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VIRTUAL REALITY THERAPY: MOTOR COORDINATION AND BALANCE ANALYSIS IN CHILDREN AND TEENAGERS WITH DOWN SYNDROME

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ABSTRACT

Introduction: The aim of the study was to evaluate the effects of Virtual Reality Therapy on motor coordination and balance of children and adolescents with Down Syndrome. Material and Methods: It is an analytical, prospective and quantitative study. This study included 12 participants were divided into two groups, five of them were part of the Control Group which performed regular institution activities, and the Protocol Group was composed of seven individuals who participated in the Virtual Reality Therapy program and also performed regular institution activities. First, the participants underwent an anthropometric assessment, Körperkoordinatonstest Für Kinder and Pediatric Balance Scale. The Virtual Reality Therapy program consisted of 16 sessions of 20 minutes each. After the program the participants were reassessed. Results and Discussion: There was a statistically significant increase, in motor coordination of Protocol Group. The balance increase was also statistically significant in the final score obtained in Protocol Group, being 46.86 + 7.98 to 53.57 + 1.99. A negative correlation was recorded between body mass index and the value obtained in the Pediatric Balance Scale test, with r = -0.76 and p = 0.04. The Control Group showed no significant changes in any of the variables. Discussion: We conclude that performing the Virtual Reality Therapy program, conducted in short sessions on average 12 minutes, associated with normal activities of the institution, may be included as an adjunct to children and adolescents with Down Sindrome physiotherapy treatment, contributing to a better performance in motor coordination and balance

Key words: physical rehabilitation, down syndrome, virtual reality

TERAPIA DE REALIDAD VIRTUAL: COORDINACION MOTORA Y ANALISIS DEL EQUILIBRIO EN NIÑOS Y ADOLESCENTES CON SINDROME DE DOWN

RESUMEN

Introducción: El objetivo del estudio fue evaluar los efectos de la Terapia de Realidad Virtual sobre la coordinación motora y el equilibrio de niños y adolescentes con Síndrome de Down. Material y Métodos: Es un estudio analítico, prospectivo y cuantitativo. Este estudio incluyó a 12 participantes que se dividieron en dos grupos, cinco de ellos eran parte del Grupo de Control que realizaba actividades regulares de la institución y el Grupo de Protocolo estaba compuesto de siete individuos que participaron en el programa de Terapia de Realidad Virtual. En primer lugar, los participantes fueron sometidos a una evaluación antropométrica, Körperkoordinatonstest Für Kinder y Pediatric Balance Scale. El programa de Terapia de Realidad Virtual consistió en 16 sesiones de 20 minutos cada una. Después del programa los participantes fueron reevaluados. Resultados y Discusión: Hubo un aumento estadísticamente significativo, en la coordinación motora del Grupo de Protocolo. El aumento del balance fue también estadísticamente significativo en la

puntuación final obtenida en el Grupo de Protocolo, siendo 46.86 + 7.98 a 53.57 + 1.99. Se registró una correlación negativa entre el índice de masa corporal y el valor obtenido en la prueba de la escala de equilibrio pediátrica, con r = -0.76 y p = 0.04. El Grupo Control no mostró cambios significativos en ninguna de las variables. Discusión: Concluimos que la realización del programa de Terapia de Realidad Virtual, realizado en sesiones cortas de 12 minutos, asociado con actividades normales de la institución, puede ser incluido como complemento a niños y adolescentes con tratamiento de Fisioterapia Down Sindrome, contribuyendo a un mejor desempeño en coordinación motora y equilibrio.
Palabras clave: rehabilitación física, síndrome de down, realidad virtual

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INTRODUCTION

Down syndrome (DS) is a genetic condition characterized by the presence of an extra chromosome or part of an extra chromosome, leading to a tripling of the genetic material on a chromosome pair 21 (Dowjat et al. 2007). This condition results in specific physical and mental characteristics, causing a delay in the development of skills such as motor deficits, and changes in motor coordination that could limit independence in daily activities of children and teenagers with DS (Ribeiro, Barbosa & Porto, 2011).

