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Changes in Motor Control in Developmental Coordination Disorder Patients in Two Neuromotor Treatment Models

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Summary

Purpose: Developmental coordination disorder (DCD) is a condition characterized by difficulties in performing both, gross and fine motor activities, that affect school performance and everyday activities. It affects 5-6% of all children among 5-11 years old. Studies suggest that coordination problems persist beyond adolescence and can have long-term consequences such as anxiety and depression, as well as an increased incidence of overweight and obesity. There is no consensus on the management of DCD, therapies based on neuromotor training programs and virtual reality systems have been used with promising results. The aim of this study was to evaluate the changes in motor control in DCD patients in two models of neuromotor treatment: physical and occupational therapy (PT and OT) vs. virtual reality system (VR).

Methods: This was a prospective, longitudinal, experimental, randomized, open clinical trial in which patients with diagnosis of DCD between the ages of 5-11 years old from the Pediatric Rehabilitation Service were included. Patients were divided into two groups: Intervention and control. The intervention group received motion-based interaction therapy (Nintendo Wii), the control group received conventional physical and occupational therapy, the patients in both therapy programs had sessions 3 times a week for 12 weeks, with an average duration of 40 minutes per day**.** A total of three evaluations were made, one initial evaluation, one at 6 weeks and the last at 12 weeks, the MABC-2 instrument was applied every time. The measurements were determined with a general linear model for repeated measurements with analysis of variance and covariance. Using the Hotelling Trace statistic.

Results: A sample of 44 patients was obtained, 20 children were treated with virtual reality and 24 children were treated with PT and OT. There was a significant improvement in the final percentages of each evaluation with both approaches at the MABC-2 scale; for the VR group, the scale percentage at first evaluation was 0.29 +/-0.4, by the second evaluation was 3.40 +/-3.9, and final evaluation was 14.15 +/-7. 7; for the PT and OT group scale percentages started at 0.20 +/-0.3, second evaluation was 3.63 +/-5.8 and up to 14.71 +/-10.4 (Friedman test, p = 0.0001), therefore, treatment with this later intervention was slightly superior.

Conclusion: This study shows that both approaches, therapy modality with Nintendo Wii Fit, as well as the conventional physical and occupational therapy, are equally effective in addressing motor coordination problems in children with DCD.

Keywords: Developmental coordination disorder; MABC-2; Movement-based interaction therapy

Background

Children with Developmental Coordination Disorder (DCD) are characterized by difficulties in the acquisition and performance of motor skills; it is estimated that DCD affects approximately 6% of children between the ages of 5 and 11, and such difficulties have been shown to persist into adolescence and adulthood [1]**.** Motor impairment include marked delays in achieving motor milestones, clumsiness, poor sensory-motor coordination, lack of balance and handwriting, poor postural control and motor learning difficulties, strategic planning, synchronization, sequencing of movements, etc [2]. Since the beginning of the 20th century, the scientific community has recognized the difficulties in the development of mo-tor skills in many children, for which no specific medical cause has been found. The etiology of DCD is unknown and seems to be related to alterations in the process of maturation of the central nervous system. Several heterogeneous factors have been associated: prematurity, periventricular leukomalacia in premature children, deterioration of the dominant cerebral hemisphere, sensory integration disorder, basal ganglia dysfunction, delay, or incomplete development of the cerebellum, etc. [3]**.** DCD is a common disorder, and prevalence rates have been established mainly as a result of the definition used and the tools chosen to assess the child or adult; in the United Kingdom a population-based study showed a prevalence of 1-7% in children aged 7-8. More than 3.2% of children have also been identified as having "probable" DCD with broader cut-off criteria in motor coordination tests and activities of daily living. There is a

consensus that the condition is more common in boys than in girls, with estimates ranging from a small difference to a 3:1 ratio [4]. There appears to be a high risk of DCD in premature and low birth weight infants. It is recommended for these children to be evaluated and have a follow-up during the first 12 months of life, since this is the period in which extremely useful in-formation can be obtained for the early diagnosis of developmental disorders [5]. In diagnosing DCD, it is important to remember that the core of the condition is the major motor disorder. However, the so-called pure individual with DCD, who has only motor difficulties, is the exception rather than the rule. It has been shown that DCD often overlaps with other developmental disorders. And yet, despite the compelling evidence showing the heterogeneous nature of DCD, it is not commonly recognized by clinicians and remains the 'Cinderella' of developmental disorders [6].Without intervention, it is estimated that almost three quarters of children with DCD will continue to have difficulties in adulthood [7].

