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Ocena czynników wpływających na skuteczność terapii integracji sensorycznej u dzieci w wieku przedszkolnym i wczesnoszkolnym

Assessment of factors influencing the effectiveness of sensory integration therapy in preschool and early school-aged children

Praca fizjoterapeuty z osobami niepełnosprawnymi intelektualnie

Physiotherapist's work with intellectually disabled individuals

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Virtual reality versus balance beam on walking performance in children with spastic hemiplegic cerebral palsy: A randomized controlled comparative trial

Wirtualna rzeczywistość a drążek równoważny w poprawie chodu u dzieci z porażeniem mózgowym spastycznym typu hemiplegicznego: randomizowane badanie porównawcze

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Abstract

Background. Virtual reality and balancing beam are widely acknowledged as a highly successful approach for improving balance as well as walking performance among children suffering from hemiplegic cerebral palsy (CP). Purpose. The aim of this study was to compare between the impact of virtual reality and balance beam on walking performance (balance and functional walking capacity) in children with hemiplegic CP. Subjects and methods. A total of seventy-five children with hemiplegic CP, comprising 31 boys and 44 girls, aged between 7 and 11 years of both genders, were included in this study. The participants were allocated randomly into three groups (n = 25), A (control group) and B, C (study groups). All children received designed physical therapy programs based on neurodevelopmental technique, in addition to balance and gait training exercises for control group A, virtual reality training for group B and balance beam training for group C. The treatment program was administered to each group three times weekly for three consecutive months, lasting one hour each session. All children were examined clinically pre- and post-treatment using HUMAC balance and tilt system, and 6-minutes walking test (6mWT) to assess balance, walking functional capacity respectively. Results. There was a significant improvement in balance and 6MWT of three groups post treatment when contrasted with that pretreatment ($p < 0.001$). Furthermore, group B and C's measured variables showed a substantial improvement over group A's when compared ($p < 0.01$), while group B and C did not differ significantly ($p > 0.05$). Conclusions. Virtual reality and balance beam training have an effective influence on the improvement of balance and walking performance.

Keywords

balance beam, cerebral palsy, functional walking capacity, hemiplegic, virtual reality

Streszczenie

Wprowadzenie. Wirtualna rzeczywistość i drążek równoważny są powszechnie uznawane za skuteczne metody poprawy równowagi oraz wydajności chodu u dzieci cierpiących na porażenie mózgowe spastyczne typu hemiplegicznego (PM). Cel. Celem niniejszego badania było porównanie wpływu wirtualnej rzeczywistości oraz drążka równoważnego na wydajność chodu (równowagę i funkcjonalną zdolność chodzenia) u dzieci z PM typu hemiplegicznego. Uczestnicy i metody. W badaniu wzięło udział 75 dzieci z PM typu hemiplegicznego, w tym 31 chłopców i 44 dziewczynki, w wieku od 7 do 11 lat, z obu płci. Uczestnicy zostali przydzieleni do trzech grup (n = 25) w sposób randomizowany: A (grupa kontrolna) oraz B i C (grupy badane). Wszystkie dzieci otrzymały zaprojektowane programy fizjoterapii oparte na technice neurorozwojowej, dodatkowo ćwiczenia równowagi i trening chodu dla grupy kontrolnej A, trening w wirtualnej rzeczywistości dla grupy B oraz trening na drążku równoważnym dla grupy C. Program leczenia był realizowany dla każdej grupy trzy razy w tygodniu przez trzy kolejne miesiące, trwając jedną godzinę na sesję. Wszystkie dzieci zostały zbadane klinicznie przed i po leczeniu przy użyciu systemu równowagi i przechyłu HUMAC oraz 6-minutowego testu chodu (6mWT) w celu oceny równowagi oraz funkcjonalnej zdolności chodzenia odpowiednio. Wyniki. Zaobserwowano znaczącą poprawę w równowadze i wynikach 6mWT we wszystkich trzech grupach po leczeniu w porównaniu z okresem przed leczeniem ($p < 0,001$). Ponadto, zmierzone zmienne w grupach B i C wykazały znaczącą poprawę w porównaniu z grupą A ($p < 0,01$), natomiast między grupą B i C nie stwierdzono znaczących różnic ($p > 0,05$). Wnioski. Trening w wirtualnej rzeczywistości oraz na drążku równoważnym skutecznie wpływają na poprawę równowagi i wydajności chodu.

