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Original Article

Influence of the Microsoft Kinect® games on the motor and functional performance of a child with developmental coordination disorder[1]

Joyce Cristina Cândido Soares[a], Bárbara Letícia Costa de Moraes[a], Clarissa Cardoso dos Santos Couto Paz[b], Lívia de Castro Magalhães[a]

[a]Universidade Federal de Minas Gerais – UFMG, Belo Horizonte, MG, Brasil.
[b]Universidade de Brasília – UnB, Brasília, DF, Brasil.

Abstract: Introduction: A good motor coordination is essential to children to be able to perform daily activities at school, at home, and in other social environments. However, some children have Developmental Coordination Disorder (DCD), which makes it difficult to perform these activities. As a new approach, virtual reality is being used in different rehabilitation contexts, with an emphasis on the use of motion-based games. Objective: The aim of this case study was to investigate the influence of the use of Microsoft Kinect® games on the motor and functional performance of an eight years old child with DCD, trained individually. Method: Pre and post-assessment of motor coordination, physical fitness, balance, and functional performance in selected activities were conducted using the Developmental Coordination Disorder Questionnaire (DCDQ-Brazil), the Movement Assessment Battery for Children, 2nd edition (MABC-2), the Perceived Efficacy and Goal Setting System (PEGS), the Canadian Occupational Performance Measure (COPM), and the 2-minute walk test. Results: The child presented clinically significant gains in the COPM, increased scores on items related to gross motor skills in the DCDQ-Brazil, as well as improvement in physical conditioning during the intervention, which was not maintained in the post-intervention phase, suggesting that the use of Microsoft Kinect® games should be further explored as therapeutic strategy for children with DCD. Conclusion: The limitations of the case study are discussed as a means to subsidize future studies.

Keywords: *Motor Coordination, Virtual Reality, Motor Skills Disorders.*

Influência do uso de jogos do Microsoft Kinect® sobre o desempenho motor e funcional de criança com transtorno do desenvolvimento de coordenação

Resumo: Introdução: Boa coordenação motora é essencial para que crianças sejam capazes de desempenhar diversas atividades cotidianas na escola, em casa e em outros ambientes sociais. Algumas crianças, no entanto, apresentam Transtorno do Desenvolvimento da Coordenação (TDC) o que dificulta tais atividades. Abordagens de realidade virtual (RV) vêm sendo utilizadas em diversos contextos da reabilitação, com destaque para o uso de jogos baseados no movimento. Objetivo: Investigar a influência do uso de jogos do Microsoft Kinect® sobre o desempenho motor e funcional de uma criança de 8 anos, com TDC, com treinamento individual. Método: Antes e após o treino, a coordenação motora, o condicionamento físico, o equilíbrio e o desempenho funcional nas atividades selecionadas foram avaliados com uso do Questionário de Transtorno do Desenvolvimento da Coordenação (DCDQ-Brasil), do *Movement Assessment Battery for Children* -2ª edição (MABC-2), do *Perceived Efficacy and Goal Setting System* (PEGS), da Medida Canadense de Desempenho Ocupacional (COPM) e do teste de caminhada de 2 minutos. Resultados: A criança obteve ganho clinicamente significativo nos resultados da COPM, aumento na pontuação nos

Corresponding author: Lívia de Castro Magalhães, Escola de Educação Física, Fisioterapia e Terapia Ocupacional, Universidade Federal de Minas Gerais, Campus Pampulha, Av. Presidente Antônio Carlos, 6627, CEP 31270-901, Belo Horizonte, MG, Brasil, e-mail: joycecriscandido@gmail.com
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itens relacionados à habilidades motora grossa no DCDQ-Brasil, bem como melhora no condicionamento físico durante a intervenção, que não foram mantidos na fase pós-intervenção, sugerindo que jogos do Microsoft Kinect® devem ser melhor explorados como estratégia terapêutica para crianças com TDC. Conclusão: As limitações do estudo de caso são discutidas com vistas a subsidiar estudos futuros.