The DSM-5 criteria for the diagnosis and classification of DCD have recently been published, each criterion needs to be obtained from families and documented by experts to facilitate a comprehensive diagnosis. It is essential to take these criteria to arrive to the proper diagnosis [8]. The measurement of significant gross motor difficulties and fine motor skills can only be fully determined with the use of a standard motor assessment [9]. During the consultation, checklists can be used to help target appropriate information relevant to motor function. Several authors recommend the use of the Movement Assessment Battery for children, the 3-5-year-old Movement Checklist; DCD-Q for children in school age; and the DCD checklist for adults can also be used [10]. The Movement Assessment Battery for Children (MABC-2) is the most widely used experimental, individually applied instrument for assessing children with DCD, with a sensitivity of 41% and specificity of 88% [11]. However, other instruments such as the Bruininks-Oseretsky test and the Detailed Assessment of Speed of Handwriting can be used to assess school-aged child. Early identification, assessment and therapeutic intervention are likely to impact the quality of life of patients with this motor disorder [12]. There are two broad definitions of therapeutic approaches commonly used by therapists to meet these goals, including the process-oriented model and the skill-oriented model. Process oriented model approaches focus on addressing deficiencies, alterations in the structure and function of the body, whereas the skill-oriented model focuses on addressing problems in motor learning and control and cognitive processes [13]. A recent review of the most effective interventions for treating DCD, using MABC-2, suggests that skill-oriented models produced greater effects on functional improvement compared to process-oriented approaches. Examples of skill-oriented models include neuromotor task training, cognitive orientation daily at work, performance approach, and virtual reality or video game activity [14].

These interventions have shown positive effects at improving functional outcomes in children with DCD [14]. For the planning of the therapeutic intervention it is important to consider the aspects that facilitate participation, commitment, and motivation to engage in therapy for a considerable period, to result in changes in the motor domain [15]. Neuromotor training activities and training with Nintendo Wii Fit have been identified as promising strategies to

support children with motor coordination problems. Neuromotor training is based on cognitive neuroscience, motor control and mo-tor learning theories; these activities are recommended for children of all ages, including children with low intellectual levels. Cognitive strategies should be used during training to reduce fear, increase motivation, and achieve improved motor control processes **[12].** Nintendo Wii® is a game system that incorporates both biofeedback and virtual reality aspects. This technology, with a motion sensor in the form of a hand-held controller and a balance board, is used to activate the player in video game scenarios. Hand-eye coordination has also been reported to improve by 50% among adults after training with the Nintendo Wii® **[16].** In a study by Hammond in 2013, a randomized controlled clinical trial was conducted with a total of 18 children with DCD of which 10 were treated with the Nintendo Wii® three times a week for 10 minutes per session for 1 month and 8 received conventional physical treatment. Pre- and post-intervention assessments considered motor domain, self-perceived ability and satisfaction, and parental assessment of emotional and behavioral problems. They concluded that children had significant gains in motor competence, child perception of motor ability, and improvement in emotional well-being. Improvements of 30% were also reported in the domains of motor activity that are not specifically practiced (i.e., fine motor accuracy), suggesting that Nintendo games can help develop motor coordination skills **[17].** Another quasi-experimental study was conducted by G.D. Ferguson in 2013, where they evaluated and intervened 46 children aged 6-11 years with DCD, 37of which received a group neuromotor physical training, for 9 weeks with 2 sessions per week, with a duration of 45-60 minutes per session, and 19 children had a treatment with Nintendo Wii® 3 times a week during 6 weeks for 30 minutes per session; they concluded in their study that both treatment approaches are effective in addressing motor coordination, strength and cardiorespiratory conditioning, however the Nintendo Wii® training intervention did not achieve such significant improvements with neuromotor training **[16].**

The aim of this study was to determine the changes in motor control in patients diagnosed with DCD incorporated into two models of neuromotor treatment over a period of 12 weeks, as well as to determine additional factors, such as the duration of the disorder, the degree of motor involvement and to identify the presence of comorbidities associated with the disorder and their impact on clinical evolution. Regarding Latin American population, this will be the first published study that allows us to carry out an analysis of the impact of DCD in Mexican children. Through this research we will be able to better understand how different comorbidities influence the evolution and response to treatment of children with this condition.

Methods

Study design

This was a prospective, longitudinal, experimental, randomized, open clinical trial. We included children between the ages of 5 and 11 years, who signed the letter of informed consent approved by the ethics committee of the Instituto Nacional de Rehabilitación Luis Guillermo Ibarra Ibarra (National Institute of Rehabilitation). Children were detected at the pre-consultation assessment, their clinical history was prepared and later sent to the Pediatric Rehabilitation Clinic under the diagnosis of suspected DCD.

Statistical analysis

The measurements were determined with the general linear model for repeated measurements with analysis of variance and covariance, using the Hotelling Trace statistic.

