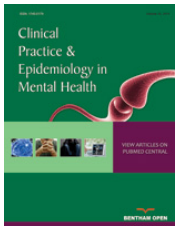
1745-0179/20

Send Orders for Reprints to reprints@benthamscience.net



Clinical Practice & Epidemiology in Mental Health

Content list available at: https://clinical-practice-and-epidemiology-in-mental-health.com

REVIEW ARTICLE

Exergames for Children and Adolescents with Autism Spectrum Disorder: An Overview

João L. Lima[1], Glaciane Axt[1], Diogo S. Teixeira[2], Diogo Monteiro[3,4,*], Luis Cid[3,4], Tetsuya Yamamoto[5], Eric Murillo-Rodriguez[6] and Sergio Machado[1]

[1]*Laboratório de Neurociência da Atividade Física, Programa de Pós-graduação em Ciências da Atividade Física, Universidade Salgado de Oliveira (UNIVERSO), Niterói, RJ, Brazil*

[2]*Faculty of Physical Education and Sport, ULHT, Lisbon, Portugal*

[3]*Research Centre in Sports, Health and Human Development, CIDESD, Vila Real, Portugal*

[4]*Sport Science School of Rio Maior, Polytechnique Institute of Santarém, Rio Maior, Portugal*

[5]*Graduate School of Technology, Industrial and Social Sciences, Tokushima University, Tokushima, Japan*

[6]*Laboratorio de Neurociencias Moleculares e Integrativas, Escuela de Medicina, División Ciencias de la Salud, Universidad Anáhuac Mayab, Mérida, Mexico*

Abstract: Autistic Spectrum Disorder (ASD) is a complex neurodevelopmental disorder associated with various etiologies and characterized by deficits in social interaction, emotional reciprocity, communication, motor skills and cognitive functions. Studies have proposed that limited levels of physical activity and late motor skills and fitness, particularly in children and adolescents with ASD, may accentuate social and emotional deficits. In view of this, exergames, which are active video-games, can be considered a low-cost and safe type of exercise for children and adolescents with ASD, since they are more enjoyable than ordinary physical activities, influencing on treatment adherence. Thus, our study aims to evidence the effects of exergames on physical fitness, cognitive functions, and repetitive behaviors in children and adolescents with ASD. Despite the small number of studies investigating the effects of exergames as new strategy in children and adolescents with ASD, results suggest exergames as potential tool for the treatment of children and adolescents with ASD for improvement in physical fitness, cognitive functions and repetitive behavior. Our review pointed towards the importance of exergames for children and adolescents with ASD. Despite few studies conducted about this issue, we can consider exergames a potential tool to increase physical fitness, cognitive functions and to decrease repetitive behavior in children and adolescents with ASD. Moreover, health professionals should be careful when attempting to help this population, because the current literature is unclear yet about the improvement of ASD features through exergames.

Keywords: Autism spectrum disorder, ASD, Cognitive functioning, Exergames, Physical exercise, Repetitive behavior.

Article History	Received: August 28, 2019	Revised: December 22, 2019	Accepted: December 27, 2019

1. INTRODUCTION

Autistic Spectrum Disorder (ASD) is a complex neurodevelopmental disorder associated with various etiologies and characterized by deficits in social interaction, emotional reciprocity, communication, motor skills and cognitive functions, accompanied by impairment of imagination, restricted and repetitive interests [1 - 3]. The incidence of autism has risen sharply over the years to approximately 1 child with ASD out of 160 in the world [4], and in the United States, there is a prevalence of 1 in 68 children born [5, 6]. Studies already showed that limited physical activity levels and late motor skills and fitness, mainly in children and adolescents with ASD, can emphasize social and emotional deficits. These conditions can lead to higher incidence of overweight and obesity and health complications associated with ASD, compared to typical developing young people [7, 8].

In this context, previous studies have documented that children with ASD may have a higher incidence of obesity than children without ASD [7, 9], and obesity among children with ASD may have an even more negative impact on social motivation or motivation to participate in structured physical activities with other children [10]. Due to this scenario, the impact of physical inactivity on this population is critical and new strategies to promote functionality and quality of life for people with ASD are needed, especially through the increase of physical activity levels [7 - 10].