Children with DS take longer than children with typical development in the acquisition of some motor skills such as crawling and walking independently, and subsequently have problems with balance, walking difficulties, coordination and manual co-ordination (Silva, Silva & Correia, 2013).

The literature has shown that interventions with exercise and conventional rehabilitation help in the development of motor skills of children and adults with DS, even for showing improved quality of motor responses of these children after intervention (Silva & Ferreira 2001).

Motor coordination is considered as an interaction of the musculoskeletal, nervous and sensory systems to produce accurate and balanced kinetic actions and the higher the level of complexity of a specific motor skill of coordination, the greater the level of coordination required for effective performing (Kiphard & Schilling,1974; Gallahue & Ozmum, 2005). People with DS presented a longer time for performing movements, suggesting greater dependence on feedback produced by the response, or require longer time to process feedback (Martins, Fecuri, Arroyo & Parisi, 2013).

Virtual Reality Therapy (VRT) is a technique that uses interactive games as a physical therapy resource and has shown positive results in cortical reorganization, improving functional mobility, and quality of movement (Balista, 2013; You, 2005). In the literature many protocols with interventions in individuals with DS were found to reduce body weight and body mass index (BMI), however, there was a shortage of studies when they attempt to assess the intervention of VRT motor coordination of DS teenagers (Reis, Nascimento & Tonello, 2015).

The VRT is a relatively new commercially available method, with promising results, and there has been a need to establish therapeutic strategies aiming to promote health in children and adolescents with DS. Based on these facts, the need to develop a program contemplating the basic requirements of rehabilitation using the therapy through virtual reality was noted.

The purpose of this present invstigation was study the relationship between motor coordination and balance and body mass index (BMI).

MATERIAL AND METHODS

Design

This is an analytical, prospective, a quasi-experimental and randomized study, with a control group and a quantitative approach.

Participants

Were include twelve children and adolescents with DS took part in this study. They were divided into two groups: Virtual Reality Therapy Group (VRTG) consisting of seven (58.33 %) and Control Group (CG) of five patients (41.67 %) with a mean age of 9 years ± 2.5 and 8 years ± 2.5, respectively. The description of the sample is shown in Table 1.

TABLE 1
Anthropometric characteristics of VRGT and CG.

Variables	VRTG (n=7) Mean (±SD)	CG (n=5) Mean (±SD)	P
Age (years)	*9 (2.5)*	8 (2.5)	0.55
Weight (Kg)	35.25 (9.8)	29.46 (10.69)	0.22
Height (m)	1.32 (0.19)	1.20 (0.14)	0.22
BMI	20.30 (4.08)	19.69 (3.35)	0.80

Data are expressed as mean and standard deviation (SD).
VRGT: Virtual Reality Therapy Group; CG: Control Group.

Inclusion criteria were: children and adolescents with DS, who had ability to understand simple instructions and which were physically able to perform exercise as authorized by a physician's medical certificate.

Procedure

The study was conducted at the audiovisual presentations room of the institution *Association of Parents and Friends of Exceptional Children (APAE*), in Patos de Minas, State of Minas Gerais, Brasil,

The participants were randomly divided into two groups: VRTG and CG. The VRTG was instructed to perform the VRT program and usual activities of the institution while CG performed only the usual activities of the institution. The groups were initially evaluated regarding the study variables explained below.

The intervention procedure program consisted of 4 weekly sessions of maximal 20 minutes each, performed every 48 hours, during 4 weeks, totaling 16 training sessions. After the intervention procedure, the two groups were again evaluated.

After the final assessment and checking the results of the study, the CG children were then invited to participate in the same VRT program. After completion of the study, the Xbox® 360 Kinect TM device was donated to the institution.

To facilitate the organization of the data and record the history of each participant, an evaluation sheet was drawn up, with personally identifiable information (participant's name, parent or responsible person, date of birth, address, and telephone number) and medical history (associated diseases and medication use). The height and weight data were also recorded, to perform anthropometry.

To evaluate the coordination of the participants, the *Körperkoordinatonstest Für Kinder* (KTK) body assessment test using the version proposed by Gorla, Araújo & Carminato (2004) was applied.

