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Enhancing Balance and Motor Learning in Down Syndrome: A Review of Virtual Reality Rehabilitation

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ABSTRACT

BACKGROUND OF THE STUDY: Down syndrome is one of the most common genetic causes of developmental delays. Virtual reality is an innovative tool of rehabilitation based on computer technology. It has been applied in the rehabilitation of many developmental areas. Virtual reality-based therapy (VRT) has been used nowadays as a balance and motor learning tool in order to facilitate the development and learning process in down syndrome.
OBJECTIVE OF THE STUDY: The objective of the present study is to review the articles for identifying the Effect of virtual reality-based therapy on balance and/or motor learning in down syndrome Patients.
METHODOLOGY: We had searched for articles and abstracts that were published from 2010 to 2023 and were included in this review. Randomized controlled trials and non-randomized controlled trials, systemic reviews, cohort studies and comparative studies were included in this review of literature.
RESULT: From the selected 13 relevant research reports almost, studies included in the review showed that Virtual Reality is most effective treatment to improve balance and motor learning in down syndrome.
CONCLUSION: From this review of literature concluded that virtual reality therapy (VRT) may be helpful in helping people with Down syndrome become more agile and strong, as well as helping their children to improve more balance, coordination and motor learning.

KEY WORDS: Down Syndrome, Virtual Reality based Rehabilitation, balance, motor learning

INTRODUCTION

Down syndrome (DS) is the most frequently diagnosed chromosomal disorder in new-borns, [1- 3] formerly scientifically described by John Langdon Down in the second half of the 19th century as "Mongolian family" and then "Mongol idiot" [4] based on their innate physical characteristics. Due to his discovery, he was called as "father of this disease" and named derived from his name.[5] The cause of

DS was only discovered in 1959 by Jerome Lejeune, when he realized that individuals with the syndrome had an extra chromosome in their karyotype, totally or partially accompanying chromosome 21. Thus, DS became understood as an imbalance in the chromosomal constitution of chromosome 21.[6] Therefore, Down syndrome, also known as trisomy-21. It can affect individuals of any race or ethnicity, and the overall prevalence is 10 per 10,000 live births worldwide; however, in recent years, the prevalence has been increasing. [7] The discovery of a link between a supernumerary chromosome 21 and the DS phenotype was first reported in 1959[8] and was an important landmark for the development of genetic medicine. Mouse models for the study of DS were first developed in 1990[9] and the complete nucleotide sequence of the long arm of Homo sapiens chromosome 21(HSA21) was published in 2000 by a multinational consortium of investigators.[10] Substantial progress has been made in the ensuing 19 years in understanding the molecular pathophysiology of the different phenotypic manifestations of DS, which is currently considered a disorder of gene expression dysregulation. In addition, widely used screening methods have been introduced for the prenatal detection of DS.[11-14]

Individuals with Down Syndrome have unique physical, neurological, musculoskeletal, sensorimotor and learning and communication characteristics that can impact each other as well as the Individuals' ability to develop age-appropriate skills. [15,16,17]

The most effective traditional approaches for treating sensorimotor problems in children with DS include: Sensory integrative (SI) therapy, Perceptual-motor (PM) approach, Neurodevelopmental treatment (NDT) [18] while one of the advance treatment approaches for Down syndrome is virtual reality.

Virtual Reality

Virtual reality is a simulated experience that can be similar to or completely different from the real world.[19] It means to a user–computer interface that consists of real-time environmental simulation, that is, the users could interact with the scenario or environment via multiple sensory channels.[20] It is a highly interactive, computer-based multimedia environment in which the user becomes the participant in a computer-generated world.[19] Virtual learning environments provide three-dimensional (3D) insights into the structures and functions of any system desired. It is known that VR can make the artificial as realistic as, and even more realistic than, the real [19]. VR can be used as an auxiliary tool involving a playful, motivational objective that can facilitate the development of perceptions and motor skills through the training of planning skills and motor control as well as stimulation of the plasticity of the central nervous system. [21,22] Applications of virtual reality include entertainment (e.g. video games), education (e.g. medical or military training) and business (e.g. virtual meetings). Other distinct types of VR-style technology include augmented reality and mixed reality, sometimes referred to as extended reality. Currently, standard virtual reality systems use either virtual reality headsets or multi-projected environments to generate realistic images, sounds and other sensations that simulate a user's physical presence in a virtual environment. A person using virtual reality equipment is able to look around the artificial world, move around in it, and interact with virtual features or items. The effect is commonly created by VR headsets consisting of a head-mounted display with a small screen in front of the eyes, but can also be created through specially designed rooms with multiple large screens. Virtual reality typically incorporates auditory and video feedback, but may also allow other types of