Słowa kluczowe

drążek równoważny, porażenie mózgowe, funkcjonalna zdolność chodzenia, hemiplegiczny, wirtualna rzeczywistość

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Introduction

Cerebral palsy (CP) is a term used to describe a collection of permanent conditions that affect the development of movement and posture. These conditions result in restrictions in activity and are caused by non-progressive disruptions in the developing brain of a fetus or child [1]. It is additionally characterized as a neurodevelopmental disorder that starts in early childhood and continues throughout a person's entire lifespan. The mean occurrence is roughly 2-2.5 per 1000 live births [2].

Hemiplegic CP is characterized by a paralysis that affects one side of the body, with the upper limbs being more significantly impacted than the lower limbs. Hemiplegia is a prevalent subtype of spastic CP, including around 20% to 30% of overall cases of CP. It is primarily caused by injury to one side of the developing brain, resulting in asymmetrical muscle tone abnormalities as well as deformities on one side of the body [3]. As a result of an imbalance in the trunk, motor dysfunction in hemiplegic CP manifests as asymmetrical gait, shorter strides and steps, a shorter stance phase on the affected side, and slower walking speeds. Postural sway, uneven weight distribution, and pelvic obliquity all have an impact on their balance when standing and when walking [4].

Balance is described as ensuring optimal body placement in space in addition to preserving body alignment as well as stability through controlling the center of gravity within the base of support [5]. Children with CP commonly experience impaired balance and postural control, which are crucial for maintaining stability during upper as well as lower limb activities. These abilities are essential for regulating balance reactions and successfully performing functional tasks, such as reaching and walking [6].

Children with CP often experience obvious impairments in walking and gait. Children with CP commonly exhibit decreased gait velocity, cadence, and stride length, which are spatiotemporal gait parameters [7]. Children diagnosed with hemiplegia experience motor deficits, including challenges in regulating their trunk, unstable balance, and limited walking ability. These difficulties arise from aberrant sensation, decreased motor function, and muscular weakness on one side of their body [8].

Virtual reality (VR) is a highly advanced and promising method of rehabilitation that provides a secure and regulated setting for conducting personalized and engaging rehabilitation exercises. These exercises facilitate the acquisition of motor skills [9]. The program's entertaining character serves as a motivating factor for children to actively engage in the rehabilitation process, and it holds significant potential for enhancing neuro rehabilitation [10].

Beam walking is like walking on the ground, but it poses a greater challenge to maintaining dynamic balance because of its utilization of the lateral instability inherent in walking [11]. Performance on the balance beam is a useful measure of coordination and balance which has been validated, that includes the execution of static and dynamic balance, as regular walking on a line of ground [12]. Although, there are previous studies conducted regarding the effect of both modalities on balance and walking capacity, till now there are no studies compared between their effect on the previously mentioned outcomes. Therefore, the aim of this study was to compare the impact of VR and balance beam on walking performance among children suffering from hemiplegic CP.

Methods

Study design and participants

The present research was a randomized controlled comparative trial carried out at Outpatient Clinic, Faculty of Physical Therapy, Cairo University and Abu Rish Japanese Hospital, lasting from October 2022 up to May 2023. Parental written agreement for their children's involvement in the study was acquired before the research began. The ethical approval for this study was obtained from Cairo University's Faculty of Physical Therapy (P.T.R.E.C/ 012/003683). Under the number (NCT05463718), this study was recorded at Clinical Trial.gov.

Through screening test for spastic hemiplegic CP from both genders among children of Outpatient Clinic, Faculty of Physical Therapy, Cairo University and Abu Rish Japanese Hospital, A total of seventy-five children who met the study's inclusion criteria were recruited for the current research. Inclusion criteria for this study's subjects were as follows: 1) They were between the ages of 7 and 11, 2) Based on the Modified Ashworth Scale, their level of spasticity varied between 1 as well as 1+ [13], 3) According to the Gross Motor Function Classification System, they were classified as Level I and II. [14], 4) The instructions were clear and easy for them to follow. Researchers did not include participants who met any of the following criteria: 1) problems with vision or hearing, 2) injuries sustained during orthopedic surgeries or botulinum toxin injections in the past.

