THE EFFECT OF VIRTUAL REALITY REHABILITATION ON FUNCTIONAL MOBILITY, CAPACITY, INDEPENDENCE AND BALANCE IN CHILDREN WITH CEREBRAL PALSY

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Approval of Project Report

This is to certify that the research project report prepared by HADEELL MOHAMMED ALBEDEWI titled "THE EFFECT OF VIRTUAL REALITY REHABILITATION ON FUNCTIONAL MOBILITY, CAPACITY, INDEPENDENCE AND BALANCE IN CHILDREN WITH CEREBRAL PALSY" has been approved by her department as satisfactory completion of the research project report requirement for the degree of Master of Public Health in Health Informatics.

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Abstract

Introduction: The most common cause of physical disability in children is cerebral palsy (CP). Rehabilitation is considered the primary treatment for children with CP where they can acquire and improve their motor and sensory abilities. Virtual reality (VR) rehabilitation involves the use of a virtual and interactive environment to help people regain motor or sensory skills. Using virtual reality in rehabilitation has been demonstrated in several medical conditions such as stroke, multiple sclerosis, developmental coordination disorders, and cerebral palsy. The focus of this study will be on mobility, capacity, independence, and balance in CP.

Objectives: This study aims to assess the effect of adding VR to conventional rehabilitation on functional mobility, functional capacity, functional independence, and functional balance in comparison to conventional rehabilitation alone in children with Cerebral Palsy.

Method: In this quasi-experimental study, 19 CP children were enrolled consecutively in the control group (n=9, age 6±2) or in VR group (n=10, age 8±4). Both groups received conventional physical therapy sessions for 4 weeks. The VR group received VR sessions using a VR headset tool (Oculus Quest 2®) twice a week for 4 weeks. Functional measures including Timed Up and Go (TUG), 6-minutes-walk test (6MWT), Functional Independence Measure for children (WeeFIM), and Pediatric Balance Scale (PBS) were obtained before and after the intervention for both groups. Paired t-test was used to assess the difference within-group. Independent samples t-test was used to assess the difference between groups.

Results: After the intervention, paired t-test showed a significant improvement in TUG, 6MWT, WeeFIM, and PBS for both groups ($P < .05$). However, the difference in the improvement did not significantly differ between the two groups using Independent samples t-test.

Conclusion: Although VR might not be superior to conventional rehabilitation in CP in terms of functional outcomes, this approach should be considered for its engaging and motivational attributes. Future studies that assess user experience as well as influences on social engagement and cognitive skills are recommended.

Key words: Cerebral palsy; virtual reality; rehabilitation; functional measures; physical therapy.

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1. Introduction & Literature Review

1.1.Background

Cerebral Palsy (CP) is one of the most common causes of physical disability in children (1). Globally, the prevalence of CP is estimated to range from 1.5 to 3.9 per 1,000 children (2, 3). CP can be a result of a stroke, abnormal vascular development, intraventricular bleeding, and any type of brain injury that happens during the early stages of brain development. Manifestations of CP include impairment of movement, lack of motor function control, and cognitive developmental delay (4). There are two main categories of CP, spastic and dyskinetic, with spastic accounting for most CP cases. Among spastic CP, hemiplegia or unilateral CP is the most common type seen in children (5). Rehabilitation is considered the primary treatment for children with CP where they can acquire and improve their motor and sensory abilities (6).

Virtual reality (VR) is an emerging technology that provides a real-time simulation using both audio and visual inputs. There are four main types of VR based on the level of interaction: non-immersive, immersive, augmented, and mixed (7). VR rehabilitation involves the interaction with a three-dimensions virtual environment to help individuals regain motor or sensory skills (8). This VR environment offers challenging tasks in a repetitive manner which can stimulate and enhance neuroplastic changes (9, 10). In addition, receiving feedback upon accomplishments creates a rewarding and inviting experience (10).

The use of VR in rehabilitation has been demonstrated in several medical conditions such as stroke, multiple sclerosis, developmental coordination disorders, and cerebral palsy (11). In cerebral palsy, studies assessed the effect of VR rehabilitation on motor function, coordination, and cognitive abilities (12). The focus of this study will be on mobility, capacity, independence, and balance.