Evaluation protocol

The Movement Assessment Battery (MABC-2) and the screening questionnaire for DCD (DCDQ'07) are the most widely used experimental tools in the assessment of children with DCD. This background was used to design the evaluation protocol for this study. As a result of the assessment in the Pediatric Rehabilitation Clinic, a diagnostic confirmation of DCD was made by applying the criteria established by the Diagnostic and Statistical Manual of Mental Disorders (DSM-5). At the same time, the Developmental Disorder of Coordination Screening Questionnaire (DCDQ-'07) was applied. Then, children who were classified with suspected DCD based on the Questionnaire (score between 15-46), were asked to take the Movement Assessment Battery (MABC-2). This helped classify the children into three categories: children with DCD, children at risk of DCD, and finally children without DCD. Once the patients with DCD were detected by the MABC-2, they were randomly assigned into 2 therapeutic models during 12 weeks of therapy. Additionally, the patients incorporated to the sample were evaluated by other specialists in the health area to rule out possible sensory alterations. For the IQ assessment, the WPPSI test of intelligence and the WISC-R test was applied to preschoolers and schoolchildren, respectively; followed by a clinical evaluation to determine the attention capacity and the possibility of participation in the Nintendo Wii ® group as they had to be attentive to obey simple orders.

Randomization: A simple randomization method with odd numbers for experimental and even numbers for control was used in the selection of the treatment. A table of random numbers was used as a base tool and a starting point was chosen at random and then the direction of movement was selected to be kept constant throughout the table. The assignment was kept hidden in sealed envelopes that were opened until each patient was included to the corresponding study group.

Group A: A conventional rehabilitation program with physical and occupational therapy was indicated, which consisted of the following: They were carried out 3 times a week, each session had a duration of 40 minutes, for a total time of 80 minutes; The physical therapy consisted of exercises to improve the corporal scheme, exercises for coordination and static balance, exercises for dynamic coordination of hands, activities to improve the oculomanual coordination, exercises for general dynamic coordination, dynamic balance with and without help, activities to improve the rhythm of movements, spatial orientation and skill in the reaction of movements, strengthening and general muscular resistance; The occupational therapy consisted of activities promoting fine and gross manipulation, bilateral coordination activities, balance and sensory stimulation; it should be noted that this program was carried out based on the suggestions established in the Ecological Intervention Manual of the MABC-2 instrument. Both therapies were carried out at the Physical and Occupational Therapy area of the Luis Guillermo Ibarra Ibarra National Institute of Rehabilitation, assisted by a Physical and Occupational Therapy graduate, providing the patient aminimum risk of adverse events.

Group B: A virtual reality therapy program was indicated (motion-based interaction) using Nintendo Wii ®, the therapy was applied 3 times a week with 40 minutes per session. The virtual reality game has a guide for its proper application and use, so that, at the time of application, the child was receiving information on the quality with which he was performing the activities and how to correct an inaccurate action. The games used were Wii Fit ® and Wii Fit Plus®, they consist of aerobic, resistance, balance, and coordination exercises; they allow to increase the level of complexity of each game. Different established games were used in a standardized way: Running, jumping, walking in a tightrope, coordination movements with skiing and coordination with soccer. During each and every session the patient was assisted by a doctor to avoid any eventuality.

Measurement procedures: In both groups the motor changes recorded are those assessed by the MABC-2 assessment tool which are manual dexterity, aim and catch, and balance. An initial motor assessment was performed before starting treatment, and later an intermediate assessment at 6 weeks and a final assessment at 12 weeks of treatment using the MABC-2 tool were applied. The study was blinded to the testing staff, the interpreter and the analyst of the data obtained.