The KTK, was developed with the objective of diagnosing motor deficiencies in children with brain injuries or behavioral changes. .This test is suitable for children from 5 to 14 years and 11 months and includes the following items: coordination, rhythm, balance, strength, laterality, speed and agility.

In our study we used the version proposed by Gorla and Araújo (2007) composed of a battery of four tests: task 1: balance beam; Task 2: monopedal jump; Task 3: side jump; and Task 4: transfer on platform.

After application of the tests, the absolute values obtained were submitted the application in regulatory tables (Figure 1) by Carminato (2010) and calculated the motor quotient (MQ) also presented in absolute values, for each task performed and the following was calculated the general motor quotient (GMQ) too on indices of absolute values.

Classification	Motor Quotient (MQ)
Disturbing the Coordination	Less than 70
Coordenation failure	From 71 to 85
Normal coordination	From 86 to 115
Good coordination	From 116 to 130
Very good coordination	From 131 to 145

FIGURE 1: Rating by sum of MQ in accordance with the Manual KTK. Indice score presented on absolute values. Carminato (2010).

To evaluate the balance, the Pediatric Balance Scale (PBS) was used (Miyamoto et al, 2004; Reis, Nascimento & Tonello, 2015). This test is also known as “Berg Sacale” and was first proposed by Berg, Wood-Dauphinee, Williams & Gayton (1989).

The test evaluates the performance of functional balance in 14 items common to daily life. The maximum score is 56 (indices of absolute values) and each item has an ordinal scale of five alternatives that range from 0 to 4 points. The points are based on the time in which a position can be maintained or to complete a task by integer and the higher the score, the better the balance (Miyamoto et al. 2004, Reis, Nascimento & Tonello, 2015).

VRT program

For the VRT program, an Xbox® 360 Kinect TM game (Microsoft) was installed in the audiovisual presentations room of the *APAE* with the "Kinect Adventures®" game; this game was chosen because it involves body movements using skills such as balance, coordination visual-manual and gross motor coordination. At first the Kinect sensor was calibrated for recognition of all body movements, allowing the acknowledgment of the participant at each session.

Two games were used from "Kinect Adventures®." The first game is called "River Rush®"; in this game the objective is to drive a small boat down a turbulent river to a safe place, without forgetting to collect items that are worth points along the way. Therefore, the player must perform movements to the sides of the body, thus changing the direction of the boat. At certain points the player also needs to jump to reach areas difficult to access in order to get even more points and this game was our first choice. The second game used was "Hall of ricochets®," requiring the player's time reactions, as the player must throw a ball against wooden blocks in the background of the screen. The player must also use his/her body to reach the quick balls when they come back after hitting the blocks. Thus, it is necessary to move the arms, legs, and head to destroy the largest number of blocks in the shortest possible time.

Before the beginning of the study all participants had an early contact with the games. For about two weeks the aim was to ensure the participants understood the controls required by the games. Both games had feedback at the end of each completed stage, which consisted of three types of virtual medals - bronze, silver and gold, and regardless of the result, motivational phrases at the end of each stage were spoken, such as "Congratulations," "Very well you could…," "You got silver medal," and "Go to gold." The program period consisted of 16 sessions performed on consecutive days, except Saturday and Sunday, with the duration maximal of 20 minutes per session.

Data analysis

Data analysis was performed using SPSS for Windows version 17, and the non-parametric Wilcoxon test and Mann-Whitney were applied, and to find the correlation the Spearman correlation coefficient was used. The level of significance adopted was 0.05, on a bilateral test. Finally, for the pre and post intervention comparisons in VRT group, was also calculated the effect size (D-Cohen test), which represents a descriptive statistical analysis, that serves as a complement to the test of statistical significance. In this analysis, were used the following values for'd ' for: small ($0.20 \leq d < 0.50$); medium ($0.50 \leq d <0.80$) and large ($d \geq 0.80$) in accordance with Cohen (1988).

Ethical considerations

The project was submitted to the Research Ethics Committee of the University of Franca, under CAAE number: 43968515.0.0000.5495. Those responsible for the participants were informed about project procedures and signed a Consent Agreement and Informed Consent. A consent form was also presented to the volunteer. The data were collected only after signing.