Interventions aimed at increasing self-perceived motor

* Address correspondence to this author at the Sport Science School of Rio Maior, Polytechnique Institute of Santarém, Rio Maior, Portugal; Research Centre in Sports, Health and Human Development, CIDESD, Portugal;
Tel: 00351 243 999 280; E-mail: diogomonteiro@esdrm.ipsantarem.pt

skills, cognitive functioning and repetitive behavior of individuals with ASD through physical exercise have been the focus of some studies [11 - 15]. Physical exercise is known to provide numerous benefits for children [16], including but not limited to ASD-specific behaviors, such as the reduction of repetitive behaviors [11] and improvement of cognitive functions [11] and physical fitness [12, 13, 15]. However, it is known that the traditional methods of exercise have limitations regarding the adherence of people with ASD, which can make additional treatment difficult. Thus, it is essential to work on new strategies to provide physical exercise for this population, and exergames seem to be a potential tool to reach high adherence rate, since it is able to overcome the limiting barriers through playfulness [17, 18].

Given that, exergames, which are games characterized by the physical interaction of participants with video games, can be considered a low-cost and safe type of exercise for people with ASD, since they are more enjoyable and playful than common physical activities, which may influence treatment adherence [17, 18]. The most commonly used consoles are the Xbox Kinetic, Nintendo Switch, and PlayStation Move, and the most common games are sports (Kinetic Sports), dance (Just Dance), and adventure (Kinetic Adventure) games [19 - 21]. These games have been mentioned as a relevant way to promote exercise for the elderly [19], individuals with hypertension [22], Parkinson's disease [23], intellectual disability [21], and other neurological disorders [24]. Consequently, exergames are a great alternative for promoting physical exercise for ASD [25, 26]. For example, a previous study [11] showed that the effects of a single 20-minute exergame bout were able to generate a significant decrease in repetitive behavior as well as improved cognitive performance (*e.g*. working memory and inhibitory control) of students with ASD compared with the control group (watched TV).

According to the increased interest in the effects of exergaming on individuals with ASD, this review was conducted to review the current evidence from existing literature on physical fitness, cognitive functions and repetitive behavior in children with ASD. Therefore, we searched the Pubmed/Medline, ISI Web of Knowledge and PEDro databases, in the English language and with the keywords: autism spectrum disorder, ASD, exergames, active video games, exergaming. From the references found in the electronic databases, a manual search of these references was also performed.

2. EXERGAMES: EVIDENCE OF A NEW STRATEGY OF TREATMENT IN CHILDREN AND ADOLESCENTS WITH ASD

Despite few studies examining the effects of exergames as a new strategy in children and adolescents with ASD, findings indicate exergames as a potential tool to treat children and adolescents with ASD [11 - 15], more specifically, physical fitness, cognitive functions and repetitive behavior.

Anderson-Hanley *et al*. [11] were the first researchers to examine the acute effects of exergames in adolescents with ASD. In this study, the authors conducted two pilot studies. The first pilot study, in a crossover design, examined the behavioral and cognitive benefits of exergames in 12 ASD children, where the participants performed an acute bout of Dance Dance Revolution (DDR) for 20 min and a control task in different days. In the second pilot study, ten additional youths executed an acute bout of cyber cycling for 20 min. Both exergames conditions, when compared to control condition, showed a significant reduction in repetitive behaviors and an improvement in executive functions. In another study, Edwards *et al*. [14] investigated whether the exergames practice can increase the actual and perceived object control skills of 11 children with ASD in comparison to 19 TD matched children. The ASD group improved significantly in self-perceived motor skills; however, the use of active video game as a play-based intervention may not provide enough opportunity for children to perform the correct movement patterns to influence skill. However, playing such games may influence perceptions of skill acquisition in children with ASD, which could improve motivation to participate in physical activities.