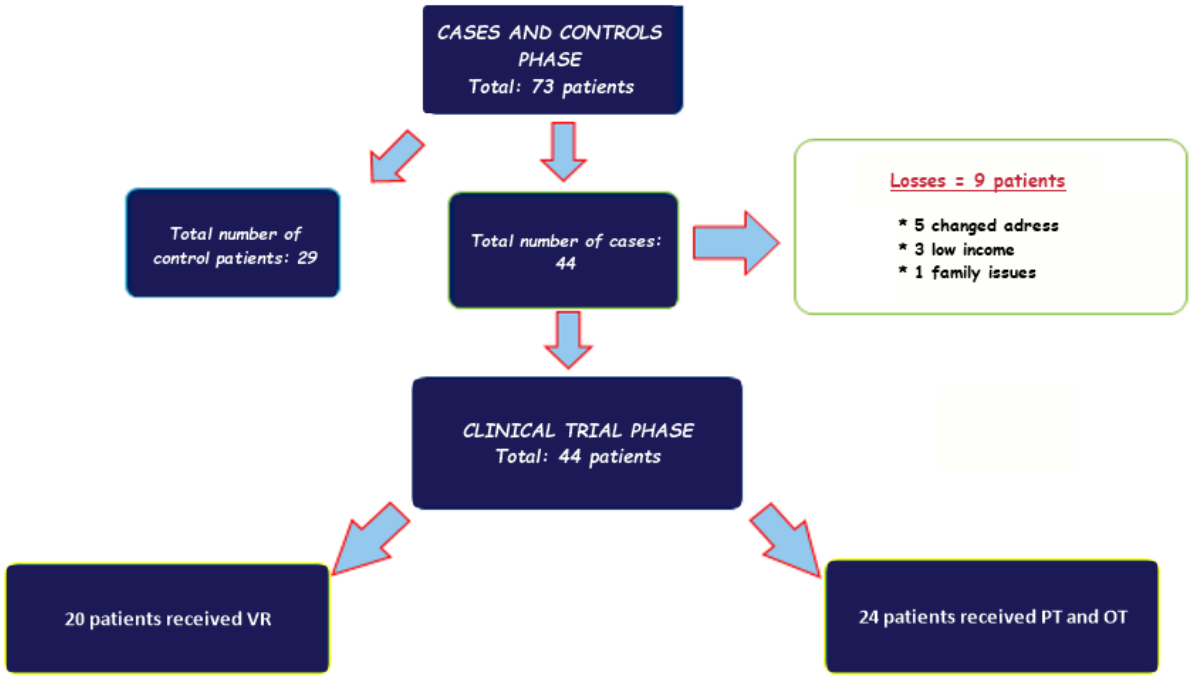
Ethical Aspects

It was a minimum risk research, patients and parents/guardians were informed with an informed consent letter about the study; the Helsinki criteria for research in human beings were met and the project was reviewed and authorized by the re-search and ethics committees of Luis Guillermo Ibarra Ibarra National Institute of Rehabilitation.

Results

Sample description

Controlled clinical trial: A sample of 44 patients was included, 20 children were treated with motion-based therapy (virtual reality) and 24 children were treated with physical and occupational therapy. It is important to mention that there were 9 patient losses, 5 were due to patients changing their address outside Mexico City, 3 due to lack of economic resources to pay the costs of transportation to the hospital and finally 1 due to family problems **(Figure 1)**.



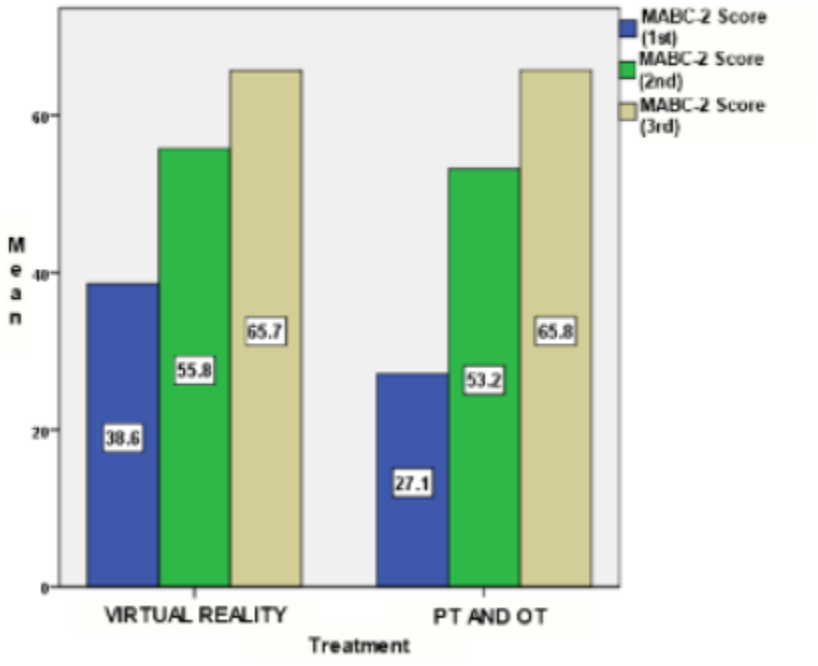
The treatment groups (Virtual Reality vs. PT and OT) showed differences in age, gender and baseline score on the MABC-2 test; as shown in **Table 1**, the children treated with VR were 7.40 +/-1.6 years old on average while those treated with PT and OT were 6.38 +/-1.5 years old (student t: p = 0. 04), on the other hand, in the first group the percentage of male patients was 85% compared to only 50% of those in the group treated with PT and OT (Chi square: p = 0.01); in the MABC-2 scores the group exposed to VR had a significantly higher mean score (p = 0.001). For the rest of the variables the groups were comparable.