RESULTS

Every VRT session lasted 20 minutes, however, the time for effective practice of the exercise for each participant varied due to distractions and their own individual characteristics. Therefore the average time of physical exercise per session per participant was recorded. The minimum average time was 3.3 minutes, participant 4 (P4), and the maximum time was 20 minutes, participant 6 (P6) (Table 2).

TABLE 2
Time in minutes of each participant during the VRT program.

Participants	P1	P2	P3	P4	P5	P6	P7
Mean (±SD)	14 (2.1)	8.6 (0.4)	12.4 (1.1)	3.5 (0.2)	14.5 (1.1)	20 (3.9)	12.3 (1.1)

Data are expressed as mean and (Standard Deviation). Regarding the coordination evaluated before and after the intervention period.

The results of each task assessed by the KTK test are shown in Table 3. The VRTG showed significant differences in all the tasks proposed after the VRT program.

TABLE 3
Motor Quotient obtained by the participants in the KTK test in VRTG and CG in the pre and post VRT.

Variables	VRTG Mean (±SD)				CG Mean (±SD)		
	Pre	Post	P	D-Cohen Effect	Pre	Post	P
MQ 1	45.14 (11.51)	46.71 (11.54)	0.04*	0.78	48.8 (11.30)	48.8 (11.30)	0.55
MQ 2	60.71 (22.34)	69.29 (21.87)	0.01*	1.15	72.00 (20.06)	72.00 (20.0)	0.80
MQ 3	39.29 (16.81)	43.14 (17.31)	0.02*	0.92	44.40 (18.76)	44.40 (18.70)	0.32
MQ 4	32.86 (9.12)	39.57 (15.55)	0.01*	0.99	35.80 (9.20)	35.80 (9.20)	0.46
GMQ	62.14 (13.96)	67.46 (15.18)	0.01*	1.02	68.00 (14.35)	68.00 (14.3)	0.22

Data are expressed as mean and (Standard Deviation) on absolute values. MQ1 - Motor Quotient of the first task; MQ2 - Motor Quotient of the second task; MQ3 - Motor Quotient of the third task; MQ4 - Motor Quotient of the fourth task; GMQ - General Motor Quotient. A significant differences in all the tasks proposed to VRTG after the VRT program was founded, but CG showed no statistically significant difference at the end of the study. The values adopted for D-Cohen test were: for small (0.20 ≤ d < 0.50); medium (0.50 ≤ d <0.80) and large (d ≥ 0.80).

According to the results in Table 4, statistically significant differences were found among the task values: reaching forward with an outstretched arm in the pre-treatment situation; standing with one foot forward; standing on one foot; reaching forward with an outstretched arm in the pre and post treatment situations; and in the final score in the post-treatment situation; the highest values were obtained by VRTG, in all situations (table 4).

TABLE 4
Mean and standard deviations (SD) of the measurements obtained from the PBS test, of VRTG and CG, found in the pre situation and the post-treatment situation.