Sample size estimation

The sample size was calculated using the G*POWER statistical software (version 3.1.9.2; developed by Franz Faul at the University of Kiel, Germany). The results showed that, considering the expected large difference between the three groups, 22 patients per group were needed for this investigation. α = 0.05, power 80%, and effect size = 0.4 are used in the calculation.

Randomization

This study was a randomized controlled comparative trial. The current study assessed 80 children with spastic hemiplegic CP for potential involvement. The study did not include three children because they did not meet the inclusion requirements, and the parents of two of those children declined to take part. Three groups were formed from the remaining 75 children: group A, which served as a control, and groups B and C, which were study groups. The method of randomization involved the use of sealed envelopes, with each envelope containing a sheet of paper indicating whether the child belonged to the control or study groups. An unbiased individual, unaware of the study's objectives or procedures, conducted the randomization process. The flow of participations was illustrated using a flow chart that adhered to the consolidated standards of reporting trials (CONSORT) (Figure 1).

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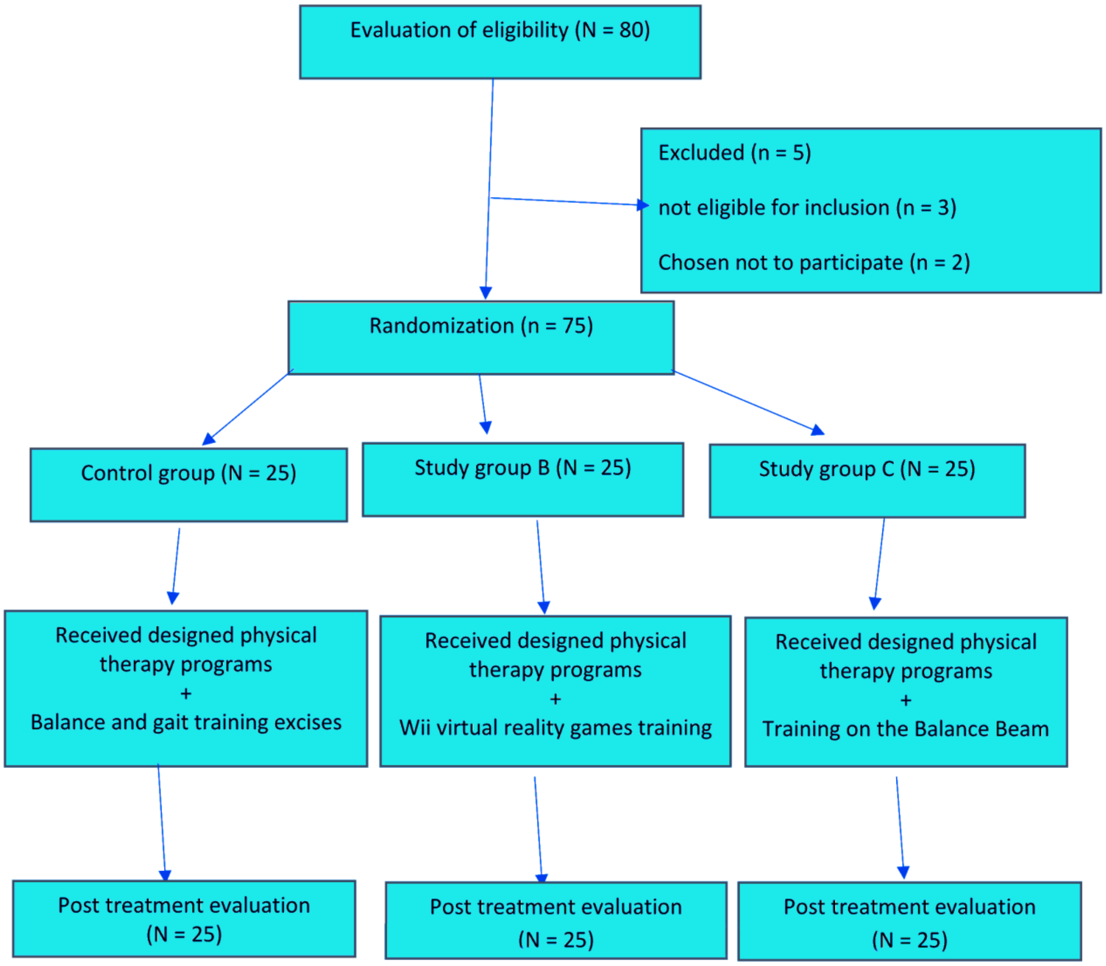