Subsequently, two similar case-control studies were conducted [12, 13]. Both studies compared the energy expenditure among different exergames and verified which one leads to the greatest amount of time classified as “moderate to vigorous”. In the study of Getchell *et al*. [12], individuals performed 2 to 3 sessions of exergames for 20 min during 2 weeks and both groups expended similar amounts of kilcalories in all activities, except for Wii Fit, in which the ASD group expended significantly more kilocalories. For the ASD group, EE was greatest in running, followed by walking, Dance Dance Revolution, Wii Fit, and Wii Sport. Walking, running, and Dance Dance Revolution all had at least 75% of the total time spent in moderate to vigorous intensity levels. In addition, Golden and Getchell [13] conducted an experiment where 4 sessions of exergames were performed by each group. ASD individuals spent 76.25% of their time in moderate-to-vigorous physical activity during active video games compared to 99.4% during paced walking and 2.31% in a sedentary video game. Active video game can increase their overall physical activity levels, although AVG should not be seen as a replacement for walking or other forms of PA. Similarly, Dickinson and Place [15] investigated the effects of an exergaming protocol on Eurofit fitness test and body mass index of ASD children. They found a statistically significant improvement on all tests other than flexibility in favor of exergames group compared to the control group (Table **1**).

Little is known about the relationship between the improvement of cognitive functioning and repetitive behavior in ASD, with the practice of physical exercise, such as exergames [27]. It is well-known that physical exercise is promising for reducing repetitive behaviors in children with ASD, and improving cognitive functioning, especially executive function, in healthy individuals [28]. The neurophysiological mechanisms responsible for their improvement in cognitive functioning through physical exercise are not yet fully understood. For example, immediate and long-term improvements in cerebral blood flow lead to a better supply of oxygen and nutrients, as well as the removal of brain byproducts [29]. In addition, studies have examined the chronic effects of exercise on brain health and cognitive

functioning by examining biomarkers, such as brain-derived neurotrophic growth factor, and neuroimaging studies, looking at structural changes in various brain areas after exercise, such as the anterior cingulate cortex [30].

It is possible that physical exercise in children and adolescents with ASD combined with improved executive functioning may indicate a mechanism behind the reduction in repetitive behaviors. Early evidence showed that children with ASD reduced their self-stimulating behaviors in the classroom after physical exercise [31]. Similarly, Kern *et al*. [32] verified the influence of jogging, ball-playing, and academic response to self -stimulation in children with ASD, where only jogging reduced self-stimulating behavior after the end of the study. Similarly, Rosenthal and Mitchell [33] found that 20 minutes of running compared to no exercise promoted a reduction in classroom self-stimulating behaviors in children with ASD. These findings indicate that decreased self-stimulating behaviors may be the result of fatigue, however, this theory has been criticized because studies have shown that exercise not only decreases repetitive behaviors, but also has positive effects on the attention and academic response of children with ASD [33].

Table 1. Study design and key findings.

Author(s), year, Country	Study Design	Sample Size (attrition %)	Age (Range) M (SD)	Exposure	Platform	Key Findings
Anderson-Hanley *et al*. [11], USA	Pre–post test: two independent pilot studies	N = 24 (8.3%); two participants dropped out	Pilot I: 10–18 years 14.8 (2.7) Pilot II: 8–21 years 13.2 (3.8)	Pilot I: one session for 20 minutes Pilot II: one session for 20 minutes	DDR; Cybercycling	Participants in both exergaming groups indicated significant improvement in behavioral control and executive functions including working memory, task-switching capacity, and inhibition.
Golden and Getchell [12], USA	Case-control study	N = 19 (10.5%); ASD = 9; TD= 8; 2 participants dropped out.	ASD: 10.5 (0.88) TD: 10.46 (1.22)	Four sessions in total, 20 minutes for each session.	Xbox Kinect	Participants with ASD spent 76% of time in MVPA during exergaming compared with 99% during walking. Although exergaming may not replace walking and other forms of physical activities, it can increase overall physical activity levels.
Getchell *et al.* [13], USA	Case-control study	N = 30; ASD = 15; TD= 15; No participants dropped out.	ASD: 17.5 (2.4) TD: 17.23 (4.1)	Two or three sessions per week over a 2-week period, 20 min for each session.	Nintendo Wii Sport; Wii Fit; DDR	Expended energy in ASD and TD groups was not significantly different in activities, such as running, walking, and exergaming. The ASD group had over 75% of exergaming time in MVPA when playing DDR.
Edwards *et al.* [14], Australia	Case-control study	N = 30; ASD = 15; TD= 15; No participant dropped out.	6–10 years TD: 7.89 (1.45) ASD: 7.64 (1.12)	TD: one session per week for 6 weeks, 50 min for each session. ASD: three sessions per week for 2 weeks, 45–60 min per session	Xbox Kinect	Exergames may not provide adequate opportunities to develop actual motor skills for ASD and TD groups. But self-perceived skills significantly increased after the exergaming intervention.