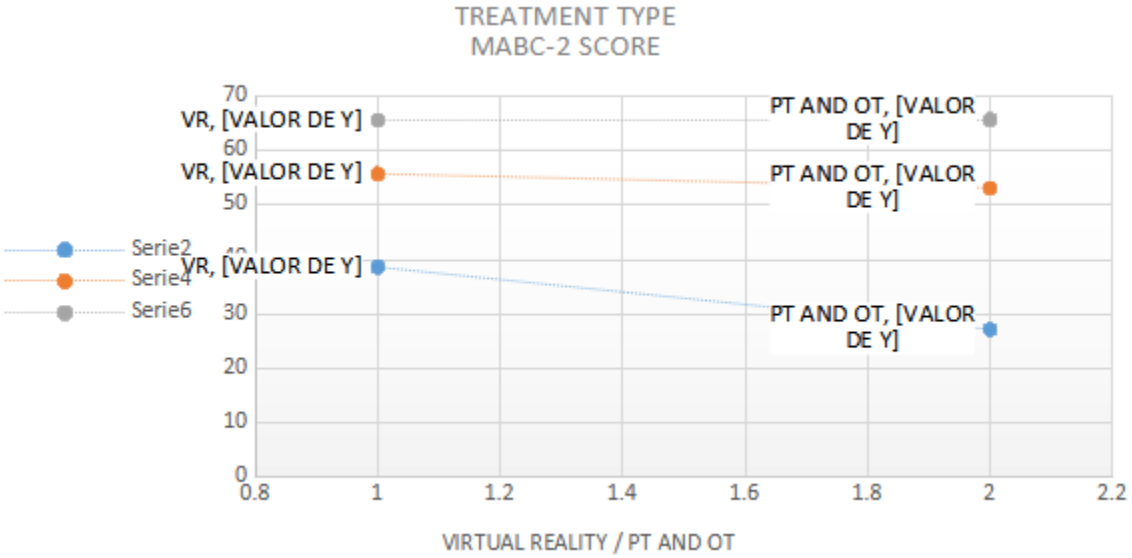
Table 1. Baseline comparability between treatment groups.

Variables	Virtual Reality (n = 20)	Physical Therapy and Occupational Therapy (n = 24)	p
Age	**7.40 +/- 1.6**	**6.38 +/- 1.5**	**0.04**
Male	**17 (85%)**	**12 (50%)**	**0.01**
Mother´s age at pregnancy	28.0 +/- 4.9	26.3 +/- 6.8	0.38
Gestational age at birth	36.0 +/- 4.5	37.0 +/- 3.6	0.44
Birth weight	2839.2 +/- 732.2	2660.6 +/- 672.2	0.40
Apgar 5 min	8.4 +/- 0.7	8.1 +/- 1.1	0.27
Intellectual quotient	98.7 +/- 6.3	97.3 +/- 5.6	0.46
Test DCD	40.8 +/- 7.7	38.5 +/- 7.3	0.30
MABC-2 score (1)	**38.6 +/- 9.5**	**27.1 +/- 11.2**	**0.001**
MABC-2 percentage (1)	0.29 +/- 0.4	0.20 +/- 0.3	0.43

With both treatments the increase in MABC-2 scores was significant **(Figure 1)**. Patients subjected to VR increased from 38.6 +/-9.l5 to 55.7 +/-5.5 and had a final score of 65. 7 +/-5.7 (Friedman's test: p = 0.0001); while those subjected to PT and OT improved from 27.1 +/-11.2 to 53.2 +/-9.3 with a final score of 65.7 +/-5.7 (Friedman's test: p = 0.0001).

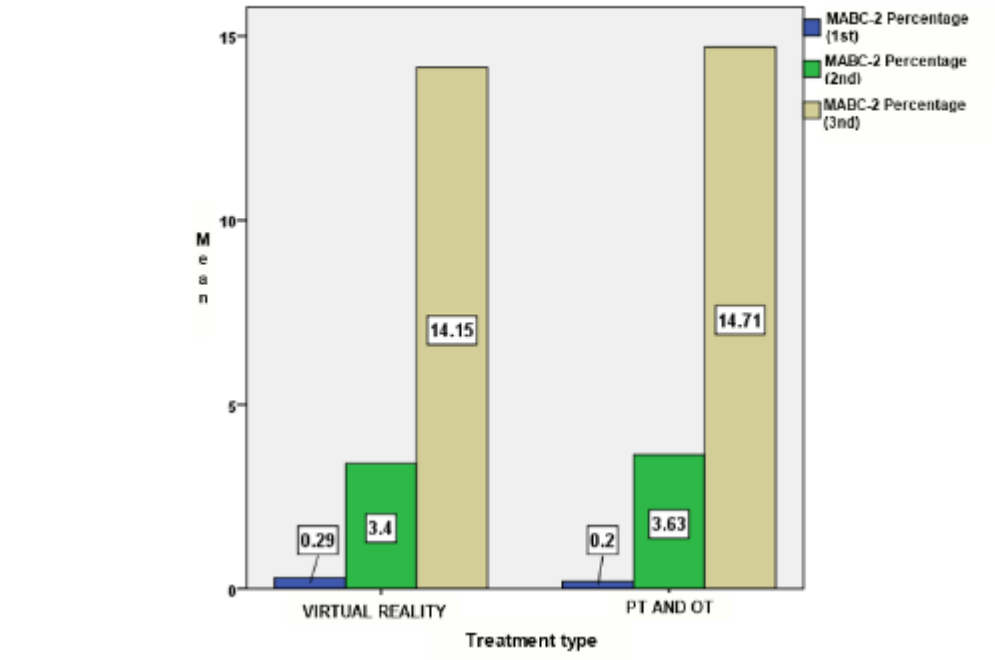
Figure 1. Evolution of MABC-2 scores in both treatment groups.