Palavras-chave: *Coordenação Motora, Realidade Virtual, Transtornos das Habilidades Motoras.*

1 Introduction

During the motor development and throughout the learning process in the early years of life, the child acquires important skills for performing activities of daily living, including the ability to coordinate and control movements efficiently. However, some children have uncoordinated movements different from others of the same age group and characterize the Developmental Coordination Disorder (DCD) (BLANK et al., 2019).

According to the Diagnostic and Statistical Manual of Mental Disorders - Fifth Edition (DSM-5), the criteria for diagnosing DCD are: a) Motor skills substantially below the expectations for the chronological age and opportunities for acquiring and using these skills; b) The deficit described in the criterion above significantly and persistently interferes with the performance of activities of daily living, affecting the school performance and productivity, pre-vocational, work and leisure activities; c) Symptoms appear early in the developmental period; d) Motor deficits are not attributed to other neurological conditions that affect movement (AMERICAN…, 2013).

It is estimated that 5 to 6% of school-age children have DCD, occurring more in boys (AMERICAN…, 2013). In Brazil, the prevalence rate ranges from 4.3% to 19.9% (CARDOSO; MAGALHÃES; REZENDE, 2014; VALENTINI et al., 2012). Besides the motor repercussions, DCD can interfere with school performance and social participation, with psychosocial impact on adolescence and adulthood, and it is important to investigate intervention strategies that minimize such problems (TEIXEIRA et al., 2010).

Virtual reality (VR) started as a therapeutic resource used in Brazil in the 1990s, driven by technological advances and successful research abroad. Currently, through games, VR is proving to be a useful tool in the assessment and treatment of individuals with different motor disorders, gaining strength in children due to the strong motivational and playful factor that stimulates adherence and acceptance of treatment (SOUSA, 2011; SMITS-ENGELSMAN; JELSMA; FERGUSON, 2017).

Several tools are used for VR, particularly with industrial motion sensors for entertainment. The use of the Nintendo Wii® is most cited in the literature and shows good scientific evidence, including training children with impaired motor coordination, showing to be effective in improving dynamic balance, aerobic capacity, and agility (SOUSA, 2011; SMITS-ENGELSMAN; JELSMA; FERGUSON, 2017). In another study using this resource, motor skills acquired in the VR environment are transferred to real contexts in a similar proportion for children with and without DCD (BONNEY et al., 2017).

However, a newer technology with potential integrate it to VR is the Microsoft Kinect® for Xbox 360. Some of the advantages of this system over others VRs are the not required use of a control/joystick, enabling patients without the power of handgrip to use it (DUTTA, 2012; CLARK et al., 2012), the low cost and portability, not requiring specific clothing, reducing discomfort during its use.

Another positive factor is the possibility of being applied to different health conditions, acting directly on deficits and not on specific diseases (DUTTA, 2012; CLARK et al., 2012). In recent years, there were some studies published using Kinect as a resource for the evaluation of postural control (CLARK et al., 2012); its use to detect features of Parkinson's disease, such as postural changes and tremors (SOOKLAL; MOHAN; TEELUCKSINGH, 2014), and the use of Kinect-based rehabilitation games in the treatment of s Stroke (NOROUZI-GHEIDARI; LEVIN; PHILIPPE, 2013). Although potentially relevant for motor training in children, few studies have addressed the effect of VR on children with DCD, and none have used Kinect.

This study aims to evaluate the influence of the use of Microsoft Kinect® games on the motor and functional performance of a child with DVD. We used a case study method to investigate the therapeutic potential of VR to improve children's performance in ball games. The hypothesis investigated showed that the addition of a structured Microsoft Kinect® game intervention program would result in improved motor coordination, fitness, and performance in ball games in children with DCD.

2 Method

2.1 Study design

This is a case study with four-stage evaluations: baseline; after one month without intervention; after one month of intervention; at follow-up after one month of the intervention. The design A1-B-A2 was used as follows: A1: baseline/pre-intervention; B: virtual training; A2: Follow-up, lasting four weeks each.