(Table 1) contd.....

Dickinson and Place [15], England	RCT	N = 100 Intervention = 50 Control = 50 No participant dropped out.	5–15 years	15-minute session, three sessions per week for three academic semesters.	Nintendo Wii	Benefits of exergaming intervention were identified in participants' fitness levels, such as cardiorespiratory function, explosive strength, speed, agility, and abdominal strength and endurance.

Note: ASD: Autism Spectrum Disorder; DDR: … ; MVPA: … ; Randomized Controlled Trial; TD: Typically Developing.

Exercise seems to promote health benefits for children and adolescents with ASD [16, 27, 28]. However, several studies indicate the existence of challenges for the physical exercise practice of children and adolescents with ASD [17, 18]. For example, the inability or difficulty to perform complex movements may impair their adherence to exercise [17]. It was observed that autists were more interested in participating in activities with exergames as recreational activity [18]. Therefore, exergames may be a potential intervention tool in promoting physical activity for children and adolescents with ASD [11 - 15]. Some positive features of exergames include fun, interaction with other people, and whole-body movements. These features can encourage lifelong involvement in moderate to vigorous physical activity. Corroborating the above findings, participants using Xbox Kinect spent 76% to 94% of their time playing at moderate to vigorous intensity [13, 34], within the ACSM guidelines, which recommend at least 150 minutes of moderate-intensity aerobic exercise per week [35]. Thus, an exergame protocol of three to four sessions of one hour per week will lead the subject to be within the recommended levels of physical activity.

The evidence summarized in this review shows only one randomized controlled trial in the literature, and it reported no mental health benefits, only fitness levels improved. The other studies were case-control studies, which according to research guidelines provide very low evidence of therapeutic efficacy in contrast to randomized control trails that provide level 1 or 2 of evidence. Thus, this is a key point to be taken into account during evidence interpretation.

3. FUTURE DIRECTIONS ON EXERGAMES FOR CHILDREN AND ADOLESCENTS WITH ASD

Regarding future perspectives on the use of exergames with children and adolescents with ASD, an important factor is the improvement in self-perceived skills performance [14]. It is suggested that for a better perception of motor skills, there should be a higher motivational level for the practice of physical exercise. Despite the positive results associated with the use of exergames, nothing was observed regarding the development of motor skills and emotional regulation in the literature. Therefore, prescribing exergames to children and adolescents with ASD should be cautious about the expectation of obtaining benefits for emotional regulation and/or motor skills development. The study by Edwards *et al*. [14] differs from three other studies with low methodological quality [36 - 38], which showed minor changes in emotional regulation as well as behavior management [36 - 38]. Contrary to these studies, Edwards *et al*. [14] did not observe improvement of social behavior or expressions of positive affection after video game intervention. Findings can be explained due to the dose-dependent effects of the interventions applied. It seems that the duration of the intervention applied in the study by Edwards *et al*. [14] was not long enough to produce significant effects on emotional regulation. Another point to note is that exergames may not offer adequate opportunities for the correct execution of targeted skills. Therefore, further integrative studies are needed to further advance towards how to impact motor skill development and emotional regulation using exergames in children and adolescents with ASD.