1.2.Literature Review

1.2.1. VR Rehabilitation and Functional Mobility

A few studies have assessed the impact of VR rehabilitation on motor functions in CP (13-15). One study conducted on children with CP (n=12) showed a significant improvement in motor functions measured by Gross Motor Ability after 10 sessions of immersive VR training ($P = .025$) (14). Another study showed that VR training for children with CP (n=3) improved upper motor function after 20 sessions (13). However, both studies are limited by the lack of a control group. In a study of children with CP (n=17) that included a control group, eight weeks of VR training significantly improved Gross Motor Function Measure when compared to conventional rehabilitation ($P < .05$) (15). Another study showed that a 12-sessions VR rehabilitation significantly improved Functional Mobility Scale compared to conventional rehabilitation in children with CP (n=41, $P < .05$) (16).

Timed Up and Go (TUG) is another essential measure used to assess functional mobility. A study of children with CP (n=30), showed that TUG has significantly improved after 24 sessions of VR training when compared to conventional rehabilitation ($P < .001$) (17). Similarly, a 16-session VR based rehabilitation resulted in an improved TUG score for children with CP (n=10, $P < .05$) (18). However, this study was limited by the lack of a comparison group. In contrast, a study of children with CP (n=25) showed no significant improvement in TUG after two weeks of personalized VR training (19).

1.2.2. VR Rehabilitation and Functional Capacity

A study conducted on children with hemiplegia CP (n=12) showed a significant improvement in functional capacity measured by 6-minutes-walk test (6MWT) after 10 sessions of immersive VR training ($P = .002$) (14). However, this study lacked a control group. Among children with CP (n=30), the time for 10-meter-walk test (10mWT) significantly decreased after 24 sessions of VR in comparison to conventional rehabilitation ($P < .001$) (17). Another study conducted on children with CP (n=56) has shown that 12 weeks of VR rehabilitation resulted in a significantly improved functional capacity as measured by 2-minutes-walk test (2MWT) ($P < .05$) with no significant changes in the conventional rehabilitation group (20). Similarly, eight weeks of VR treadmill training in children with CP (n=18) significantly improved functional capacity in terms of speed (10mWT) and endurance (2MWT) compared to regular treadmill training ($P < .005$) (21). On the other hand, another study of children with CP (n=18) found that

VR did not significantly differ from conventional rehabilitation in terms of functional endurance as measured by the 2MWT (22).

1.2.3. VR Rehabilitation and Functional Independence

After ten sessions of immersive VR training, children with CP (n=12) showed significant improvements in functional independence, as measured by the Functional Assessment Questionnaire ($P = .025$) (14). A significant limitation of this study is that there was no control group. Another study of 60 children with CP showed that eight weeks of VR training improved their Functional Independence Measure (WeeFIM) score compared to conventional therapy (23). Similarly, another study conducted on children with CP (n=30) showed that 24 sessions of VR training resulted in a significant improvement in WeeFIM score compared to conventional rehabilitation ($P < .001$) (17).

1.2.4. VR Rehabilitation and Functional Balance

In a study that assessed balance as measured by Pediatric Balance Score (PBS) in children with CP, eight weeks of VR-based rehabilitation resulted in a significant balance improvement (n=10, $P < .05$) (18). However, this study is limited by the lack of a comparison group. Another study conducted on children with CP (n=30) has shown a significant improvement in balance as measured by Star excursion balance test after 8 and 12 weeks of VR rehabilitation ($P < .05$) (24). However, the study showed no significant difference between VR and conventional rehabilitation. In contrast, another study conducted on children with CP (n=20) showed that VR training significantly improved dynamic balance in comparison to conventional rehabilitation ($P < .005$) (25). Similarly, another study conducted on children with CP (n=32) showed that two weeks of VR rehabilitation significantly increased PBS score in comparison to the control group ($P < .005$) (26). Furthermore, another study of children with CP (n=56) receiving 12-week VR rehabilitation showed significantly improved PBS scores ($P < .005$), while conventional rehabilitation showed no significant changes (20).

There are some discrepancies in the results based on this review of the literature. In addition, most studies were limited either by the small sample size or the lack of a control group. It is therefore necessary to conduct a research study that involves a variety of functional measures on a greater number of participants with a control group.

1.3.Research Question(s)

Can the use of a standalone VR device twice a week for four weeks in addition to conventional rehabilitation significantly improve functional mobility, functional capacity, functional independence, and functional balance in comparison to conventional rehabilitation alone in children with Cerebral Palsy?

1.4. Aim and Objectives

This study aims to assess the effect of adding VR to conventional rehabilitation on functional mobility, functional capacity, functional independence, and functional balance in comparison to conventional rehabilitation alone in children with Cerebral Palsy.