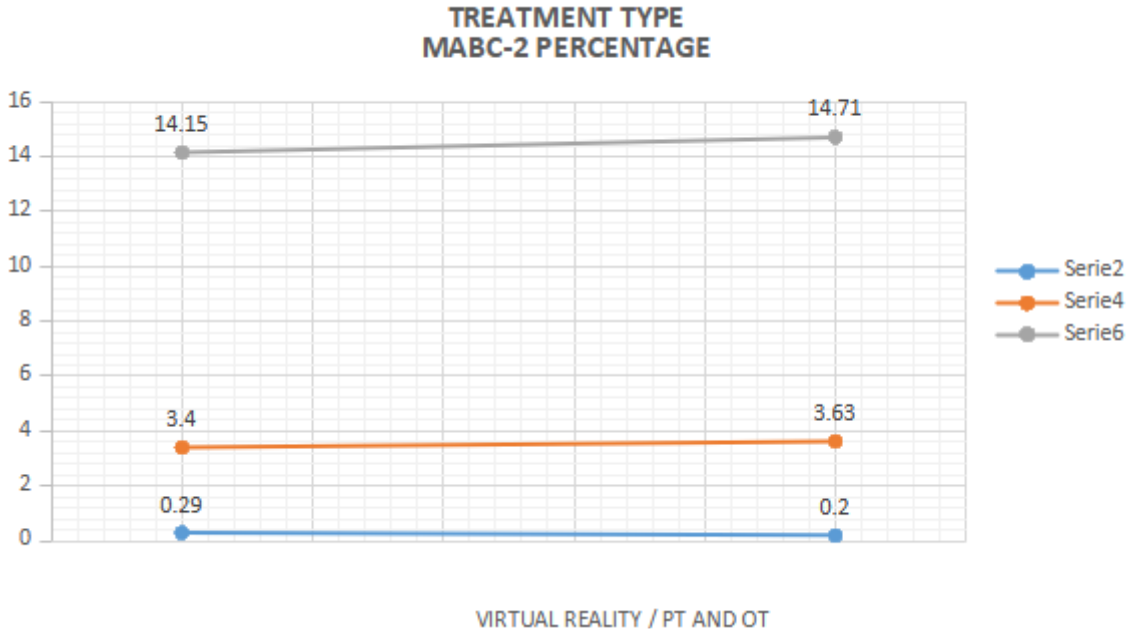




As expected, increases expressed in percentages of the MABC-2 scale were equally significant in both groups **(Figure 2)**; with 0.29 +/-0.4, 3.40 +/-3.9 up to 14.15 +/-7.7 for those treated with VR compared to 0.20 +/-0.3, 3.63 +/-5.8 up to 14.71 +/-10.4 respectively for those treated with PT and OT (Friedman's test, p = 0.0001).

Figure 2. Evolution of MABC-2 percentages in both treatment groups.





In the case of the MABC-2 scores, when adjusted by covariance analysis to make the groups comparable from the baseline, treatment with PT and OT had a 3.1 point increase over that obtained with VR (p = 0.06); in terms of percentages, the differential increase in favor of PT and OT was 1.5% (p =0.55) **Table 2**.

Table 2. Comparison of the effects on MABC-2 between treatments adjusted by Covariance Analysis.

Covariate MABC-2	Treatment		P
	VR	PT and OT	
Score 32.24	64.0 +/- 1.1	67.1 +/- 1.0	**0.06**
Percentage 0.24	13.6 + /- 1.8	15.1 +/- 1.7	0.55

Note that if the groups had started at the same score of the MABC-2 test (co-variate 32.24) they would eventually be more effective than VR **(Table 2)**.

Comparing the results by gender with two-factor ANOVA and simultaneous covariance analysis shows that with both treatments the final means of MABC-2 were lower in the male gender, but, obviously, the higher means were in favor of PT and OT **(Figure 3)**.

Figure 3. Comparison of MABC-2 means according to type of treatment and gender of patients.