Tasks Evaluated	VRTG Mean (±SD)	CG Mean (±SD)	P	D-Cohen Effect
From sitting to standing – pre	3.86 (0.38)	4.00 (0.00)	0.39	
From sitting to standing – post	4.00 (0.00)	4.00 (0.00)	1.00	
Standing to sitting – pre	3.71 (0.49)	3.80 (0.45)	0.74	
Standing to sitting – post	4.00 (0.00)	3.80 (0.45)	0.23	
Transfers – pre	3.43 (0.53)	3.40 (0.89)	0.85	
Transfers – post	4.00 (0.00)	3.40 (0.89)	0.08	
Standing without support – pre	3.71 (0.49)	3.80 (0.45)	0.74	
Standing without support – post	4.00 (0.00)	3.80 (0.45)	0.23	
Sitting without support – pre	3.86 (0.38)	3.80 (0.45)	0.80	
Sitting without support – post	4.00(0.00)	4.00 (0.00)	1.00	
Standing with eyes closed – pre	3.71(0.76)	3.40 (1.34)	0.70	
Standing with eyes closed – post	3.86 (038)	3.40 (1.34)	0.70	
Standing with feet together – pre	4.00 (0.00)	3.40 (0.90)	0.08	
Standing with feet together – post	4.00 (0.00)	3.40 (0.89)	0.08	
Stand with one foot forward – pre	2.86 (1.68)	1.40 (1.95)	0.14	
Stand with one foot forward – post	3.57 (0.79)	1.40 (1.95)	0.04*	1.30
Standing on one foot – pre	1.14 (1.68)	1.20 (0.84)	0.55	
Standing on one foot – post	3.00 (1.41)	1.20 (0.84)	0.03*	1.25
Turning 360 degrees – pre	2.86 (1.68)	4.00 (0.00)	0.10	
Turning 360 degrees – post	4.00 (0.00)	4.00 (0.00)	1.00	
Turning to look back – pre	3.71 (0.49)	3.80 (0.45)	0.74	
Turning to look back – post	4.00 (0.00)	3.80 (0.45)	0.23	
Picking up object from the floor – pre	4.00 (0.00)	4.00 (0.00)	1.00	
Picking up object from the floor – post	4.00 (0.00)	4.00 (0.00)	1.00	
Alternating feet on the step / footrest – pre	2.57 (1.62)	2.80 (1.64)	0.86	
Alternating feet on the step / footrest – post	3.14 (0.90)	2.80 (1.64)	0.93	
Reaching forward, with outstretched arm – pre	3.43 (0.53)	2.20 (1.10)	0.03*	0.82
Reaching forward, with outstretched arm – post	4.00 (0.00)	2.20 (1.10)	0.001*	1.25
Total – pre	46.86 (7.98)	45.00 (7.78)	0.46	
Total – post	53.57 (1.99)	45.20 (7.69)	0.01*	0.99

Data are expressed as mean and (Standard Deviation) on absolute values. A significant differences in only some of the tasks proposed to PBS were founded after the VRT program between VRTG and CG. The values adopted for D-Cohen test were: for small (0.20 ≤ d < 0.50); medium (0.50 ≤ d <0.80) and large (d ≥ 0.80)

A negative correlation was found between BMI and the results of the KTK test, but it was not considered statistically significant. But when the correlation between BMI and PBS was evaluated, a significant negative Spearman correlation coefficient was found: R = -0.7638 and P = 0.046.

DISCUSSION AND CONCLUSIONS

There are several articles reporting the effects of VRT in physiotherapy in individuals with conditions such as cerebral palsy, cerebrovascular accident (stroke) and Parkinson's, hospitalized patients, and ankle sprain, however, its use in children with DS has been poorly investigated (Monteiro Junior, Carvalho, Silva & Bastos, 2011; Holden, Todorov, Callaban & Bizzi, 1999; Sin & Lee, 2013; Gutiérrez et al. 2013; Luna-Oliva et al. 2013; Ilg et al. 2013; Vernadakis, Derri, Tsitskari & Antoniou, 2014).

This study used the XBOX® Kinect game as an instrument of VRT because it does not require the participant to be positioned on a platform and hold the game controller, emphasizing the point that this could make it easier for the use of the game in this population. The use of the XBOX® can be considered an effective tool for our study as it showed a significant improvement in motor coordination and balance of children and adolescents participating in the VRT program in all tests (balance, lateral jumping, monopedal jumping and lateral transposition) compared to CG, which only performed the activities of the institution. However, individual differences among participants may have affected the outcome of this study.

It is possible to consider that the 16 sessions with an average of 12.2 minutes duration each and total time in which they were performed of 4 weeks, has been a determinant in favour of results found. This is because, the present study showed similar results with studies of a similar nature where the expenditure of time in the intervention phase was significantly higher.

A study in nine individuals, aged between six and eleven years with intellectual disability, performed a sequential program for 10 weeks with 23 sessions, showing significant progress in most group members. Intervention may have occurred according to the authors, for diversity of individual difficulties, for example, strength deficit in the lower limbs, and difficulty shown by the permanence of one foot. Although it is considered easy to apply, this task might not be suitable to be applied to children with intellectual disabilities, according to the authors (Gorla et al. 2004). This shows that in an intellectually disabled population, individual differences are a remarkable fact, which makes it difficult to find a homogeneous sample, as in present study.