Objectives:

1. To assess baseline functional mobility as measured by Timed Up and Go (TUG), functional capacity as measured by 6-minutes-walk test (6MWT), functional independence as measured by Functional Independence Measure for children (WeeFIM), and functional balance as measured by Pediatric Balance Scale (PBS).
2. To assess post intervention functional mobility as measured by TUG, functional capacity as measured 6MWT, functional independence as measured by WeeFIM, and functional balance as measured by PBS.
3. To compare the difference in functional mobility as measured by TUG, functional capacity as measured by 6MWT, functional independence as measured by WeeFIM, and functional balance as measured by PBS between VR rehabilitation group and conventional rehabilitation group.

2. Methods

2.1.Study Design

This is a quasi-experimental study with pre-test/post-test control group design. In this study, a four-weeks VR-based rehabilitation intervention was added to conventional rehabilitation in children with Cerebral Palsy and compared to the conventional rehabilitation alone in terms of functional mobility, capacity, independence and balance (**Figure 1**). Outcome measures were obtained at the baseline and after four weeks of rehabilitation. The results were then compared within groups and between the two groups to determine the effectiveness of VR based rehabilitation in the study population. The VR based rehabilitation method is already being used by a few physical therapists. This study aims to assess the difference between this new method and the standard protocol used by other physical therapists.

2.2.Study Settings

The study took place in the inpatient pediatric unit at Sultan Bin Abdulaziz Humanitarian City (SBAHC) in Riyadh. A conventional physical therapy was provided by certified physical therapists and was given for both groups. The conventional physical therapy was 5 sessions per week, lasting for 30-45 min. Each session includes approximately general stretching and strengthening exercises for lower limbs muscles, sitting, and standing balance and exercises, gait training, and endurance exercises. Also, functional mobility training was given depending on the patient’s current level of functional ability and it might include all or some of the following: (transfers, locomotion, and stair training). The intensity, frequency, and level of assistance was given depending on the patient's ability.