2.2 Recruitment

The eligibility criteria of the study were to have the DCD diagnosis criteria according to DSM-5 and aged between seven and ten years old. The Developmental Coordination Disorder Questionnaire (DCDQ-Brazil) (PRADO; MAGALHAES; WILSON, 2009) is the DCD screening questionnaire used to identify potential participants and document difficulties in functional performance. The test Movement Assessment Battery for Children, 2nd Edition - MABC-2 (HENDERSON; SUGDEN; BARNETT, 2007) was used as a motor performance criterion, percentile ≤ 15. As an additional criterion, when analyzing VR games, there were few options for manual dexterity training. Thus, we used gross motor coordination games, as they are more conducive to ball sports training. Thus, one of the criteria for sample selection was poor performance in the MABC-2 ball and/or balance tests. The Columbia Mental Maturity Scale performed a cognitive assessment to exclude the possibility of intellectual deficit. This test evaluates the mental capacity and the intellectual maturity of children (ALVES; DUARTE, 1993), applied individually by a psychologist.

We evaluated three children, but one did not meet the inclusion criteria, one was recruited for a pilot study and procedure training, and the last was the case study. The study participant was recruited for convenience on the waiting list of the Sensory Integration Laboratory of the Federal University of Minas Gerais and contacting with therapists working in the children's area. The time between the start of participant recruitment and the completion of the study was approximately one year.

2.3 Participant

The recruited participant was eight years old, male, 25kg, and 1m25cm tall, right-handed and born at term. Previously he had a speech-language and occupational therapy follow-up due to a complaint of hypotonia (that is, "he was limp"), but without history of other illnesses and recent drug use.

He lived with his parents in a middle-class neighborhood of the city of Belo Horizonte, studied in the afternoon in a private school, where he attended the 3rd grade of elementary school. His parents have completed college. The parents reported that the child had a good academic performance but with difficulties in writing. According to the mother, the child had a quiet daily routine, and his preference was playing with computer games, dolls, and cycling, but avoided certain group activities, such as soccer. The child reported interest in sports, despite not performing them well.

2.4 Instruments

For the definition of the functional skills and objectives to be worked during the intervention, we used the Perceived Efficacy and Goal Setting System (PEGS) (MISSIUNA; POLLOCK; LAE, 2004), an interview questionnaire that uses pictures to help the child reflecting on their performance in play and activities of daily living and identify their difficulties. Only sports performance and the gross motor activity cards were used to allow treatment goals to be set in these specific areas. In PEGS, the child indicated that he would like to improve his performance in soccer and basketball, sports practiced in a physical education class in which he had difficulties.

After identifying the goals with the child, a scale from 1 to 10 was used, according to the Canadian Occupational Performance Measure (COPM) scoring protocol (LAW et al., 2009), so parents in collaboration with the child could score the importance of each activity, the level of performance and the degree of satisfaction with the performance. According to Law et al. (2009), a difference of two points or more in COPM is suggestive of clinically significant change.

The child's performance in each functional task was filmed and scored at baseline/phase A1 and the end of phase B and follow-up/A2. The child was recorded with a digital camera at a suitable distance for the task framing, in a clinical environment, performing the tasks of playing soccer, running a circuit that simulated dribbling, goal-kicking and defense, as well as hitting a ball in a basketball hoop at a height of 2 meters and distance of 3 meters. The videos were scored by an external examiner, an experienced physical education teacher with children, and the clips were randomly ordered so that the examiner did not know if the footage had been taken before or after the intervention.

We used the following instruments for recruitment and/or outcome assessment. The DCDQ-Brazil, a parent-specific questionnaire for DCD screening, identified possible study candidates and confirmed difficulty in functional performance. The questionnaire has 15 items, subdivided into the areas of motor control during movement, fine/written motor skills and general coordination, and in the age group of 8 to 9 years and 11 months, the score between 0 - 55 indicates possible DCD (PRADO; MAGALHAES; WILSON, 2009). This questionnaire was applied at recruitment and also served as a baseline and was reapplied in the post-intervention phase.