sensory and force feedback through haptic technology.[19]

Classification

VR is classified into three major types:

1. Non-Immersive VR Systems
2. Semi-Immersive VR Systems
3. Immersive (Fully Immersive) VR systems.[19]

Virtual reality video games such as

1. Nintendo Wii
2. Wii Fit
3. Wiihab

1. Nintendo Wii: is played with a wireless controller, fitted with acceleration sensors. This controller responds to changes in direction and speed, and interacts with the player through a motion detection system [23].
2. Wii Fit: is a video game released for Nintendo Wii that is played using a special Wii balance board in order to perform activities like yoga jogging and aerobics [24].
3. Wiihab: is an abbreviation for "Wii habilitation" a new idea that came about after the introduction of the Nintendo Wii to use the console for habilitation and rehabilitation. Nintendo's Wii changed the way video games were viewed because it actively involved the gamer in the playing of the game [25].

Objective of the Study

The objective of the present study is to review the articles for identifying the Effect of virtual reality-based Rehabilitation on balance and/or motor learning in down syndrome Patients.

METHODOLOGY

Search duration: Article published from 2010 - 2023 were included in this review.

Search database: Studies were identified from the following databases:

- Google scholar, Wikipedia.org, ncbi.nlm.nih.gov, PubMed, Physiopedia, springer.com, sciencedirect.com, researchgate.net

Study design: A Literature Review.

Inclusion criteria:

- Articles published in English language
- Articles between 2010 to 2023
- The Primary aim of the study was to find out the Effect of virtual reality-based rehabilitation on balance and/or motor learning in down syndrome Patients
- The publication had been peer reviewed.

Exclusion criteria:

- Articles published in languages other than English
- Case reports
- Comments and letters or report information
- Study includes the Effect of virtual reality-based rehabilitation other than down syndrome patient
- Study includes the Effect of virtual reality-based rehabilitation other than balance and motor learning

REVIEW OF LITERATURE

No	Author/year	Study title	Place of Study	Type of Study	Conclusion
1	Samia Abdel Rahman Abdel Rahman [26]2010	Efficacy of Virtual Reality-Based Therapy on Balance in Children with Down Syndrome	Egypt	Randomized control trial	This study showed that improvement in postural stability of children with DS, aged 10 to 13 years, was possible through the use of VR-based therapy in the form of Wii-Fit.
2	Yee-Pay Wuang, Ching-Sui Chiang, Chwen-YngSu, Chih-	Effectiveness of virtual reality using Wii gaming technology in children with	Taiwan	Quasi-experimental Study	Inconclusion, therapeutic intervention (i.e., VR Wii or SOT) conducted at a regular basis was beneficial in improving