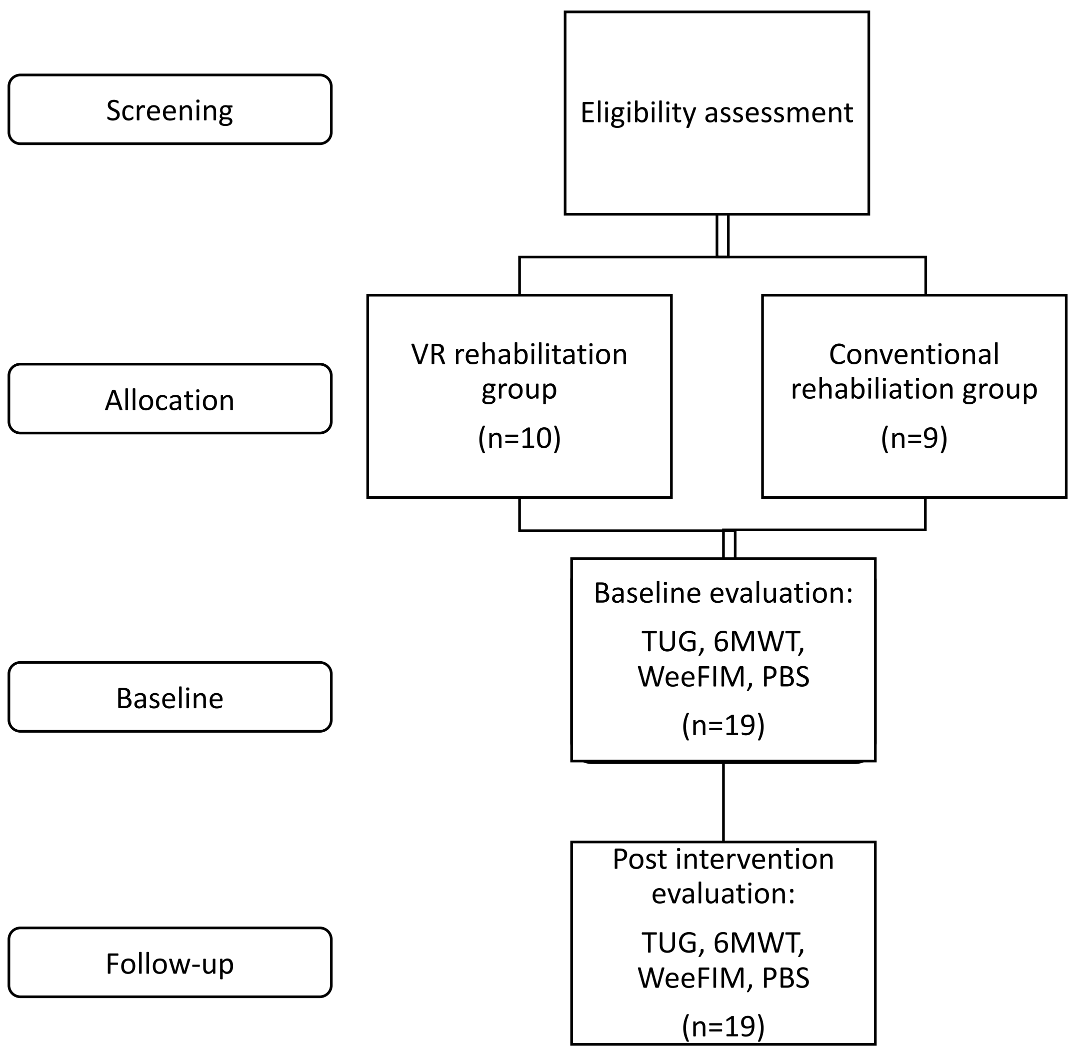

Figure 1. Study flowchart.
TUG: Timed Up and Go. 6MWT: 6-minutes-walk test. WeeFim: Functional Independence Measure for children. PBS: Pediatric Balance Scale.

For the VR rehabilitation group, the following was used: Oculus Quest 2® standard without controller modifications. Adjustable ergonomic head strap for better headset stability. Balight® anti-spasticity finger rehabilitation auxiliary gloves splint finger recovery grip impairment fixed hand wrist support for controllers for the weak hand. Tablet for casting and real time feedback from VR to the outer screen. Proper space at least 3 meters by 3 meters to reduce any risks. Exercise mat with the same dimensions. A lit room for better controller tracking. A quiet area to prevent any distractions and enhance concentration. Two 60-minute sessions per week.

2.3.Study Population

2.3.1. Inclusion Criteria:

1. Age: 5 – 14 years.
2. Sex: both boys and girls.
3. Diagnosis: cerebral palsy.
4. Gross motor function classification system class between I to III.

2.3.2. Exclusion Criteria:

1. Uncontrolled epileptic seizures.
2. A history of orthopedic surgeries less than six months prior to the study.
3. Severe intellectual disability.
4. Severe visual or hearing impairment that influences the ability to perform the task.

2.4. Sample Size Estimation

The primary outcome in our study is the difference in functional mobility as measured by TUG between VR and conventional rehabilitation groups. Based on the study of (17) with a mean of 14.67, and a standard deviation of 4.54 for the conventional rehabilitation group, and a mean of 10.62, and a standard deviation of 3.30. Using G*Power 3.1, the effect size was 1.020478. With an alpha of 0.05, and 80% study power, the estimated sample size was 17 for each group. After accounting for 15% dropout, the estimated sample will be 20 participants in each group. In this study, a consecutive sampling technique was used. As this is a quasi-experimental design, no randomization was needed.

2.5. Data Collection

Demographic data such as age, weight, height, Body Mass Index (BMI) and type of CP were collected from medical records. At the baseline, four measures were performed as follows: Functional mobility was assessed using Timed Up and Go (TUG) following the recommended instructions (27). Functional capacity was assessed using 6-minutes-walk test (6MWT) in accordance with recommended guidelines (28). Functional independence as measured by Functional Independence Measure for children (WeeFIM), an 18-item scale where each item is graded from 0 to 7 following the recommended protocol (29). Functional balance was measured by Pediatric Balance Scale (PBS), a 14-item scale where each item is graded from 0 to 4 as recommended (30). All four measures were repeated after four weeks.

2.6.Statistical Analysis

All data were analyzed using Statistical Package for Social Science Statistics IBM SPSS, version 25.0. Categorical data are presented as frequencies and percentages. Shapiro-wilk test was used to determine normality **(Appendix 1).** Normally distributed data were presented as mean and standard deviation (SD) while not normally distributed variables were presented as median and interquartile range (IQR). The difference before and after the intervention in continuous outcomes (namely, UGT, 6MWT, WeeFIM, and PBS) was assessed using paired t-test for normally distributed variables and Wilcoxon signed rank test for not normally distributed variables (within group). The difference before and after the intervention between the two groups was assessed using independent samples t-test for normally distributed variables and Mann-Whitney U test for not normally distributed variables (between groups). A P-value < 0.05 was considered significant for all tests.