Figure 1. Flow chart of the study design

Outcome measures

The balance and walking capacity of all children were evaluated before and after treatment using the HUMAC balance as well as the tilt system also, the 6MWT respectively.

Balance

Both static as well as dynamic balance were evaluated using the HUMAC balance as well as the tilt system. It is a valid and reliable instrument for assessing and training balance among children with spastic CP according to Jens et al. and Park et al. which demonstrated its effectiveness in comparison to the outcomes of the conventional force platform [15,16,17]. It consists of; force platform, which has a Universal Serial Bus (USB), operating device (laptop) [18].

Balance was evaluated by HUMAC balance as well as tilt system through the following tests: modified Clinical Test of Sensory Integration of Balance (mCTSIB), Center Of Pressure test (COP), Limit Of Stability test (LOS). Before the beginning of evaluation procedures, the anatomical zero position of platform was set up using its horizontal and vertical lines. After that, each child was told to stand in upright position on the platform; then by using the scales of the balance board, the child's foot position was recorded, once these positions were recorded, the child was instructed not to move their feet for the duration of each test according to Koltermann et al. [17].

The balance tests were conducted for each child as the following:

A) The Modified Clinical Test of Sensory Integration of Balance (mCTSIB) was employed to assess the sensory integration of balance, including the measurement of sways in terms of their amount, velocity, and direction. This assessment was conducted while the participants were standing on a balance board, under both open and closed eye conditions. As soon as the assessor had established where the child's two feet would be on the platform, which was approximately three feet away from the wall, the test could begin. Having the child fix his gaze on a wall-mounted target at eye level for 30 seconds, followed by another 30 seconds of eye closure, was the prescribed procedure. Once with the eyes open and once with them closed, the operation was repeated. Every condition was tested three times, and the best result was used for each according to Lotfi et al. [19].

B) Center Of Pressure test (COP) was employed to evaluate the static balance ability of each child. To conduct the test, the child was directed to stand on the platform. Once the position of their feet was determined, the child was informed that the purple point on the screen represents the movement of their body. They were instructed to keep this point stable at the cen-

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ter between the X and Y axis by minimizing their body movement and maintaining as much stability as possible. The test process had a duration of 30 seconds and was done three times, with the greatest value obtained according to Szturm et al. [20].
C) Limit of stability test (LOS) was employed to evaluate the maintenance of body posture. Initially, the child was directed to position themselves on the platform. Prior to conducting the test, the child was given an opportunity to practice the initial trial to ensure comprehension of the test before the measurement. Each child was instructed that the mobile purple point symbolizes their physical body that moves precisely in line with their own bodily movements. He was directed to track the illuminated target with his body and maintain stability for one second before another target appeared. He was then required to move and capture the new target, maintaining stability until the next target appeared. This process continued for one minute, with the targets representing movement in eight different directions (front, back, front/right, back/left, right, left, back/right, and front/left). The test was administered three times to each child, and the average score was determined according to Alsalaheen et al. [21].

Functional walking capacity
It was assessed using a 6MWT. It is a standardized, straightforward walking test used to assess the functional capacity of children with CP [22]. Children with spastic CP who are able to walk can benefit from the 6MWT, a highly reliable test that gives valuable clinical information about their gait capability (r value = 0.955 and P value < 0.0001) [23].
The evaluations were conducted on a smooth, level, thirty-meter-long corridor devoid of any obstructions; the children were permitted to wear their preferred footwear during the process. All participants were verbally encouraged or given directions throughout the test procedure, that allows for one comment every minute. " The goal of the test is to see how far child can walk in 6 minutes" the children were told before the test even began. To keep an eye on the child without slowing him down, the evaluator walked behind him as he performed the test. The child's distance covered in meters was recorded at the end of the test which was accepted by [24]. who used 6MWT among children suffering from spastic CP as well as those developing typically.

