P-45

The Impact of Virtual Reality-Assisted Rehabilitation on C5 Palsy Recovery

- A Randomized Clinical Trial -

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Purpose

Virtual Reality (VR) has demonstrated promise across medical disciplines, including physical rehabilitation. However, its application in enhancing recovery from neurological complications such as C5 palsy following posterior cervical spine surgery remains underexplored. This study evaluates the efficacy of VR-assisted rehabilitation in improving motor function and quality of life in patients with C5 palsy.

Material and Methods

- A prospective, randomized controlled trial was conducted with 10 patients (≥20 years) who developed C5 palsy post-surgery. Patients were randomized into a VR-assisted rehabilitation group (VR group) and a conventional rehabilitation group (control group). The VR group used a head-mounted display for gamified exercises targeting shoulder flexion and abduction, such as collecting virtual apples. Difficulty was adjusted for progressive engagement, with sessions lasting one hour daily in the first postoperative week and at follow-ups (3, 6, 12, 24 weeks). Functional metrics included the maximum height reached and the number of apples collected. The control group followed standard rehabilitation protocols with passive range-of-motion and strengthening exercises.
- Outcome measures included self-report assessments such as the Neck Disability Index (NDI), EuroQol 5-Dimension (EQ-5D), Visual Analog Scale (VAS) for pain, and the Hospital Anxiety and Depression Scale (HADS); physiologic evaluations including Maximum Voluntary Isometric Contraction (MVIC) and muscle fatigue analyzed through dynamic electromyography (EMG) and power spectrum analysis; and functional metrics such as the maximum height reached and the number of virtual apples collected during VR rehabilitation tasks.

Results

- The VR group (N=4) showed significant improvements in both muscle activity and patient-reported outcomes compared to control group (N=6). At 24 weeks, %MVIC of the middle deltoid during flexion was lower in the VR group (0.8 [0.7–1.1]) than in controls (1.2 [1.0–2.0], p = 0.025), indicating better muscle efficiency (Table 2), indicating better muscle efficiency.
- Similarly, %MVIC for shoulder abduction was 0.9 [0.6–0.9] in VR vs. 1.8 [1.0–3.2] in controls (p = 0.014). Quality of life (EQ-5D: 0.7 [0.6–0.8] vs. 0.5 [0.0–0.7], p = 0.032) and arm pain (VAS: 0.0 [0.0–10.0] vs. 35.0 [0.0–80.0], p = 0.048) also improved in the VR group (Table 3). Functional performance increased, with the maximum height reached rising from 90.0 cm to 145.0 cm, and apples collected from 25 to 55.

Table 1. Demographic and surgical data of the included patients

Variables	Total (N=10)	Control (N=6)	VR (N=4)	*P*
	N(%) or Median (Min-Max)			
Sex (Male, %)	10 (100.0)	6 (100.0)	4 (100.0)	>.999
Age (years)	61.0 (42.0-78.0)	68.5 (48.0-78.0)	53.5 (42.0-61.0)	0.054
Height (cm)	169.5 (160.0-190.0)	169.0 (163.0-171.7)	170.5 (160.0-190.0)	0.668
Weight (kg)	70.0 (65.0-100.0)	68.0 (65.0-91.9)	80.0 (68.0-100.0)	0.166
Diabetes mellitus	4 (40.0)	4 (66.7)	0 (0.0)	0.076
Hypertension	3 (30.0)	2 (33.3)	1 (25.0)	>.999
CVA	9 (90.0)	5 (83.3)	4 (100.0)	>.999
Number of operated segments	4.0 (3.0-6.0)	4.0 (3.0-6.0)	4.0 (4.0-4.0)	0.694
Surgical procedure				0.870
Laminoplasty	6 (60.0)	4 (66.7)	2 (50.0)	
PAP surgery	4 (40.0)	2 (33.3)	2 (50.0)	
Surgical level				0.619
C3-6	1 (10.0)	1 (16.7)	0 (0.0)	
C3-7	6 (60.0)	2 (33.3)	4 (100.0)	
C3-T1	1 (10.0)	1 (16.7)	0 (0.0)	
C3-T2	1 (10.0)	1 (16.7)	0 (0.0)	
C4-T1	1 (10.0)	1 (16.7)	0 (0.0)	
Surgery time (minutes)	252.5 (207.0-327.0)	239.0 (207.0-292.0)	280.0 (221.0-327.0)	0.336
Estimated blood loss (mL)	450.0 (150.0-700.0)	450.0 (150.0-700.0)	425.0 (200.0-550.0)	0.747
Palsy side (right side, %)	4 (40.0)	2 (33.3)	2 (50.0)	>.999
MRC of flexion at the time of paralysis	2.0 (1.0-4.0)	2.0 (1.0-4.0)	1.75 (1.0-2.0)	0.640
MRC of abduction at the time of paralysis	2.0 (1.0-2.0)	1.67 (1.0-2.0)	2.0 (2.0-2.0)	0.175