3. Results

The study included 19 participants who were admitted to SBAHC between October 2023 and March 2024. Nine children were enrolled in the conventional rehabilitation group and 10 children in the VR group. The mean age of all the participants was 7.2 ± 2.3. There was a comparable distribution between male and female participants (58% vs. 42%, respectively). The demographic characteristics for each group are shown in **Table 1**. Children in the VR group were significantly older than those in the conventional rehabilitation group with a median age of 8 (4) vs. 6 (2), respectively. There was no significant difference between the groups in terms of gender, weight, height, BMI, and type of CP.

Baseline outcome measures for both groups are shown in **Table 2**. Independent samples t-test showed no significant difference in 6 MWT, WeeFIM, Transfer, and Locomotion at the baseline between the conventional rehabilitation and the VR rehabilitation group. Similarly, there was no significant difference in TUG, PBS, and Self Care at the baseline using Mann-Whitney U test.

Table 1. Demographic characteristics of all participants.

	Conventional (n=9)	VR (n=10)	*P* value
Age	6 (2)	8 (4)	**0.042**
Gender			
Male	5 (55.6%)	6 (60%)	0.845
Female	4 (44.5%)	4 (40%)	
Weight	21.3 (5)	23 (5.9)	0.506
Height	117.2 (11.5)	121.4 (10.9)	0.432
BMI	15.3 (0.94)	15.4 (2.4)	0.863
Type of CP			0.375
Hemiplegia	2 (22.2)	1 (10)	
Diplegia	4 (44.4)	7 (70)	
Hemiparesis	3 (33.3)	1 (10)	
Tetraparesis		1 (10)	

Data are shown as mean (SD) for normally distributed variables and median (IQR) for non-normally distributed variables. Gender and type of CP are shown as frequency (percentage). BMI: Body Mass Index.

Table 2. Baseline functional measures for the control and VR group.

	Conventional (n=9)	VR (n=10)	*P* Value
TUG	20.7 (35.3)	12.6 (4.3)	0.191
PBS	48 (29)	42.5 (13)	0.567
6 MWT	261.4 (160.4)	262.4 (113)	0.914
WeeFim	75.7 (28.3)	86.2 (27.8)	0.424
Self-Care	17 (16)	17.5 (20)	0.652
Transfer	12 (6.4)	13 (5.2)	0.711
Locomotion	7.2 (4.2)	9 (3.8)	0.347

Data are shown as mean (SD) for normally distributed variables and median (IQR) for non-normally distributed variables. TUG: Timed Up and Go. 6MWT: 6-minutes-walk test. WeeFIM: Functional Independence Measure for children. PBS: Pediatric Balance Scale.

Table 3 shows post-intervention measures for both groups. Independent samples t-test showed 6 MWT, WeeFIM, Transfer, and Locomotion to be comparable between the conventional rehabilitation and the VR rehabilitation group. In the same way, Mann-Whitney U test showed no significant difference in TUG, PBS, and Self Care after the intervention between the two groups.

Table 3. Post-intervention functional measures for the control and VR group.

	Conventional (n=9)	VR (n=10)	*P* Value
TUG	12.7 (19.11)	9.9 (3.5)	0.307
PBS	51 (15)	49 (10)	0.459
6 MWT	334.9 (131.2)	332.8 (68.1)	0.968
WeeFim	87.3 (23.6)	95.7 (23.3)	0.449
Self-Care	22 (14)	20 (16)	0.838
Transfer	15.6 (3.8)	15 (5)	0.790
Locomotion	9.9 (3.7)	10.5 (3)	0.694

Data are shown as mean (SD) for normally distributed variables and median (IQR) for non-normally distributed variables. TUG: Timed Up and Go. 6MWT: 6-minutes-walk test. WeeFIM: Functional Independence Measure for children. PBS: Pediatric Balance Scale.

The difference in all the outcome measures after the intervention is shown in **Table 4**. Paired t-test showed a significant improvement in 6 MWT, WeeFIM, Transfer, and Locomotion for both groups ($P < .05$). Similarly, TUG, PBS, and Self-Care showed a significant improvement after the intervention in both groups using the Wilcoxon signed rank test. However, the improvement did not significantly differ between the two groups using independent samples t-test for 6 MWT, WeeFIM, Transfer, and Self-care and Mann-Whitney U test for TUG, PBS, and Locomotion.