	Chung Wangb[27] 2011	Down syndrome			sensorimotor functions in school-aged children with DS. More effort should be made to help these children generalize the training effects to the functional tasks that demand similar motor skills
3	Lilian Del Ciello de Menezes1, Thais Massetti1,3 Et al [28]2015	Motor Learning and Virtual Reality in Down Syndrome; a Literature Review	Brasil	Literature Review	They conclude that individuals with Down syndrome respond positively and effectively, with improvements in sensory motor control, when stimulated with tasks that are complementary to conventional therapy, including therapy involving virtual reality.
4	Juliana Ribeiro Gouveia Reis 1; CassianoMerussi Neiva 2; Et al [29] 2017	Virtual Reality Therapy: Motor Coordination And Balance Analysis In Children And Teenagers With Down Syndrome	Brazil	Quasi-experimental Study and randomized control trial	In their study they concluded that performing the Virtual Reality Therapy program, conducted in short sessions, associated with normal activities of the institution, may be included as an adjunct to children and adolescents with Down Syndrome physiotherapy treatment, contributing to a better performance in motor coordination and balance
5	Mohamed A. Abdel Ghafar, Osama R. Abdelraouf [30] 2017	Effect Of Virtual Reality Versus Traditional Physical Therapy On Functional Balance In Children With Down Syndrome: A Randomized Comparative Study	Egypt	Randomized Comparative Study	Wii games-based balance training has the potential to improve the functional balance in children with Down syndrome and it can be used as an alternative modality whenever conventional physical therapy is not feasible.
6	Carlos Bandeira de Mello Monteiro1,2, et al [31] 2017	Short-term motor learning through non-immersive virtual reality task in individuals with down syndrome	USA	Experimental Study	In their study they concluded that individuals with DS who started with low performance improved coincidence-timing task with virtual objects, but were less accurate than typically developing individuals.
7	Jamile Benite Palma Lopes,1 Luanda André Collange Grecco,2 et al [32] 2017	Protocol study for a randomised, controlled, double-blind, clinical trial involving virtual reality and anodal transcranial direct current stimulation for the improvement of upper limb motor function in children with Down syndrome	Brazil	Randomised Controlled Trial	Non-invasive brain stimulation method (TDCS) will be employed to facilitate motor cortical excitability in the areas subjacent to stimulation to enhance the effects of motor control and learning
8	Nicolás Gómez Álvareza, Alexandra Venegas Mortecinosb et al [33]2018	Effect of an intervention based on virtual reality on motor development and postural control in children with Down Syndrome	Brazil	Intervention based research	A virtual reality-based intervention was effective in GWBB, providing low-impact exercises to improve postural control and thus leading to improved motor skills in children with DS.
9	Reham A. Mohamed, Samia A. Abd El-Rahman.et.al.,[34] 2019	Virtual Reality for Motor Rehabilitation of Children with Down Syndrome: Systematic Review	Egypt	Systematic Review	Studies included in their article gave moderate evidence regarding the effectiveness of virtual reality in motor rehabilitation of children with Down syndrome. Further well designed randomized controlled trials on the effectiveness of virtual reality on children with Down syndrome are necessary.
10	Jessica Stander1 Jennifer C. du Preez1 et al [35] 2021	Effect of virtual reality therapy, combined with physiotherapy for improving motor proficiency in individuals with Down syndrome: A systematic review	South Africa	Systematic Review	In their study they concluded that VRT may be valuable to improve agility and strength in individuals with Down syndrome, and balance and coordination in children with Down syndrome.
11	Jamile Benite Palma Lopes, Isabela Marques Miziara et al [36]2022	Brain activity and upper limb movement analysis in children with Down syndrome undergoing transcranial direct current	Brazil	Randomised Controlled Trial	VR activities constitute a promising resource in the rehabilitation process by promoting the repetition of movements during functional and motor training, the improvement of sensorimotor and adaptive

		stimulation combined with virtual reality training: study protocol for a randomized controlled trial			information, and the overcoming of difficulties with regards to activities of daily living.
12	ElvioBoato GeizianeMelo,et al [37] 2022	The Use of Virtual and Computational Technologies in the Psychomotor and Cognitive Development of Children with Down Syndrome: A Systematic Literature Review	Brazil	Systematic Review	The games used in these studies were able to stimulate, through the visual field, the skills of global motor skills, balance, body scheme and spatial organization, in addition to the learning of mathematical concepts, in order to directly influence the autonomous life activities, language skills, social skills and educational aspects of people with DS.
13	Joypriyanka Mariselvam1, Surendran Rajendran1 and Youseef Alotaibi [38] 2023	Reinforcement learning-based AI assistant and VR play therapy game for children with Down syndrome bound to wheelchairs	Saudi Arabia	Experimental Study	In their study they concluded that when compared to other reinforcement algorithms, the performance of the AI helper agent is at its highest when it is trained with PPO-Actor Critic and A3C.

