International Journal of EXERCISE SCIENCE

Technical Note

Efficacy of a 6-week Novel Exergaming Intervention Guided by Heart Rate Zones on Aerobic Performance in Children with Fetal Alcohol Spectrum Disorder and Attention-deficit/Hyperactivity Disorder: A Feasibility Study

TRENT YAMAMOTO*, BILAL PANDIT*, MICHAEL VIGGIANO*, KRISTIN DANIELS*, MITCHELL S. MOLOGNE*, DAVID GOMEZ‡, and BRETT A. DOLEZAL‡

Airway & UCFit Digital Health-Exercise Physiology Research Laboratory, David Geffen School of Medicine, University of California-Los Angeles, Los Angeles, CA, USA

*Denotes undergraduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 16(3): 710-720, 2023. The purpose of this study was to determine the feasibility of a novel exergaming intervention guided by heart rate zones for children and adolescents with fetal alcohol spectrum disorder (FASD) and attention-deficit/hyperactivity disorder (ADHD). Eight study participants (6 females, 2 males, mean age= 11.4±1.4 years old) participated twice weekly over six weeks to complete twelve multimodal exergaming sessions. Participants significantly improved 6MWT from baseline to week 6 (575.4±55.0 m to 732.8±58.9 m; P<0.01), which conferred a 31% improvement in estimated VO_{2max} (31.5±5.5 ml/kg/min to 40.9±5.9 ml/kg/min), respectively. There was an upward trend of the mean percentage of time spent in the intermediate HR zones over the course of the 6-week intervention. These findings may provide value to the field as they support the clinical utility and promising effects of cardiovascular improvement in children who engage in a compelling exergaming intervention. In doing so, this establishes a preliminary understanding of how to augment routine physical exercise through exergaming using visually targeted heart rate zones.

KEY WORDS: Exercise, FASD, ADHD, aerobic training

INTRODUCTION

Alcohol consumption during pregnancy can result in the development of Fetal Alcohol Spectrum Disorder (FASD) (34). FASD is diagnosed in the presence of distinctive facial abnormalities and growth deficiencies that manifest into a number of other physical, cognitive, and neurobehavioral impairments (19). According to a recent estimate, FASD is prevalent in 8 out of 1000 in the general population (21). A frequent comorbidity of FASD is attention-deficit/hyperactivity disorder (ADHD), as over 80% of children diagnosed with FASD also meet the diagnostic criteria for ADHD (12). Although pharmacologic stimulants are the primary treatment for ADHD, there is often relatively limited success (32), and with behavioral

interventions being comparatively ineffective long-term, alternative treatments are needed for these shortcomings.
Exercise presents a viable method of treatment for both ADHD and FASD. While recent research has primarily focused on addressing the cognitive deficits of FASD (16), relatively few studies have assessed its implications on cardiovascular health within these clinical populations. Exercise has been shown to result in upregulation of brain-derived neurotrophic factor in rodents (7), which plays an integral role in hippocampal functioning and long-term potentiation for learning, memory, synaptic plasticity, neurogenesis, and neuroprotection (24). Voluntary aerobic exercise has also shown a positive correlation with corpus callosum growth, which can improve overall neural signaling (27). Exercise interventions have been shown to reduce both the risk and trajectory of cardiovascular disease, hypertension, and blood pressure in adults and even starting in childhood, respectively (22). Given that children with an ADHD diagnosis are significantly less likely to meet the Academy of American Pediatrics' daily standard of 60 minutes of physical activity (26), an exercise intervention may be an optimal course of treatment.

While physical activity can provide these benefits in a sustainable manner, adherence to regular exercise, especially among children, can be hindered when exercise is considered monotonous, too rigorous, and/or unenjoyable (17). This perception is heightened with children of ADHD and FASD; thus, it is essential for the exercise mode to be both engaging and fun in order to have the greatest impact.