Table 4. The difference in functional measures between the control and VR group.

	Conventional (n=9)			**VR** (n=10)			**Difference**
	Pre	Post	*P* Value	Pre	Post	*P* Value	*P* Value
TUG	20.7 (35.3)	12.7 (19.11)	**0.008**	12.6 (4.3)	9.9 (3.5)	**0.017**	.142
PBS	48 (29)	51 (15)	**0.018**	42.5 (13)	49 (10)	**0.005**	0.512
6 MWT	261.4 (160.4)	334.9 (131.2)	**0.017**	262.4 (113)	332.8 (68.1)	**0.019**	0.408
WeeFim	75.7 (28.3)	87.3 (23.6)	**0.001**	86.2 (27.8)	95.7 (23.3)	**0.003**	0.523
Self-Care	17 (16)	22 (14)	**0.011**	17.5 (20)	20 (16)	**0.013**	0.153
Transfer	12 (6.4)	15.6 (3.8)	**0.028**	13 (5.2)	15 (5)	**0.001**	0.672
Locomotion	7.2 (4.2)	9.9 (3.7)	**0.032**	9 (3.8)	10.5 (3)	**0.018**	0.428

Data are shown as mean (SD) for normally distributed variables and median (IQR) for non-normally distributed variables. TUG: Timed Up and Go. 6MWT: 6-minutes-walk test. WeeFIM: Functional Independence Measure for children. PBS: Pediatric Balance Scale.

4. Discussion

The primary objective of this study was to assess the effect of combining VR sessions with conventional rehabilitation on functional mobility, capacity, independence and balance in children with CP. Our findings show that using a standalone VR device such as Oculus Quest 2® combined with conventional rehabilitation has the same improvement as conventional rehabilitation alone. Our findings are inconsistent with most studies in the literature that showed VR rehabilitation to be significantly more effective in improving functional measures in comparison to conventional rehabilitation (15-17, 20, 21, 23, 25, 26). However, there are other studies in the literature that did not demonstrate a significant difference between the control and VR group (22, 24, 31).

There are a few explanations for these findings. First, the difference in functional measures may have not been large enough to be detected in such a small sample. Furthermore, neuroplasticity effects of VR may not be directly manifested in functional outcomes. In a study conducted on individuals with stroke to compare between conventional and VR rehabilitation, both approaches resulted in improved functional outcomes. However, VR rehabilitation produced a significantly more pronounced enhancement in the functional connectivity as assessed by functional Magnetic Resonance Imaging (fMRI) (32). Interestingly, brain activity was higher in regions related to learning and cognitive tasks in the VR group while the control group had higher brain activity in mechanical-related regions.

Another explanation could be the number of weekly sessions as well as the total period for the intervention in our study. A meta-analysis of VR impact on CP rehabilitation concluded that five sessions per week for at least three months is recommended to receive the maximum benefit of VR rehabilitation in CP children (33). Furthermore, children in the VR group in our sample were significantly older than the control group. Two recent meta-analyses have shown that the impact of VR rehabilitation in CP was more evident in preschoolers or children aging six years or less in comparison to school-age children (34, 35).

Aside from improving functional outcomes, adding VR to rehabilitation has the potential to improve the quality of life for children with CP. Due to its entertaining nature, VR can improve children's motivations, engagement, and compliance during rehabilitation sessions which can lead to a faster recovery time. A recent review has concluded that using VR in rehabilitation can be effective in enhancing social and cognitive abilities of children with CP (36). Likewise, another review has demonstrated the positive impact of VR on social involvement in children with CP (37).

This study has a few limitations. The main limitation of this study is its small sample size. The significant age difference in our sample between the two groups may have also influenced our findings. In addition, the provided conventional physical therapy was not unified in terms of duration and type of exercise across all participants. Furthermore, a follow-up assessment would have provided more insights on the long-term effects of using

VR in rehabilitations. Additionally, other assessments related to the quality of life, social participation and user experience were not performed. Despite these limitations, this study provides a comprehensive assessment of a wide range of functional outcomes. Furthermore, the quasi-experimental nature of the study increases its generalizability (38). Unlike controlled trials, this study design resembles the real-life settings in which clinicians will be incorporating VR into their rehabilitation practice.

