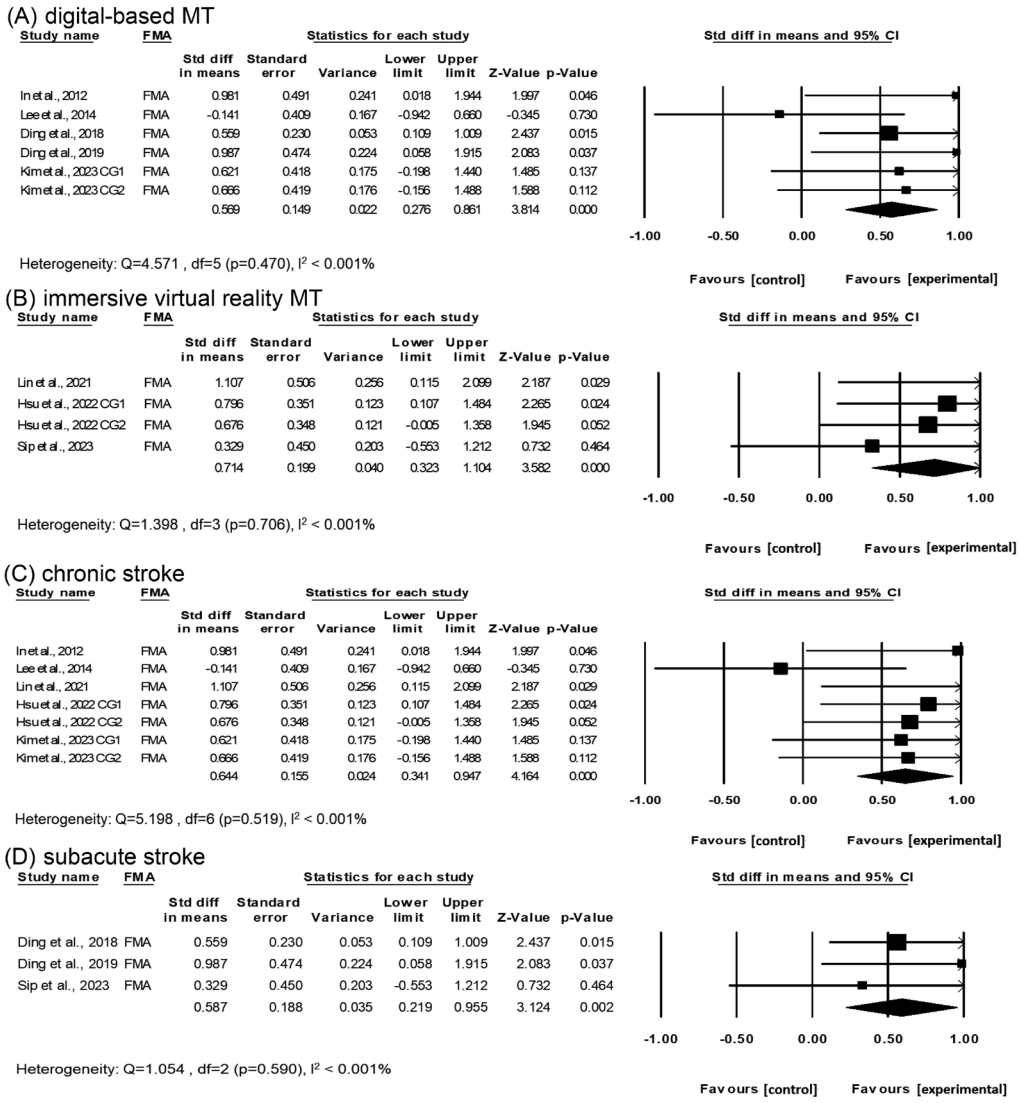


Figure 6　Forest plots of the meta-analysis comparing (A) digital-based and (B) immersive virtual reality mirror therapy with control treatment on the Fugl-Meyer Assessment. Subgroup analyses comparing novel mirror therapy with control treatment on the Fugl-Meyer Assessment in (C) chronic and (D) subacute stroke.