Intervention
All children were given designed physical therapy programs based on neurodevelopmental technique. These exercises were incorporated into the program: stretching exercises for tightened muscle, approximation, hand weight bearing exercises, proprioceptive training, strengthening of weak muscles, bridging exercise, knee to chest with ball between both legs [25]. The exercise was carried out for a duration of 40 minutes, 3 times each week, over a period of 12 weeks, additionally.

Group A
Children in this group were given traditional balance and gait training: as balance training from different positions (balance from kneeling and half kneeling positions on mat, standing on balance board, single limb support and step standing forward, backward, and sideway). Gait training included the following exercises: walking between parallel par, walking by placing obstacles of different heights across walking tract (stepper), ascending soft ramp on wedges, and climbing up and down wooden stairs [26]. It was carried out 3 times/week for 12 weeks, for a total of 20 minutes.

Group B
Children in this group were given VR training conducted for 20 minutes, three times per week for 12-week. The VR device used in the present study was Wii-Fit which was a videogame training composing of different games. The device consisted of Wii balance board, four sensors that assess COP and load distribution, in which they were mounted on a top of TV [27]. In this study training was provided for each participant through four games: tilt table- balance board game, balance bubble game, ski slide game, and walking on rope game. Before VR training, general guidelines on how to use Wii-Fit system were given and illustrated for each child through an educational session. At the beginning of each game training, children were instructed to stand in a relaxed position having their arms as well as hands at their sides and with their eyes open. In the tilt table- balance board and balance bubble games, children moved their COP anteroposterior and mediolateral to get balls into the holes and to avoid hitting the wall respectively. In the ski slide game, children moved their COP anteroposterior to swerve between flags within a continually tilting platform. Eventually, in the walking on rope game, children tried to maintain COP in all direction during walk in tight rope to protect themselves from falling. Each game was practiced for four to five minutes with one to two minutes rest in between [28].

Group C
Children in this group were given walking exercises on balance beam in different directions (forward and backward) with and without obstacles. The wooden balance beam apparatus was 1-meter length with a flat surface, 3 cm high and 5 cm width (intermediate width), it was rested above two wooden blocks with 10 cm height for each one. Without obstacle training, children were asked to stand and maintain their balance before walking then were allowed to begin walking on balance beam with comfortable speed in forward direction step by step with a heel-to-toe gait until reaching the end of beam then make another round. With obstacle training, children were asked to walk forward with comfortable speed stepping over obstacles (5 cm height) which were placed at the first and second thirds of balance beam, until reaching the end of beam then make another round. Each child took five minutes rest between with and without obstacles training according to Kasuga et al. [29]. The session lasted 20 minutes and occurred three times weekly for 12 weeks.

Results

Data analysis
The Multivariate analysis of variance test (MANOVA) was performed for comparison of subject characteristics among groups. Chi squared test was performed for comparison of sex as well as affected sides distribution among groups. Kruskal-Wallis was performed for comparison of GMFM levels among groups. The Shapiro-Wilk test was used to detect if

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the data followed a normal distribution. A Levene's test was performed to assess the homogeneity of variances between groups. Mixed MANOVA was conducted to contrast within as well as among groups effects on the LOS test, COP test, mCTSIB as well as 6MWT. For following multiple comparison, post hoc tests were conducted using the Bonferroni correction. The statistical tests were conducted with a predetermined level of significance of $p < 0.05$. All statistical analysis was performed through the statistical package for social sciences (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

Subject characteristics

Table (1) presented the subject characteristics of group A, B as well as C. There was no substantial difference among groups regarding subject characteristics ($p > 0.05$).