4.1. Conclusions

This study assessed the effect of combining a standalone VR device with conventional physical therapy on functional measures in children with CP. Although VR may not be superior to conventional rehabilitation in terms of functional outcomes in CP children, this approach might be considered for its potential engagement and motivational impact. Future studies that assess user experience as well as the influence on social involvement and cognitive skills are recommended. Furthermore, investigating the influence of incorporating virtual reality in rehabilitation might be extended to include medical conditions other than cerebral palsy.

5. Declarations

5.1. Authors' Contributions

Study conception and study design: Ms. Hadeel Albedewi, Mr. Hussain Alhassan, Mr. Baha Alsharafi, Prof. Abdullah Alanizi.

Data collection: Mr. Hussain Alhassan, Mr. Baha Alsharafi, Ms. Hadeel Albedewi.

Statistical analysis and results interpretation: Ms. Hadeel Albedewi.

Manuscript preparation: Ms. Hadeel Albedewi.

Supervision: Prof. Abdullah Alanizi.

5.2. Scientific and Ethics approval

This study was scientifically and ethically approved by the Institutional Review Board (IRB) at Sultan Bin Abdulaziz Humanitarian City.

5.3. Sources of Funding

This research was not funded.

5.4. List of Abbreviations

2 MWT	2-minutes-walk test
6MWT	6-minutes-walk test
10mWT	10-meter-walk test
BMI	Body Mass Index
CP	Cerebral Palsy
fMRI	functional Magnetic Resonance Imaging
IQR	Interquartile Range
PBS	Pediatric Balance Scale
SBAHC	Sultan Bin Abdulaziz Humanitarian City
TUG	Timed Up and Go
VR	Virtual Reality
WeeFIM	Functional Independence Measure for children

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7. Appendix

7.1. Appendix A: Data Collection Sheet

Data Collection Sheet

Table 1. Demographic characteristics.

Demographic characteristics	
Case number	
Date of birth	
Age (years)	
Sex	○ Male ○ Female
Diagnosis	
Height (cm)	
Weight (kg)	
BMI (kg/m^2)	
GMFCS level	○ I ○ II ○ III ○ IV

BMI: body mass index. GMFCS: gross motor function classification system.

Table 2. Baseline and post intervention functional mobility, functional capacity, functional independence, and functional balance measurements.

Functional mobility, functional capacity, functional independence, and functional balance measurements		
Case number		
	Baseline	**4 weeks after**
TUG test		
Test date		
TUG time (seconds)		
6MWT		
Test date		
6MWT distance (meters)		
PBS		
Test date		
Sitting to standing (0-4)		
Standing to sitting (0-4)		
Transfers (0-4)		
Standing unsupported (0-4)		
Sitting unsupported (0-4)		
Standing with eyes closed (0-4)		

Standing with feet together (0-4)		
Standing with one foot on front (0-4)		
Standing on one foot (0-4)		
Turning 360 degrees (0-4)		
Turning to look behind (0-4)		
Retrieving objects from floor (0-4)		
Placing alternate foot on stool (0-4)		
Reaching forward with outstretched arm (0-4)		
PBS total score (0-56)		
WeeFIM		
Test date		
Self-care		
Eating (0-7)		
Grooming (0-7)		
Bathing (0-7)		
Dressing (upper body) (0-7)		
Dressing (lower body) (0-7)		
Sphincter control		
Toileting (0-7)		
Bladder management (0-7)		

Bowel management (0-7)		
Transfer		
Chair/wheelchair (0-7)		
Toilet (0-7)		
Shower (0-7)		
Locomotion		
Walk/wheelchair/crawl (0-7)		
Stairs (0-7)		
Communication		
Comprehension (0-7)		
Expression (0-7)		
Social cognition		
Social interaction (0-7)		
Problem solving (0-7)		
Memory (0-7)		
WeeFIM total score (0-126)		

TUG: Timed Up and Go. 6MWT: 6-minutes-walk test. WeeFim: Functional Independence Measure for children. PBS: Pediatric Balance Scale.

7.2. Appendix B: Normality Testing

Table 5. Normality testing using Shapiro-Wilk test.