DISCUSSION

Down Syndrome is a genetic disorder caused when abnormal cell division results in extra genetic material from chromosome 21. They have difficulty with equilibrium, balance, protective response and graded muscle movement leading to wide base of support in sitting and standing and delay in postural control and locomotion [39,40,41]. Slow postural responses to loss of balance lead to inefficiencies in maintaining stability. Such balance problems may result from higher-level postural control mechanisms such as delayed cerebellar maturation and a relatively small cerebellum and brainstem [42,43]. The most effective traditional approaches for treating sensorimotor problems in children with DS include sensory integrative (SI) therapy, the perceptual-motor (PM) approach, and neurodevelopmental treatment (NDT)[19]. The impact of VRT on motor and psychosocial outcomes in children who have a developmental coordination disorder, showed a significant improvement in their motor proficiency [44]. Virtual reality therapy can also improve the spatial orientation capacity and activate the cerebral cortex, thus facilitating better balance control and motor function [45]. Virtual Reality could create an exercise environment in which the practice intensity and positive sensory feedbacks (i.e. auditory, visual, and proprioceptive) can be manipulated systematically in different natural-like environments to allow for individualized motor training programs [46].

In our review article two of the studies shows effectiveness of VR on Balance. In which Samia Abdel Rahman Abdel Rahman et at [2010] reported that VR based therapy in form of Wii-fit could improve balance and confidence via Wii-fit balance board and improve functional mobility in older adults via VR exercise, improve postural control via virtual cycling training [26]. It is supported by other article reported that VR in form of Wii games is superior than traditional physical therapy to improve functional balance in children with down syndrome. Wii games involves augmented forms of sensory feedback enhance different balance challenges by detection of posture and balance disturbances and corrections, thus allowing the participant to use both timely feedback control and feed-forward preparatory control required during different balance challenges [30].

There are few studies that shows effectiveness of VR on Motor learning. In which Two of the study reported that improvement in motor learning by using VR. Wii that adaptively modulated muscle activity, producing rapid bursts to contrast sudden variations joints or restore basic muscle hypotonia during relaxed limp oscillation. Repetitive intensive training, observation, practice and representation on screen of task specific activities can facilitate

brain plasticity in down syndrome that engage the mirror neuron system that enhance sensorimotor function. [27,28]

Felipe fregeni et al in their study they concluded that short term motor learning through non immersive VR task in individuals with down syndrome was facilitate the performance of temporary effects during acquisition but also provide improved durable performance of retention and transfer tests and also optimizing movement speed and energy efficiency [31].

In our Review there are few studies that shows effectiveness of VR on both balance and motor learning. Nicolás Gómez-Alvarez et al reported that effect of an intervention based on virtual reality on motor development and postural control in children with Down Syndrome. They also concluded that a virtual reality-based intervention was effective for the WBBG as it provides low-impact exercises to improve postural control and thereby leading to better performance in TGMD 2 in children with DS [33]. Two of the studies reported that VR for Motor rehabilitation of children with down syndrome improve motor proficiency, visual-integration abilities and SI functioning and also improve child's postural stability, UL co-ordination, Manual dexterity, strength, balance and running speed and agility. VR provide multisensory feedback that improve performance and affect brain reorganization, motor capacity, visual-perceptual skills and personal factor [34,35]. Juliana Ribeiro Gouveia Reis et al shows effect of VR on motor Co-ordination and balance using two games, one was River Rush and second was Hall of ricochets. It involves body movement such as balance, co-ordination, visual manual and gross motor co-ordination from Kinect adventure [29].

In general, most of the studies recommend to use larger no. of children with DS. Though only few studies Included in this review it gives evidence supporting the use of VR for improving balance and motor learning.

CONCLUSION

The current review discovered evidence of using virtual reality to help children with down syndrome with their balance and motor learning. Few studies have been conducted on the subject; more carefully planned randomized controlled trials are still required. High-caliber studies in the future could support the current data about VR's benefits for kids with Down syndrome. VRT may be helpful in helping people with Down syndrome become more agile and strong, as well as helping their children to improve more balance, coordination and motor learning.

Declaration by Authors

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