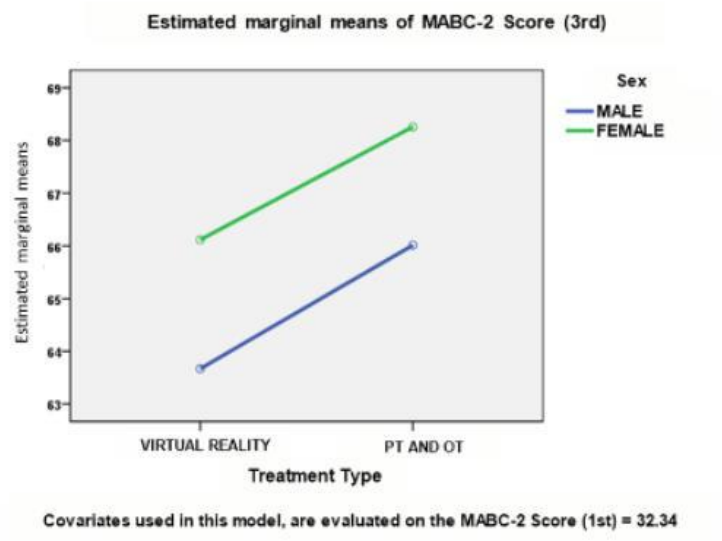
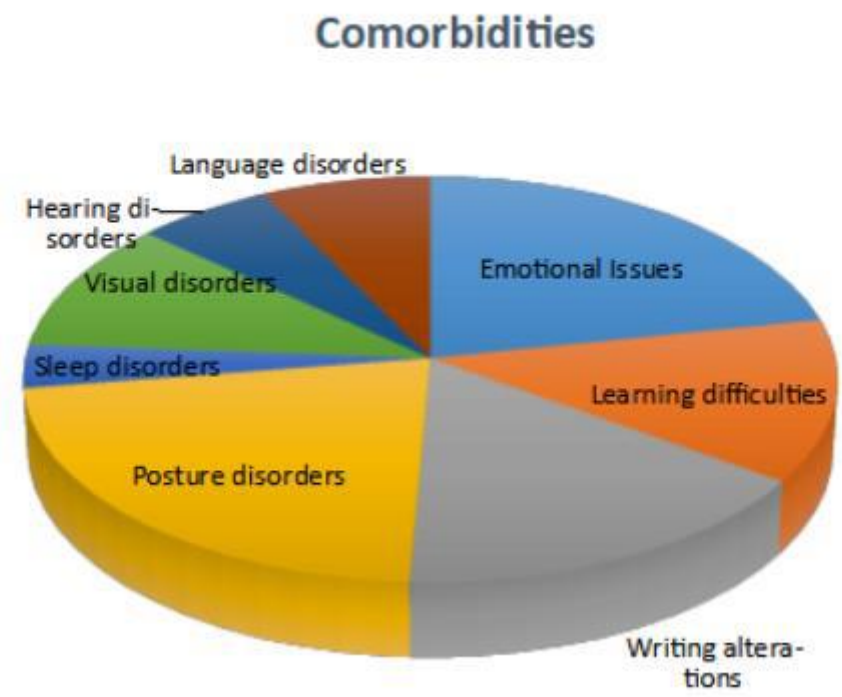


Figure 4. Comorbidities present in children with DCD.



It is important to note in **Figure 4**, that the two most prevalent comorbidities present in our 44 patients were posture disorders and emotional issues, followed by writing alterations, learning disabilities, visual and language disorders. However, there is a great dispersion of comorbidities levels between the two treatment groups so that it does not have adequate statistical power (Friedman's test: P = 0.50).

Discussion

To date, there is no information in the literature for Latin America that discusses developmental coordination disorder, the tools that can be used for its identification and diagnosis, and the therapeutic modalities that are useful. Throughout the United States and Europe, there are already several studies describing the usefulness and validity of the DCDQ'07 questionnaire and the MABC-2 battery in the timely diagnosis of developmental coordination disorder. However, there is little evidence of the usefulness of motion-based therapy (Wii Fit® virtual reality program) as a therapeutic strategy. Evaluation routes are varied and can be initiated by the concerns of parents, teachers, or health professionals **[18].** Health care or educational professionals should always consider motor coordination difficulties whenever a child has symptoms suggesting any developmental disorder, a learning disability, speech and language delay, or behavioral issues **[19]**. Neuromotor training activities and Nintendo Wii Fit® training have been identified as promising strategies to support children with motor coordination problems. Three studies in the Netherlands using MABC-2 have reported 40% improvements in children's writing skills. Niemeijer in 2007 reported a 55% improvement in motor performance using MABC-2 among children who received neuromotor training **[20].** In 2015, Gonsalves et al. conducted a

randomized clinical trial, including 40 male and female participants between the ages of 10 and 12, of whom 21 were diagnosed with DCD and 19 had normal development. The two groups of patients received motion-based interaction therapy using two consoles: Kinect® and Play Station 3, patients had body markers in specific anatomical spots, and later with a three-dimensional motion analysis system (Vicon) the position of the markers was tracked. It was concluded that the use of motion-based therapy is recommended in patients who present DCD, since an improvement was seen in the quality and precision of movement of the upper extremities **[21].**