A single trained evaluator performed all other outcome measures. Motor coordination was assessed using the MABC-2, a test consisting of eight tasks distributed in the areas of manual dexterity, ball skills, and static and dynamic balance. It was used in participant selection and repeated at each stage of the study, as a measure of motor stability and outcome. The difference of one point or more in the standardized MABC-2 score is considered significant (HENDERSON; SUGDEN; BARNETT, 2007).

The physical conditioning was evaluated with the Two-Minute Walking Test, indicating the aerobic fitness and cardiorespiratory endurance, based on the individual's performance in walking the distance they can in two minutes (BOHANNON et al., 2017). Throughout the intervention, the heart rate was monitored at the beginning and end of each game, and the child was encouraged to stay within the established aerobic training range (121 to 172 heartbeats per minute). The training heart rate was previously calculated based on the maximum frequency. The literature suggests that children and adolescents practice playful physical activities, remaining in the submaximal training range of 60% to 85% of HRmax (ROWLAND, 2008).

Figure 1 shows the study flowchart, with the evaluations performed in each phase.

2.5 Procedures

The intervention consisted of one month of virtual training, three times a week, totaling 12 50-minute sessions. The sessions were organized so that each week used different games with a total of 15 games, as described in Table 1.

By analyzing the motor demands of the activities determined as a goal by the child, the games with similar demands were chosen, which were graded and modified by level of difficulty. Each game was repeated three times each session. The sessions aimed at training relevant components for soccer and basketball practice, such as agility, aim, ball time, quick postural adjustments, uni-podal support, and physical conditioning.

We instructed the child to wear appropriate clothes and shoes for physical activity during the interventions. Figure 2 shows the virtual training and the room used. Before starting the first virtual training session, the researchers explained how the training would work and encouraged the participant to attempt to familiarize with the tasks and equipment.

The child's heart rate was checked at every session, at the beginning and the end of each game, check if they reached values that showed training heart rate for physical conditioning gain, which should be between 121 and 172 beats per minute. This value indicates submaximal training range (60 to 85% of maximum heart rate), calculated from the predictive equation of maximum heart rate 208- (0.7 x age). This equation has been validated for the child population (ROWLAND, 2008; MACHADO; DENADAI, 2011).

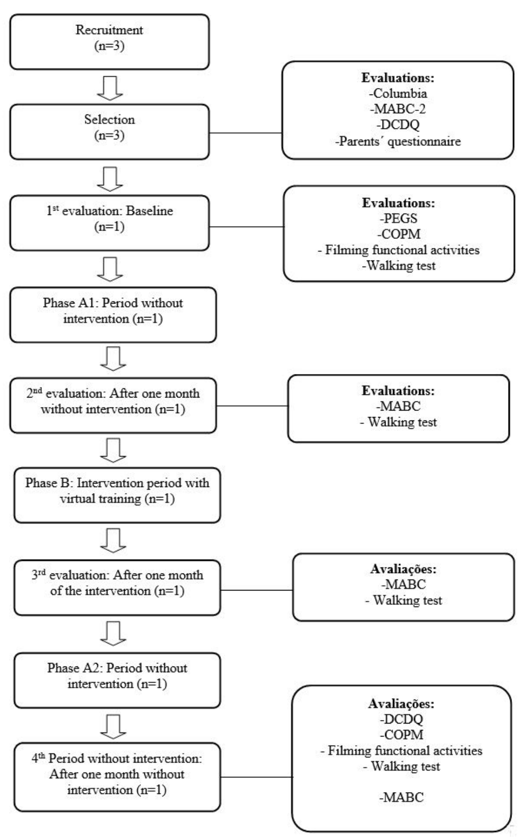

Figure 1. Flowchart of the study.

Table 1. Games used in each intervention week.