Discussion

The review and meta-analysis revealed that novel forms of MT had moderate to large treatment effects on upper limb motor function measured by the FMA and MFT in comparison with the control intervention groups, based on the good to fair study quality of the included RCT studies. Novel MT also demonstrated a moderate effect size on quality of life, and a small to moderate effect size on manual dexterity, muscle tone, and daily function. For the patients with chronic or subacute stroke, the novel MT led to a similar treatment effect on the FMA. Immersive virtual reality MT appeared to have a slightly better motor outcome than digital-based MT, according to the summary effect size of subgroup analysis (0.714 versus 0.569). Moreover, there was no significant statistical heterogeneity among the RCT studies in most analyses, and no publication bias was found in any of the analyses.

Novel forms of MT had moderate to large treatment effects on upper limb motor function as compared with the control groups, in which the effect sizes were somewhat larger than those observed in previous review studies synthesizing the treatment effects of classic MT (Thieme et al., 2018; Zeng et al., 2018). These positive findings on upper limb motor function might be attributed to the more immersive mirror illusion (Hsu et al., 2022; Lee et al., 2014; Sip et al., 2023), better ergonomic position (e.g., reduced asymmetric posture and less neck discomfort) (Choi et al., 2019; Ding et al., 2019; Ding et al., 2018; In et al., 2012), and greater sense of limb ownership (Ding et al., 2018; In et al., 2012) during the novel MT interventions. Furthermore, some digital-based MT devices provided bilateral reciprocal movements (Chang et al., 2019; Lee et al., 2014) that could not be performed during traditional MT. Patients with stroke also benefited from bilateral reciprocal movements when using delayed mirror illusions during digital-based MT. Therefore, these novel forms of MT address certain limitations of traditional MT and offer great promise as alternatives to traditional MT or conventional

rehabilitation regimens to improve the upper limb motor function.

Immersive virtual reality MT provides a multisensory environment, has fewer physical limitations than the mirror box, and can facilitate the use of simulated real-life tasks as training programs, which might also contribute to enhanced motor learning and daily task performance in stroke individuals (Hsu et al., 2022; Lin et al., 2021; Sip et al., 2023). These factors might also generate a slightly greater treatment effect of immersive virtual reality MT than that of digital-based MT on improving the FMA. However, further comparisons on the cost-effectiveness, patient acceptance, and adverse effects of different types of novel MT are needed.

There was evidence of a significantly moderate treatment effect of novel MT on quality of life (SMD = 0.501) and a significantly small to moderate effect (SMD = 0.468) on daily function as compared with the control interventions. Our findings are similar to those of prior reviews investigating the effects of traditional MT on daily function (Nogueira et al., 2021; Thieme et al., 2018). The 2 meta-analysis studies also showed a small to moderate effect favored the traditional MT on improving daily function (SMD = 0.48 and Hedges' g = 0.30) (Nogueira et al., 2021; Thieme et al., 2018). However, there was no meta-analysis study to examine the effects of upper limb MT on the outcomes of quality of life. Based on our review, only 3 and 2 individual studies have respectively investigated the effects of novel MT on daily function and quality of life. Daily function and quality of life are well-recognized and important outcomes after stroke interventions. The effects of novel forms of MT on the 2 outcomes warrant further investigations.

Very few review studies have evaluated the effect of MT on reducing spasticity after stroke. In this review, novel forms of MT showed a small to moderate effect size (SMD = −0.38) on reducing spasticity as compared with the control treatments; this finding was somewhat different from the effects of traditional MT on muscle tone (SMD = 0.12 and −0.14) (Munoz-Gomez et al., 2023; Yang et al., 2018). Based on our review,

a larger tendency of reduction of muscle tone has been found in patients with stroke treated with novel forms of MT than in those treated with traditional MT in the 2 prior reviews (Munoz-Gomez et al., 2023; Yang et al., 2018). However, the review studies of Munoz-Gomez et al. (2023) and Yang et al. (2018) included studies with both upper and lower-limb MT, whereas our review included only those with upper limb MT. In addition, one individual study required the calculation of 4 comparisons of effect sizes for this outcome, which may have led to over-representation of this study in our review. Therefore, more studies are suggested to determine whether novel forms of MT can reduce muscle tone in patients with stroke.