Variable	***P* Value**
Age	**.004**
Height	.380
Weight	.073
BMI	.230
TUG control	**< .001**
TUG VR	**< .001**
TUG Difference	**.002**
6 MWT control	.809
6 MWT VR	.938
6 MWT Difference	.214
PBS control	**.039**
PBS VR	**.004**
PBS Difference	**< .001**
WeeFIM control	.455
WeeFIM VR	.077
WeeFIM Difference	.107
Self-care control	**.017**
Self-care VR	**.046**
Self-care Difference	.206
Transfer control	.240
Transfer VR	.236
Transfer Difference	**< .001**
Locomotion control	.102
Locomotion VR	**.021**
Locomotion Difference	**.002**

7.3. Appendix C: Ethical Approval Letter

مدينة سلطان بن عبد العزيز للخدمات الإنسانية
SULTAN BIN ABDULAZIZ HUMANITARIAN CITY

مدينة سلطان بن عبد العزيز للخدمات الإنسانية
SULTAN BIN ABDULAZIZ HUMANITARIAN CITY
لجنة أخلاقيات البحوث الطبية
Institutional Review Board (IRB)

Date: **07 September 2023**
IRB No.: **102-2023-IRB**

To: **Dr. Abdullah Al Anizi**
MSc: "The Effect of Virtual Reality Rehabilitation on Functional Mobility, Capacity, Independence and Balance in Children with Cerebral Palsy"
King Saud Bin Abdulaziz University
E-mail: anaziabdul@ksau-hs.edu.sa

Subject:	Approval for MSc Research No. 98/MSc/2023
Study Title:	"The Effect of Virtual Reality Rehabilitation on Functional Mobility, Capacity, Independence and Balance in Children with Cerebral Palsy"
Study Code:	98/MSc/2023
Date of Approval:	07/09/2023
Date of Expiry:	10/10/2024
Board approval:	Approved by the members.

Dear **Dr. Abdullah Al Anizi,**

Your Project has been approved and you have the permission to conduct this study following your submitted documents as follow:

1. Curriculum Vitae for the PI researcher
2. Letter from the researcher requesting SBAHC participation in the clinical study
3. Research proposal according to SBAHC IRB Guidelines
4. SBAHC Informed Consent Template
5. Research Obligatory Agreement. Available upon the completion of the other requirements

You are required to obey by the rules and regulations of the Government of Saudi Arabia, the SBAHC IRB Policies and procedures and the ICH-GCP guidelines. You have to note that this approval mandates responding to IRB's periodic request and surveillance result. Drawing your attention to the following:

- Amendment of the project with the required modification to providing Periodical report for this project specially when study extension is required or expiry before study completion.

Page **1** of **2**

7.4 Appendix D: Curriculum Vitae

Hadeel Albedewi

Research Assistant

Contact

0562280347
hadeelbed@gmail.com
Riyadh, Saudi Arabia

Experience

2024 - Present
Office of Research - KSAUHS
Research Assistant

2021 - 2022
King Saud University
Research Assistant Volnteer

2020 - 2021
KAIMRC
Research Assistant Trainee

2019 - 2020
KFSHRC
Clinical Research Coordinator Trainee

Education

2022 - 2024
KSAU-HS
Master in Health Informatics
GPA 4.81 out of 5

2017 - 2021
King Saud University
Master of Science in Clinical Nutrition
GPA 4.84 out of 5

2011 - 2016
King Saud University
Bachelor of Science in Clinical Nutrition
GPA 4.78 out of 5

Publications

- **Albedewi, H.**, Bindayel, I., Albarrag, A., & Banjar, H. (2022). Correlation of Gut Microbiota, Vitamin D Status, and Pulmonary Function Tests in Children With Cystic Fibrosis. Frontiers in nutrition, 9, 884104.
- **Albedewi H,** Al-Saud N, Kashkary A, AlQunaibet A, AlBalawi S, Alghnam S, Epidemiology of childhood injuries in Saudi Arabia: a scoping review. BMC Pediatrics. 2021.
- Aljuaid, M., Ilyas, N., Altuwaijri, E., **Albedewi, H.**, Alanazi, O., Shahid, D., & Alonazi, W. (2022). Quality of Life among Caregivers of Patients Diagnosed with Major Chronic Disease during COVID-19 in Saudi Arabia. Healthcare.
- Alodhayani AA, Almutairi KM, Alshobaili FA, Alotaibi AF, Alkhaldi G, Vinluan JM, **Albedewi HM,** Al-Sayyari L. Predictors of Mental Health Status among Quarantined COVID-19 Patients in Saudi Arabia. Healthcare. 2021; 9(10):1271.

Skills and Expertise

Statistical Analysis

Academic Writing

Journal Submission

Laboratory Techniques

Clinical Trials Management

Research Proposals

Languages

English

Arabic

French