CONCLUSION

This review showed the importance of exergames for children and adolescents with ASD. Despite we have found few studies about that issue, exergames can be considered a potential tool to improve physical fitness, cognitive functions and to reduce repetitive behavior in children and adolescents with ASD. In addition, due to the lack of sufficient evidence about the improvement of ASD features through exergames, health professionals should be careful when attempting to help this population. Just one randomized controlled trial investigated this issue, a significant limitation since we need rigorous studies to provide a better understanding of the effects of exergames for children and adolescents with ASD. According to these limitations, future research should strive to provide rigorous evidence established by randomized controlled trials, report effect sizes of treatment, and investigate longitudinal effects of exergames.

CONSENT FOR PUBLICATION

Not applicable.

FUNDING

This study was supported by a grant from Carlos Chagas Foundation for the Research Support in the State of Rio de Janeiro (FAPERJ), Young Scientists from the State of Rio de Janeiro, E -26/203.295/2017.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

[1] American psychiatric association. Diagnostic and statistical manual of mental disorders. 2013.

[2] Kaufmann WE. DSM-5: The new diagnostic criteria for autism

spectrum disorders. Research Symposium-Autism Consortium, Boston, MA.

[3] Klin A, Lang J, Cicchetti DV, Volkmar FR. Brief report: Interrater reliability of clinical diagnosis and DSM-IV criteria for autistic disorder: Results of the DSM-IV autism field trial. J Autism Dev Disord 2000; 30(2): 163-7. [http://dx.doi.org/10.1023/A:1005415823867] [PMID: 10832781]

[4] World Health Organization. Autism Spectrum Disorders & Other Developmental Disorders. Geneva, Switzerland: World Health Organization 2013.

[5] Christensen DL, Bilder DA, Zahorodny W, *et al.* Prevalence and characteristics of autism spectrum disorder among 4-year-old children in the autism and developmental disabilities monitoring network. J Dev Behav Pediatr 2016; 37(1): 1-8. [http://dx.doi.org/10.1097/DBP.0000000000000235] [PMID: 26651088]

[6] Baio J, Wiggins L, Christensen DL, *et al.* Prevalence of autism spectrum disorder among children aged 8 years-autism and developmental disabilities monitoring network, 11 sites, United States, 2010. MMWR Surveill Summ 2014; 63: 1-21.

[7] Curtin C, Jojic M, Bandini LG. Obesity in children with autism spectrum disorder. Harv Rev Psychiatry 2014; 22(2): 93-103. [http://dx.doi.org/10.1097/HRP.0000000000000031] [PMID: 24614764]

[8] Xia W, Zhou Y, Sun C, Wang J, Wu L. A preliminary study on nutritional status and intake in Chinese children with autism. Eur J Pediatr 2010; 169(10): 1201-6. [http://dx.doi.org/10.1007/s00431-010-1203-x] [PMID: 20422215]

[9] Broder-Fingert S, Brazauskas K, Lindgren K, Iannuzzi D, Van Cleave J. Prevalence of overweight and obesity in a large clinical sample of children with autism. Acad Pediatr 2014; 14(4): 408-14. [http://dx.doi.org/10.1016/j.acap.2014.04.004] [PMID: 24976353]

[10] Zuckerman KE, Hill AP, Guion K, Voltolina L, Fombonne E. Overweight and obesity: Prevalence and correlates in a large clinical sample of children with autism spectrum disorder. J Autism Dev Disord 2014; 44(7): 1708-19. [http://dx.doi.org/10.1007/s10803-014-2050-9] [PMID: 24488158]

[11] Anderson-Hanley C, Tureck K, Schneiderman RL. Autism and exergaming: effects on repetitive behaviors and cognition. Psychol Res Behav Manag 2011; 4: 129-37. [http://dx.doi.org/10.2147/PRBM.S24016] [PMID: 22114543]

[12] Getchell N, Miccinello D, Blom M, Morris L, Szaroleta M. Comparing energy expenditure in adolescents with and without autism while playing Nintendo Wii games. Games Health J 2012; 1(1): 58-61. [http://dx.doi.org/10.1089/g4h.2011.0019] [PMID: 26196433]