Table 1. Basic characteristics of participants

Characteristics	Group A	Group B	Group C	p-value
Age, mean ± SD, years	9.16 ± 1.16	9.22 ± 1.14	9.06 ± 1.25	0.88
Weight, mean ± SD, kg	27.18 ± 3.04	28.10 ± 2.43	27.16 ± 3.18	0.43
Height, mean ± SD, cm	128.72 ± 5.17	129.84 ± 6.76	128.36 ± 5.36	0.64
GMFCS, median (IQR)	1 (2-1)	1 (2-1)	1 (2-1)	0.78
Sex, N (%)				
Girls	17 (68%)	13 (52%)	14 (56%)	0.48
Boys	8 (32%)	12 (48%)	11 (44%)	
Affected side, N (%)				
Right side	11 (44%)	12 (48%)	12 (48%)	0.94
Left side	14 (56%)	13 (52%)	13 (52%)	

SD, standard deviation; p-value, level of significance

Effect of treatment on balance and functional walking capacity

Mixed MANOVA revealed that there was a substantial interaction of treatment as well as time ($F = 25.11$, $p = 0.001$, Partial Eta Squared = 0.65). There was a substantial main effect of time ($F = 701.51$, $p = 0.001$, Partial Eta Squared = 0.98). There was a substantial main effect of treatment ($F = 7.77$, $p = 0.001$, Partial Eta Squared = 0.36).

Within group comparison

All three groups showed substantial improvements in LOS, COP, mCTSIB (both with and without the eyes open), as well as 6MWT post treatment compared to pretreatment ($p < 0.001$). The percent of change of LOS, COP as well as mCTSIB with eye opened and eye closed and 6MWT in group A was 35.4, 18.82, 22.26, 23.59 and 12%, and that in group B was 84.84, 38.02, 29.6, 44.03 and 29.81% respectively while in group C was 69.74, 37.84, 34.86, 55.31 and 24%. (Table 2).

Between group comparison

There was a substantial improvement in LOS, COP and mCTSIB with eye opened and eye closed and 6MWT of group B as well as C when contrasted with that of group A ($p < 0.01$) although there was no substantial difference between group B as well as C ($p > 0.05$). (Table 2).

Table 2. Mean LOS, COP, mCTSIB and 6MWT pre and post treatment of group A, B and C

Measured variables	Group A Mean ± SD	Group B Mean ± SD	Group C Mean ± SD	p-value A vs. B	p-value A vs. C	p-value B vs. C
LOS						
Pretreatment	14.80 ± 1.84	15.04 ± 1.42	15.20 ± 2.29	0.89	0.73	0.95
Post treatment	20.04 ± 4.81	27.80 ± 4.54	25.80 ± 5.57	0.001	0.001	0.33
MD (% of change)	−5.24 (35.4%)	−12.76 (84.84%)	−10.6 (69.74%)			
	p = 0.001	p = 0.001	p = 0.001			
COP						
Pretreatment	54.20 ± 5.82	52.28 ± 3.68	55.08 ± 4.57	0.33	0.79	0.1
Post treatment	64.40 ± 6.04	72.16 ± 7.76	75.92 ± 5.05	0.001	0.001	0.1
MD (% of change)	−10.2 (18.82%)	−19.88 (38.02%)	−20.84 (37.84%)			
	p = 0.001	p = 0.001	p = 0.001			

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Measured variables	Group A Mean ± SD	Group B Mean ± SD	Group C Mean ± SD	p-value A vs. B	p-value A vs. C	p-value B vs. C
mCTSIB with opened eyes						
Pretreatment	53.56 ± 5.25	55.12 ± 4.79	54.04 ± 3.88	0.47	0.93	0.69
Post treatment	65.48 ± 5.40	71.44 ± 8.76	72.88 ± 6.50	0.01	0.001	0.75
MD (% of change)	−11.92 (22.26%)	−16.32 (29.6%)	−18.84 (34.86%)			
	p = 0.001	p = 0.001	p = 0.001			
mCTSIB with closed eyes						
Pretreatment	53.08 ± 3.41	52.60 ± 3.75	51.56 ± 3.61	0.88	0.30	0.56
Post treatment	65.60 ± 6.66	75.76 ± 8.67	80.08 ± 7.98	0.001	0.001	0.13
MD (% of change)	−12.52 (23.59%)	−23.16 (44.03%)	−28.52 (55.31%)			
	p = 0.001	p = 0.001	p = 0.001			
6MWT (m)						
Pretreatment	291 ± 50.02	300.08 ± 54.66	310.20 ± 45.38	0.79	0.37	0.75
Post treatment	325.92 ± 56.03	389.52 ± 71.73	384.64 ± 56.27	0.001	0.004	0.95
MD (% of change)	−34.92 (12%)	−89.44 (29.81%)	−74.44 (24%)			
	p = 0.001	p = 0.001	p = 0.001			