1st Week	2nd Week	3rd Week	4th Week
Lá vem vazamento	Javelin	Dart	Rapids
Bowling (mini-game)	Ping-Pong	*Cume dos Reflexos*	Super Defense
Contagem de Rali	Object dodge	Body Ball	Soccer
Racing	Barrier race	Goal kicking	

Figure 2. Images of the assembled room and the child performing the intervention.

Table 2. Summary of the motor test results.

Motor tests	Evaluations			
	Baseline	Post phase A1	Post phase B	Post phase A2
MABC manual dexterity	25/8*	37/9*	63/11*	75/12*
MABC Ball Skills	9/6*	9/6*	5/5*	63/11*
MABC balance	9/6*	9/6*	50/10*	25/8*
MABC total	9/6*	9/6*	37/9*	50/10*
Walking test of 2min.	178m	182m	190m	165m
DCDQ	38	- -	- -	46

Note: * Percentile/Standardized Score; A1 = one month before the intervention, B = intervention period, A2 = one month without intervention.

During the research, we asked the child not to perform other interventions aimed at gaining motor skills, such as physical therapy and occupational therapy, to avoid possible biases. For the same reason, the child was instructed not to use other VR devices outside the intervention periods. The Research Ethics Committee of the Federal University of Minas Gerais / COEP / UFMG approved the project - CAAE: 23471813.0.0000.5149.

3 Results

Table 2 shows the results of the tests performed at different moments of the study. The percentile and total standardized MABC-2 score remained stable in the pretest and the phase A1. The scores increased in the evaluation immediately after the intervention (phase B2) and follow-up (phase A2), with clinically significant improvement in motor skills. In the walking test, the distance was initially below the normative value for his age, increasing after the intervention as expected, but reducing in the follow-up. In the DCDQ-Brazil, there was an increase of 8 points.

Table 3 shows the functional goals defined by PEGS and scored on a 10-point scale by the child together with their parents and the external examiner. There was a clinically significant change (above 2 points) in soccer and satisfaction gain in basketball. In the perception of the external evaluator, there was a clinically significant gain in both activities.

The performance in virtual games had a gradual improvement in the score of the games. Although the child was not the focus of the therapy, he naturally used cognitive strategies to guide his performance. The therapist recorded relevant speeches that exemplify the use of strategies: *"I need to concentrate more"; "Aiming is important, I need to have a better aim"; "Be faster in the goal"; "I need to pay more attention to the ball"; "Kick more calmly and see where I'm kicking"; "I will try to change places to defend"* (sic). At the end of the training period and after leveling up in the

Table 3. Performance and satisfaction scores on functional tasks before and after the intervention.

Measures	Before phase B	After phase B	Difference
Evaluation by the child and his parents			
COPM playing soccer – Performance	4	6	+2
COPM playing soccer – Satisfaction	3	7	+4
COPM playing basketball– Performance	4	5	+1
COPM playing basketball – Satisfaction	3	6	+3
Evaluation by an external examiner			
Playing soccer	4	7	+3
Playing basketball	3	6	+3

virtual soccer game, the child reported progress as he was chosen to play ball, and he compared himself to his peers in the real soccer game, saying *"Maybe this is my schoolmates´ level"* (sic).

4 Discussion

The VR games application through Microsoft Kinect® proved to be a viable alternative to stimulate motor performance, besides being motivating for the participant. The analysis of the COPM scores showed that the child and his parents perceived improvement and were more satisfied with soccer performance. In the basketball activity, there was a significant increase in satisfaction, without significant improvement in his performance. In the external examiner's evaluation, there was an improvement of more than two points, both in soccer and basketball. This discrepancy between the examiner's evaluation and the parents/child evaluation may be related to their observation, as the examiner scored performance videos in the clinical setting, while the parents and the child rated the performance in the natural setting, home, or school.