Most analyses in this review found no heterogeneity among the studies, and only moderate heterogeneity was found among the 3 RCT studies that used the MFT as an outcome measure (Choi et al., 2019; In et al., 2012; Kim et al., 2023). This result may be attributed to the different magnitudes of the effect sizes and differences in methodological quality among the 3 studies. The effect sizes ranged from −0.216 to 1.496, indicating that in the 3 studies using the MFT, there were negative small effects and positive large effects. The methodological quality of the studies of Choi et al. (2019) and Kim et al. (2023) was good, whereas that of the study of In et al. (2012) was only fair. In addition, two comparisons were calculated for the effect sizes in the studies of Choi et al. (2019) and Kim et al. (2023) due to the use of 2 control groups and 2 sub-scores of the MFT. This may have also partially contributed to significant heterogeneity.

In this review, the PEDro scores showed that two-thirds of the included studies were of good methodological quality and only 3 studies were of fair quality (In et al., 2012; Lee et al., 2014; Sip et al., 2023). The 3 studies commonly lacked concealed allocation, intention-to-treat analysis, blind assessor, or adequate follow-up assessment (≥ 2 studies). The Cochrane risk-of-bias 2.0 assessment revealed that a high risk of bias was primarily associated with the lack of blinded raters and incomplete reporting of data for all (or nearly all) patients in some included studies. Additionally, some concerns

were identified regarding the absence of pre-specified analysis plans or pre-established protocols in certain studies. Further individual studies investigating the effects of novel MT are suggested to enhance the study methodological quality to good and excellent quality and to decrease the risk of bias to make the results of the systematic review more robust and valid.

VR cybersickness encompasses symptoms such as nausea, headache, and impaired balance. A previous review demonstrated no reported occurrences of cybersickness in the participants with neurological impairments during VR-based motor training when less immersive settings, such as desktop or wall screen displays, were utilized (Holden, 2005). Hence, there are some advices for the immersive virtual reality MT. First, employing less immersive displays, such as desktop or wall-mounted screens instead of head-mounted displays, may reduce the likelihood of cybersickness. Second, future studies should evaluate and monitor the occurrence of cybersickness using standardized assessments, including the Virtual Reality Sickness Questionnaire and the Cybersickness in Virtual Reality Questionnaire.

In this review, we conducted subgroup analyses based on post-stroke duration, categorizing studies into subacute (< 6 months) and chronic (> 6 months) groups primarily according to the actual average time since stroke onset of the participants. While most studies fit clearly into one of these groups, some studies (i.e., Ding et al., 2018; Kim et al., 2023; Sip et al., 2023) included broader timeframes, potentially introducing heterogeneity. To address this, we classified them based on the reported mean post-stroke duration: Kim et al. was assigned to the chronic group (> 6 months), whereas Ding et al. and Sip et al. were assigned to the subacute group (< 6 months). Future studies incorporating a larger number of RCTs may allow for more detailed subgroup analyses based on stroke onset time, thereby supporting more precise and clinically relevant recommendations.

Some limitations of this review are worthy of discussion. One limitation of

this meta-analysis is the use of an unweighted approach in estimating effect sizes across the included studies. This decision was made to facilitate an initial exploratory overview of the overall trends. However, the sample sizes varied considerably among the 9 studies, and studies with larger samples may yield more precise estimates of treatment effects. Future research should consider incorporating a greater number of studies and applying weighted effect size calculations to enable a more rigorous and representative meta-analysis. Another potential limitation is the risk of publication bias, as only peer-reviewed and published studies were included in this review. The exclusion of grey literature, such as dissertations or conference abstracts, may have led to an overestimation of treatment effects. Future reviews should consider including grey literature to enhance the comprehensiveness and balance of the findings. Furthermore, although analyses in this study indicated very low heterogeneity, variations in the experimental (i.e., immersive virtual reality and digital-based MT) and control interventions used among the included studies should be taken into consideration.

In conclusion, this review suggests that novel forms of MT have demonstrated significant treatment effects on improving upper limb motor function and quality of life in patients with stroke. Further well-designed RCT studies of novel forms of MT should also be conducted to investigate the optimal treatment dosages and potential adverse effects in patients with stroke.

Acknowledgements

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