Table 2. The effect of VR on muscle activities

Action	Variable	Preop			POD 24wks			POD 24wks/Preop		
		Control (N=6)	VR (N=4)	*P*	Control (N=6)	VR (N=4)	*P*	Control (N=6)	VR (N=4)	*P*
Shoulder flexion	$MVIC_{ant.del}$	415.2 (157.3-991.3)	263.9 (92.1-545.8)	0.456	419.3 (151.5-663.9)	232.6 (48.1-425.3)	0.337	1.2 (0.2-2.9)	0.8 (0.5-1.0)	0.594
	$\%MVIC_{ant.del}$	56.0 (14.2-81.4)	74.4 (30.5-123.7)	0.241	86.8 (14.2-130.1)	75.4 (63.3-98.7)	0.594	1.5 (1.0-2.0)	1.0 (0.8-2.2)	0.337
	$MVIC_{mid.del}$	422.5 (115.1-669.4)	256.1 (154.8-628.1)	0.915	408.3 (83.2-602.2)	409.9 (46.4-642.6)	0.915	1.0 (0.2-2.8)	0.8 (0.3-3.7)	0.915
	$\%MVIC_{mid.del}$	39.6 (11.6-61.1)	47.3 (25.9-94.6)	0.594	60.9 (11.7-79.1)	47.7 (17.5-67.3)	0.594	1.2 (1.0-2.0)	0.8 (0.7-1.1)	0.025*
	$FI_{ant.del}$	4.9 (1.9-5.5)	3.9 (0.8-5.2)	0.551	-0.3 (-8.9-10.7)	3.4 (0.6-13.8)	0.594	-1.2 (-2.5-2.2)	3.6 (0.1-3.6)	0.136
Shoulder abduction	$MVIC_{ant.del}$	417.8 (163.5-988.2)	266.4 (92.4-543.0)	0.456	420.3 (154.2-654.9)	234.2 (46.6-427.3)	0.337	1.2 (0.2-2.9)	0.8 (0.5-1.0)	0.594
	$\%MVIC_{ant.del}$	51.9 (43.9-129.8)	68.7 (36.2-105.9)	>.999	73.9 (59.8-136.6)	81.4 (52.5-95.1)	0.915	1.4 (0.7-2.6)	1.1 (0.9-1.9)	0.749
	$MVIC_{mid.del}$	422.8 (115.0-737.1)	256.8 (155.0-633.9)	0.915	405.9 (86.8-603.4)	409.0 (46.4-655.1)	0.915	1.0 (0.2-2.7)	0.8 (0.3-3.6)	0.915
	$\%MVIC_{mid.del}$	45.0 (37.3-63.2)	68.3 (39.5-84.0)	0.11	91.9 (44.8-125.0)	60.0 (25.2-75.6)	0.11	1.8 (1.0-3.2)	0.9 (0.6-0.9)	0.014*
	$FI_{mid.del}$	5.5 (-1.5-7.3)	9.7 (1.1-10.2)	0.371	6.0 (-14.8-18.0)	7.8 (2.2-10.5)	>.999	0.0 (-8.3-3.3)	1.0 (1.0-2.0)	0.766