The study by Lin & Wuang (2012) performed a clinical trial with 92 teenagers divided into two groups, (Training Group-CG and Control Group-CG), which proposed the holding of a treadmill protocol and VRT using the Nintendo Wii® for 20 minutes, three times a week for six weeks, and found gain in muscle strength and increased agility when compared to CG that received no intervention.

Berg, Wood-Dauphinee,Williams & Maki (1992) described the use of a home intervention program, using four of the Nintendo Wii® rehabilitation games for 20 minutes, four times a week for eight weeks, in a 12 year old with DS and obtained improved results in balance and also manual dexterity, speed and agility results.

In another study using VRT in a group with DS, aged between seven and 13, the intervention used the Nintendo Wii for an hour twice a week for 24 weeks and found an increase in walking speed, agility and motor coordination. For evaluation of variables the following tests were applied: shuttle run, the Bruininks-Oseretsky Test of Motor Proficiency 2nd Edition (BOT-2), and an assessment used to measure the gross and fine motor skills in children and adolescents between 4-21 years (Wuang, Chiang, Su & Wang, 2011).

Abdel-Rahman (2010) held a clinical trial that included the participation of 30 children and adolescents with DS, aged between 10 and 13, who were divided into two groups: Control Group-CG with physical therapy for an hour, twice a week for six weeks and Training Group-TG with physiotherapy for an hour and three VRT games (Nintendo Wii) for five minutes each. They found improvement in balance in both groups, highlighting a higher gain in VRT Group. It is worth noting that both groups had an GMQ score below 70, this level is compatible with motor coordination disorder, i.e. the presence of a pathological model of movement (Carminato, 2010).

In the present study there was not a change in the overall motor performance level according to KTK criteria, although this change occurred only when the tasks were analyzed individually. The study by Silva & Ferreira (2001) evaluated motor coordination using KTK in nine children with DS from six to 10 years of age, who participated in a program of physical activities and observed a significant increase in the overall coordinative performance of children, however a change in motor score was not registered. By isolating the tasks, it was observed that on the balance beam task, a significant gain in engine performance was not verified.

As in the present study, these same authors performed coordination classification according to Kiphard & Schilling (1974) and found that the children in the study were presented as low level, however, according to the results, it can be observed that there was an improvement in the quality of motor responses of children with DS, as the scores obtained were higher at the end of the study, but were not statistically significant (Silva & Ferreira, 2001).

Regarding the balance variable, this study found statistically significant differences among the task value: reaching forward with outstretched arm in VRTG. However, when taking into consideration the final score, we can observe a biomechanical development in relation to balance for VRT after intervention the of program, the total score approached the maximum value obtained in the test.

When we sought to find the existence of correlation between BMI, motor coordination and balance, a negative correlation was found, statistically significant, between BMI and the results of the PBS test. This indicates that the extent to which the values of one of the variables increase, the values of other variables decrease, so it is concluded that BMI has an influence on the results of the equilibrium test. This means that the higher the BMI value, the lower the result in the PBS test.

A similar result was found in a study with typically developed children, significant differences were observed in PBS performance in relation to BMI, and other variables such as age and gender, height, and weight (Franjoine, Darr, Held, Kott & Young, 2010).

From the results found, VRT can be recommend as therapy treatment for this population because it favors the development of motor coordination and balance of children and adolescents with DS. Acording to Franjoine, Gunther & Taylor (2003), it is important to note that one of the main elements for movement to occur in order to facilitate performance while performing activities, is the overall coordination and balance, and such capabilities have been improved in present study.

Negative correlation between BMI and balance was found to be statistically significant, indicating that the increase in BMI indicates a lower score in the results of the balance test. New studies are suggested, as there is need for progress in this field to increase knowledge in the area, and improve the application of the video game as a therapeutic modality.

We concluded that the execution of a short sessions weekly of VRT associated with normal activities of the institution may be included as a treatment for children and adolescents with DS, contributing to improve their overall coordination already in a short period of time. This is important for performing leisure and daily living activities, helping to achieve important gains in health promotion strategies.

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