[13] Golden D, Getchell N. Physical activity levels in children with and without autism spectrum disorder when playing active and sedentary Xbox kinect videogames. Games Health J 2017; 6(2): 97-103. [http://dx.doi.org/10.1089/g4h.2016.0083] [PMID: 28375644]

[14] Edwards J, Jeffrey S, May T, Rinehart NJ, Barnett LM. Does playing a sports active video game improve object control skills of children with autism spectrum disorder? J Sport Health Sci 2017; 6(1): 17-24. [http://dx.doi.org/10.1016/j.jshs.2016.09.004] [PMID: 30356508]

[15] Dickinson K, Place M. A randomised control trial of the impact of a computer-based activity programme upon the fitness of children with autism. Autism Res Treat 2014; 2014419653. [http://dx.doi.org/10.1155/2014/419653] [PMID: 25400946]

[16] Sowa M, Meulenbroek R. Effects of physical exercise on autism spectrum disorders: A meta-analysis. Res Aut Spec Dis 2012; 6: 46-57. [http://dx.doi.org/10.1016/j.rasd.2011.09.001]

[17] Must A, Phillips S, Curtin C, Bandini LG. Barriers to physical activity in children with autism spectrum disorders: Relationship to physical activity and screen time. J Phys Act Health 2015; 12(4): 529-34. [http://dx.doi.org/10.1123/jpah.2013-0271] [PMID: 25920014]

[18] Bossink LWM, van der Putten AA, Vlaskamp C. Understanding low levels of physical activity in people with intellectual disabilities: A systematic review to identify barriers and facilitators. Res Dev Disabil 2017; 68: 95-110. [http://dx.doi.org/10.1016/j.ridd.2017.06.008] [PMID: 28750208]

[19] Chao YY, Scherer YK, Montgomery CA. Effects of using Nintendo Wii™ exergames in older adults: A review of the literature. J Aging Health 2015; 27(3): 379-402. [http://dx.doi.org/10.1177/0898264314551171] [PMID: 25245519]

[20] O'Donovan C, Hirsch E, Holohan E, McBride I, McManus R, Hussey J. Energy expended playing Xbox Kinect™ and Wii™ games: A preliminary study comparing single and multiplayer modes. Physiotherapy 2012; 98(3): 224-9. [http://dx.doi.org/10.1016/j.physio.2012.05.010] [PMID: 22898579]

[21] Silva V, Campos C, Sá A, *et al.* Wii-based exercise program to improve physical fitness, motor proficiency and functional mobility in adults with Down syndrome. J Intellect Disabil Res 2017; 61(8): 755-65. [http://dx.doi.org/10.1111/jir.12384] [PMID: 28585394]

[22] Monteiro-Junior RS, Figueiredo LF, Conceição I, *et al.* Hemodynamic responses of unfit healthy women at a training session with nintendo wii: A possible impact on the general well-being. Clin Pract Epidemiol Ment Health 2014; 10: 172-5. [http://dx.doi.org/10.2174/1745017901410010172] [PMID: 25614754]

[23] Ribas CG, Alves da Silva L, Corrêa MR, Teive HG, Valderramas S. Effectiveness of exergaming in improving functional balance, fatigue and quality of life in Parkinson's disease: A pilot randomized controlled trial. Parkinsonism Relat Disord 2017; 38: 13-8. [http://dx.doi.org/10.1016/j.parkreldis.2017.02.006] [PMID: 28190675]

[24] Mura G, Carta MG, Sancassiani F, Machado S, Prosperini L. Active exergames to improve cognitive functioning in neurological disabilities: A systematic review and meta-analysis. Eur J Phys Rehabil Med 2018; 54(3): 450-62. [PMID: 29072042]

[25] Graves LE, Ridgers ND, Williams K, Stratton G, Atkinson G, Cable NT. The physiological cost and enjoyment of Wii Fit in adolescents, young adults, and older adults. J Phys Act Health 2010; 7(3): 393-401. [http://dx.doi.org/10.1123/jpah.7.3.393] [PMID: 20551497]