SD, Standard deviation; MD, Mean difference; p-value, Level of significance

Discussion

Impaired balance, coordination of movement, and diminished between-limb synchronization, among children with hemiplegic CP could affect one's ability to walk and maintain an upright, weight-bearing posture [30].

The current study compared the impact of VR as well as balance beam training on walking performance among children suffering from hemiplegic CP. Treatment protocols were completed by all groups over the course of twelve weeks. A significant improvement in balance as well as functional walking capacity was observed within the group following treatment, as compared to the pre-treatment period. Moreover, when comparing groups, A and B and C, all of the assessed variables in group B and C were significantly higher, while there was no such difference among groups C as well as B.

The post treatment enhancement of balance in addition walking capacity in group B may be due to the motivated and interactive nature of VR that encourage the children to participate in the training process. This is corroborated by Chen et al. [31], who demonstrated how advancements in technology inside interactive computer games can provide clinicians with an opportunity to inspire patients, taking advantage of the games' intrinsic qualities while also collecting objective and sensitive data during patients' rehabilitation procedures. In addition, they illustrated that Wii games and balance training improve balance and gross motor function among children with CP.

Likewise, the current result is parallel with Lee et al. [32], who found that improvement of motor function, balance, as well as walking skills, was observed after the implementation of VR game-based training among children with CP. Also, the results obtained by Montoro-Cárdenas et al. [33], who assessed the impact of Nintendo Wii therapy on functional balance among children diagnosed with cerebral palsy. The study concluded that the use of Nintendo Wii therapy, in conjunction with conventional physical therapy, can effectively enhance functional and dynamic balance. The therapy sessions, lasting 20 to 30 minutes, yielded positive outcomes when conducted for a duration of more than 3 weeks, thereby supporting previously findings.

Post treatment improvement of the measured outcomes among children in group C may be due to the enhancement in performing compound movements during walking on balance beam. Which naturally has a narrow base of support and more challenging during walking that led to the improvement of walking ability. This is corroborated by Kasuga et al. [29] who found that walking on a balance beam has a purpose to give children more challenging and controlling balance during the rehabilitation processes.

Moreover, beam walking poses a greater challenge to dynamic balance and walking performance as it emphasizes on the inherent lateral instability of walking and promotes the utilization of various strategies to maintain and enhance balance. This is supported by sipp et al. [11], who found a significant enhancement in static balance, as well as dynamic stability during walking on balance beam.

Also, this result is parallel with Elshafey et al. [34], who assessed the impact of stability exercise program on balance, coordination, among children with CP. A study revealed that implementing a balance beam exercise program can enhance the balance and coordination abilities of children diagnosed with cerebral palsy.

The present study is subject to certain limitations, notably the absence of participant follow-up, which restricts our findings

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to the immediate impact of VR as well as balance beam training. Furthermore, the study only included children between the ages of seven and eleven who had a specific type of cerebral palsy and on two levels of GMFCS. So, our recommendations based on the results of this study the following recommendations are needed alternative forms of CP with varying degrees of GMFCS. A comparative study between the effect of virtual reality as well as balance beam on energy expenditure in spastic CP children.

Conclusion

The predominance of statistical evidence presented in this study suggested that VR and balance beam training have an effective influence on the improvement of walking performance among children with CP. Therefore, this training program has the potential to be a useful therapeutic tool for enhancing functional walking capacity as well as balance among children with CP. Furthermore, since this training offers motivation, it can be a more desirable approach for children and their families.

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