This study aimed to prove the fact that Motion Based Interaction Therapy (via Nintendo Wii®) provides greater quantifiable results through the MABC-2 battery in coordination, manual dexterity and balance than patients undergoing intervention with conventional physical and occupational therapy. At the beginning of the study, it was not clear whether one form of intervention would result in greater improvement compared to the other, as both interventions had previously been shown to have positive results for motor performance among children with DCD **[17].** Current evidence suggests that the use of Motion Based Interaction Therapy (Nintendo Wii®) is an effective therapeutic alternative in the management of children with DCD, however, the motor changes found with the MABC-2 assessment battery were greater with conventional physical and occupational therapy. This is consistent with the findings of a review by Smits-Engelsman et al., 2012, where interventions in children with DCD were reported to have a greater effect for ability-oriented task approaches **[22].** In the group treated with motion-based therapy (Nintendo Wii®), there was less improvement in MABC-2 manual dexterity activities, which may be due to the fact that the type of exercises used in the patients who received the Nintendo Wii® included mostly simulated coordination and balance movements. The improvements in manual dexterity scores seen among the conventional therapy group were positively surprising. Changes in this area may reflect the ability of conventional therapy to promote transfer to other skills. For both treatment groups the improvements were statistically significant.

From a clinical perspective, 7 of the 24 children (29.16%) scored in the normal range after treatment with physical and occupational therapy compared to the treatment group with motion-based therapy (Nintendo Wii®) where 5 of the 20 children (25%) scored in the normal range after the intervention. Both interventions are indicated to improve deficits in motor control, through gradual progression of tasks, in the case of physical and occupational therapy or advancement through levels of play in the case of motion-based therapy (Nintendo Wii®). In addition, the prioritization of implicit learning strategies and the provision of practice opportunities under varying conditions with positive reinforcement and feedback are also shared in the principles of the two approaches **[23].** It is possible that the differences in outcomes between the groups observed in this study were due to the way these principles have been applied and understood by study participants. The participants in this study are considered representative of children with DCD, as they were identified using accepted recommendations for the identification of DCD **[24]**. It is known that comorbidities such as attention deficit disorder **[25]**, anxiety, depression, behavior problems **[26]** and learning disabilities **[27]**, occur frequently in patients with DCD, affecting their receptivity to intervention.

In the case of our study, we believe that the difference in the performance of the two groups may have been influenced by the diversity in the patients' comorbidities. It is also possible that the impact of cognitive and attention factors, which are required for each intervention, may explain in more detail the differences in the recorded results **[28-30].** On the other hand, it is likely that in the Nintendo Wii treatment group, the children were largely unfamiliar with the game at the beginning of the study, so they probably progressed slowly through the motor learning phases and had less time to consolidate their learning than the physical and occupational therapy group. Although the number of sessions and frequency in each group was equivalent, the total duration of the sessions was different, which may have further influenced the motor learning trajectories of the two groups.

It appears that this sort of Motion-Based Interaction Therapy (Nintendo Wii®) increases therapeutic adherence since, during the course of the therapies, compliance with the protocol was observed in 100% of the patients, even with patients from the State of Mexico. This, coupled with the fact that the mothers of the patients in the experimental group showed greater enthusiasm in encouraging the patients to correct their movements and even to promote competition with the opponent, may show us the viability of establishing this type of therapeutic innovation **[31,32].**

Study Limitations

This study was very encouraging observing that children improved in a wide variety of motor skills, however, it is not known if these achievements were continued in the activities of daily life at home as well as at school, and if in addition the domains related to participation also improved. Therefore, we recommend that future research projects use satisfaction scales with treatment, as well as the perception of improvements by the patient, parents, and teachers, to establish in a more objective way the progress achieved. Although the number of sessions and frequency were equivalent by therapeutic modality, the time in the execution of the tasks differed, being twice as long in the conventional modality of physical and occupational therapy, we consider that it would be appropriate to assess whether the improvements in the scores of the treatment group with the Nintendo Wii would be greater if the duration of the sessions were increased. It should be emphasized that at present, no consensus has been established on the optimal dosage parameters for application of Nintendo Wii®. A relevant aspect that was found in our research, that is consistent with other studies, is that DCD overlaps with other developmental disorders, such as attention deficit and hyperactivity disorder (ADHD), dyslexia, etc. **[19].** However, an important limitation of our study was that the differences in the number of comorbidities between the two groups and the effect on the outcome of the therapy were not analyzed. It will be necessary in future publications to analyze these issues to understand in more detail the degree to which they impact on children with DCD.

Conclusion and Future Perspectives

This study shows that conventional physical and occupational therapy approach is effective in treating motor coordination problems in children with DCD when used in a group modality. Although the Nintendo Wii ® training intervention was found to be less effective at improving motor and coordination skills than conventional therapy, it is a useful and

practical therapeutic modality for future research. However, more studies are needed to determine the most appropriate dosage parameters, in terms of intensity, duration, and frequency, while designing specific intervention programs with the Nintendo Wii® for children with DCD. In any case, we can establish that motion-based interaction therapy (Nintendo Wii®) may be a potential alternative to obtain motor improvements in rehabilitation, since, through play, patients show greater attachment to the treatment, are more constant in their sessions, show more interest in performing them and promote competitiveness among participants.

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