[26] Costa MTS, Vieira LP, Barbosa EO, *et al.* Virtual reality-based exercise with exergames as medicine in different contexts: A short review. Clin Pract Epidemiol Ment Health 2019; 15: 15-20. [http://dx.doi.org/10.2174/1745017901915010015] [PMID: 30972138]

[27] Lang R, *et al.* Physical exercise and individuals with autism spectrum disorders: A systematic review. Res Autism Spectr Disord 2010; 4: 565-76. [http://dx.doi.org/10.1016/j.rasd.2010.01.006]

[28] Pan CY, Chu CH, Tsai CL, Sung MC, Huang CY, Ma WY. The impacts of physical activity intervention on physical and cognitive outcomes in children with autism spectrum disorder. Autism 2017; 21(2): 190-202. [http://dx.doi.org/10.1177/1362361316633562] [PMID: 27056845]

[29] Machado S, Paes F, Ferreira Rocha NB, *et al.* Neuroscience of exercise: Association among neurobiological mechanisms and mental health. CNS Neurol Disord Drug Targets 2015; 14(10): 1315-6. [http://dx.doi.org/10.2174/1871527315999151119122238] [PMID: 26585654]

[30] Wegner M, Helmich I, Machado S, Nardi AE, Arias-Carrion O, Budde H. Effects of exercise on anxiety and depression disorders: review of meta- analyses and neurobiological mechanisms. CNS Neurol Disord Drug Targets 2014; 13(6): 1002-14. [http://dx.doi.org/10.2174/1871527313666140612102841] [PMID: 24923346]

[31] Kern L, Koegel RL, Dyer K, Blew PA, Fenton LR. The effects of physical exercise on self-stimulation and appropriate responding in autistic children. J Autism Dev Disord 1982; 12(4): 399-419. [http://dx.doi.org/10.1007/BF01538327] [PMID: 7161239]

[32] Kern L, Koegel RL, Dunlap G. The influence of vigorous *versus* mild exercise on autistic stereotyped behaviors. J Autism Dev Disord 1984; 14(1): 57-67. [http://dx.doi.org/10.1007/BF02408555] [PMID: 6706897]

[33] Rosenthal-Malek A, Mitchell S. Brief report: the effects of exercise on the self-stimulatory behaviors and positive responding of adolescents with autism. J Autism Dev Disord 1997; 27(2): 193-202. [http://dx.doi.org/10.1023/A:1025848009248] [PMID: 9105970]

[34] Jozkowski AC, Lichtenwalner MA, Cermak SA. Case studies on the feasibility of exergaming to enhance physical activity in youths on the autism spectrum. Good Autism Practice 2016; 17: 24-36. [GAP].

[35] Riebe D, Franklin BA, Thompson PD, *et al.* Updating **ACSM**'s Recommendations for Exercise Preparticipation Health Screening. Med Sci Sports Exerc 2015; 47(11): 2473-9. [http://dx.doi.org/10.1249/MSS.0000000000000664] [PMID: 26473759]

[36] Hilton CL, Cumpata K, Klohr C, *et al.* Effects of exergaming on executive function and motor skills in children with autism spectrum disorder: a pilot study. Am J Occup Ther 2014; 68(1): 57-65. [http://dx.doi.org/10.5014/ajot.2014.008664] [PMID: 24367956]

[37] Caro K, Tentori M, Martinez-Garcia AI, Alvelais M. Using the FroggyBobby exergame to support eye-body coordination

development of children with severe autism. Int J Hum Comput Stud 2017; 105: 12-27.
[http://dx.doi.org/10.1016/j.ijhcs.2017.03.005]

[38] Chung PJ, Vanderbilt DL, Soares NS. Social behaviors and active videogame play in children with autism spectrum disorder. Games Health J 2015; 4(3): 225-34.
[http://dx.doi.org/10.1089/g4h.2014.0125] [PMID: 26182068]