In the motor skills, there was a clinically significant gain in the MABC-2 score, enough to change the motor category, from a suggestive result of a motor problem, pre-intervention, to percentile indicating the absence of movement difficulties, post-intervention (Table 2). There was motor balance in the first two evaluations, followed by a big gain and change of category after the intervention. The test ball skill items (grabbing tennis ball and throwing sandbags) have no direct resemblance to the ball activities trained in the study. However, strategies learned throughout the training may have contributed to improving test performance. This result possibly also reflects his learning, since MABC-2 was repeated four times within three months.

Another data suggesting improvement in functional performance is the increase in the score on the DCDQ parents´ questionnaire. The final score remains suggestive of DCD; however, as there are items of manual dexterity in the questionnaire and this skill was not the target of the study, it should be considered in which items there was an increase in the score. Considering only items related to gross motor skills, the score went from 23 to 30, that is, from the eight extra points obtained in the post-test, seven showed gain in these skills.

The increase in the distance in the two-minute walking test immediately after the intervention showed that there was an improvement in physical conditioning, but this improvement was not maintained one month after the end of the program. This loss can be explained by the principle of reversibility, in which adaptive changes in body systems in response to exercise programs are transient unless training-induced skills are regularly used in functional activities or the individual participates in intervention programs (ROWLAND, 2008; BOHANNON et al., 2017).

Regarding the performance in virtual games, there was a gradual improvement, spontaneously using cognitive strategies. This type of strategy can potentiate motor gains by leading the child to reflect on their performance and think about plans, as recommended in Cognitive-Motor Therapy (ARAÚJO, 2010). The combination of cognitive strategies and virtual training can be productive, increasing the potential for generalization of gains, which should be investigated in future studies.

The limitations of this study are inherent in the study cases, as only one child was investigated, but standardized procedures were followed, and relevant data were collected to plan future studies. One of the obstacles faced was the difficulty in choosing games due to poor description in studies using VR. For this reason, the choice of games occurred through detailed functional analysis of the activities of interest to the child, which enabled greater involvement and motivation during intervention sessions and allowed to address more directly and specifically the child's demands.

Another difficulty was to find candidates eligible to participate in the study that met all inclusion criteria.

Although the project was announced in various ways, only three candidates appeared, suggesting ignorance of the DCD or the use of VR as a means of intervention. The external examiner's evaluation should be improved. It would be interesting to use a standardized resource to quantify performance on specific tasks in the real environment. Another important improvement would be to engage teachers. Regular and Physical Education teachers in research would allow evaluating the generalization of strategies used in games in different contexts.

The improvements observed in motor and task performance are consistent with studies on the use of Wii® in children with coordination difficulties, in which dynamic balance, aerobic capacity, and agility improvement and the transference of VR skills to real contexts were improved (SMITS-ENGELSMAN; JELSMA; FERGUSON, 2017; BONNEY et al., 2017). However, parents or therapists should monitor the use of electronic games to prevent inappropriate use from reinforcing a sedentary lifestyle (SMITS-ENGELSMAN et al., 2018).

Improving children's performance in virtual games and reports of better participation in ball games with peers opens the way for the use of VR with movement games as a new intervention option for children with DCD. However, the generalization of results is limited because it is a case study.

5 Conclusion

The knowledge of children with DCD for occupational therapists and physical therapists is increasing every day, relevant to explore new approaches to functional improvement in this population. The use of games usually used in the child's daily life as a therapeutic resource can increase adherence and commitment to his treatment (HOWIE et al., 2017), and may facilitate the generalization of learned strategies since the activities used in therapy interest and motivate the child (SMITS-ENGELSMAN et al., 2018). The use of Microsoft Kinect® games seemed to positively influence the motor and functional performance of a child with DCD, but further studies are needed with a larger number of children, and the method used in this study, the discussion and its limitations may be the basis for further research.

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Author's Contributions

Joyce Cristina Cândido Soares and Bárbara Letícia Costa de Moraes participated in the study design, data acquisition and interpretation, and writing of the text. Clarissa Cardoso dos Santos Couto Paz and Lívia de Castro Magalhães actively participated in the orientation of the authors mentioned above and in the critical review of the study. All authors approved the final version of the text.

Notes

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