Table 3. Comparison of patient-reported outcomes and muscle strength between control and VR groups

PROs & MRC	Preop			POD 3wks			POD 6wks			POD 12wks			POD 24wks		
	Control (N=6)	VR (N=4)	*P*	Control (N=6)	VR (N=4)	*P*	Control (N=6)	VR (N=4)	*P*	Control (N=6)	VR (N=4)	*P*	Control (N=6)	VR (N=4)	*P*
NDI	31.0 (12.0-76.0)	25.0 (18.0-36.0)	>.999	52.0 (34.0-66.0)	68.0 (64.0-72.0)	0.247	48.0 (24.0-56.0)	44.0 (14.0-60.0)	0.902	41.0 (20.0-60.0)	31.0 (14.0-48.0)	0.334	40.0 (18.0-78.0)	20.0 (12.0-22.0)	0.069
EQ5D	0.6 (0.1-0.8)	0.8 (0.6-1.0)	0.285	0.1 (0.0-0.4)	0.2 (0.2-0.2)	0.481	0.2 (0.1-0.6)	0.5 (0.2-0.8)	0.389	0.4 (0.1-0.6)	0.7 (0.2-0.8)	0.069	0.5 (0.0-0.7)	0.7 (0.6-0.8)	0.032*
VAS_Neck	15.0 (10.0-70.0)	70.0 (40.0-90.0)	0.067	50.0 (17.0-80.0)	53.0 (41.0-65.0)	>.999	46.0 (0.0-72.0)	10.0 (0.0-25.0)	0.262	29.5 (0.0-78.0)	4.0 (0.0-19.0)	0.322	21.5 (0.0-90.0)	0.0 (0.0-9.0)	0.337
VAS_Arm	56.0 (0.0-90.0)	55.0 (30.0-70.0)	>.999	63.5 (51.0-80.0)	41.5 (20.0-63.0)	0.487	22.0 (0.0-64.0)	0.0 (0.0-10.0)	0.073	35.0 (0.0-80.0)	0.0 (0.0-10.0)	0.048*	29.5 (0.0-90.0)	0.0 (0.0-0.0)	0.072
HADS_A/21	10.0 (2.0-21.0)	11.0 (4.0-18.0)	>.999	5.5 (4.0-14.0)	13.0 (12.0-14.0)	0.34	5.0 (2.0-18.0)	7.0 (0.0-12.0)	>.999	8.5 (3.0-18.0)	6.5 (0.0-9.0)	0.392	10.0 (3.0-21.0)	3.5 (0.0-6.0)	0.109
HADS_D/21	12.0 (7.0-21.0)	10.5 (7.0-17.0)	0.667	11.0 (9.0-17.0)	13.0 (13.0-13.0)	0.481	12.0 (5.0-19.0)	9.0 (1.0-11.0)	0.27	10.0 (6.0-19.0)	7.0 (1.0-10.0)	0.241	9.5 (6.0-21.0)	4.0 (1.0-7.0)	0.067
MRC Flexion	5.0 (5.0-5.0)	5.0 (5.0-5.0)	>.999	3.0 (2.0-4.0)	2.5 (2.0-3.0)	0.556	3.0 (2.0-5.0)	3.0 (2.0-5.0)	0.909	3.5 (3.0-5.0)	4.0 (3.0-5.0)	0.568	5.0 (4.0-5.0)	5.0 (4.0-5.0)	0.878
MRC Abduction	5.0 (5.0-5.0)	5.0 (5.0-5.0)	>.999	3.0 (2.0-4.0)	3.0 (2.0-4.0)	0.817	3.0 (3.0-4.0)	3.0 (3.0-4.0)	0.878	4.0 (3.0-5.0)	4.5 (4.0-5.0)	0.556	5.0 (4.0-5.0)	4.5 (4.0-5.0)	0.350

Conclusion

VR-assisted rehabilitation significantly enhances motor function and improves psychological well-being in patients with C5 palsy. This innovative approach holds promise for integrating immersive technology into neurorehabilitation protocols.