The emerging development of 'exergaming,' digital gaming that incorporates bodily movements, can ameliorate some of these aforementioned barriers as demonstrated by its fast-growing interest from children around the world. Exergames encompass dual tasks which stimulate the brain to simultaneously generate cognitive and motor responses that require cortical and subcortical circuitry activation (1). Research has shown that participation in exergaming can improve physical activity levels for elementary school children over time (39). Moreover, among children with ADHD, multimodal exergaming interventions have demonstrated benefits in executive functioning and motor abilities (6). While these results are encouraging, there is a dearth of research on the use of exergaming interventions to improve cardiovascular performance in children with FASD and ADHD.

This study aimed to determine the efficacy and feasibility of using a novel exergaming intervention to improve cardiovascular measures of fitness in children with FASD and ADHD. With relatively few exergaming interventions at the disposal of clinicians, the potential of this novel platform warrants investigation into whether it can be an effective avenue of cardiovascular exercise training that confers significant health benefits in this population. We hypothesized that participants would improve their VO_{2max} and report that the exergaming intervention was enjoyable while physically challenging.

METHODS

Participants

A cohort of eight children (6 females, 2 males, mean age = 11.4 ± 1.4 years old) with Fetal Alcohol Spectrum Disorder (FASD) and Attention-Deficit /Hyperactivity Disorder (ADHD) were identified and recruited through the UCLA pediatric clinics and posted flyers. Children were included if they met inclusion criteria as follows: (1) aged between 8 to 17; (2) classified as FASD and ADHD diagnosed by a psychiatric physician, and (3) currently treated with or without pharmacotherapy. Exclusion criteria included: (1) significant medical diagnoses, including cardiovascular, pulmonary, musculoskeletal, or metabolic disorders that may limit the ability to exercise or increase the cardiovascular risk of exercising; (2) children with Intellectual Disability; (3) primary psychotic disorder; and (4) current suicidal ideation/plan. The racial composition of the cohort included one black male, one white male, one black female, two white females, two mixed race females, and one Asian female. All participants were being treated with the same pharmacotherapy for the past year and throughout the duration of the study. These medications did not have any documented effects on HR to our knowledge. Written consent was obtained from parents/caregivers of all participants prior to completing study procedures. The study was performed in accordance with the ethical standards of the Helsinki declaration and was approved by the Institutional Review Board. This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (30).

Protocol

This was a 6-week supervised, personalized exergaming program that took place at the UC Fit Digital Health – Exercise Physiology Research Laboratory on UCLA's campus as an afterschool program twice weekly, 50 minutes per session for a total of 12 sessions. All assessments and exergaming facilitators were administered and monitored by two trained research personnel under the direction of the lab director. Participants were asked to refrain from additional structured, vigorous activity for the course of the study.

Intervention: Described as a 'virtual playground', the Obie® (EyeClick Ltd, North America) exergaming platform included an interactive ceiling projector gaming console that casts one of over one hundred games to the floor, while advanced optical sensors allowed users to play with swipes, taps and gestures using their feet (Figure 1). The 10 ft by 10 ft projection area enabled children to participate within a large space of the gaming experience with the ability to run, jump, and move their extremities freely, allowing children to be engaged in a vast array of physical exercises. While many of these games were emotionally appealing and physically demanding, they could also be played cooperatively in pairs. The games for every intervention session were selected in advance and standardized by the research personnel. Half of the games were played cooperatively in a pair while the other half was played independently by the participant. The games for each respective session were the same for every participant. Some games lasted 3 min, others up to 5 min depending on the participant 'winning' the game. Irrespective, the total session time was always 50 min.

Figure 1: Animation of Obie® gameplay from the side of the projection area using a 2D ceiling projector (left). Fast Feet™ game, one of the more popular exergames amongst study participants. (right).

The exergaming intervention followed underpinnings of exercise physiology principles of progressive overload training – where variables like game type, minutes played, rest intervals and game sequence – could be altered within and between subsequent sessions to be more challenging physically. Periodically these were coupled with added resistance (e.g., weighted vests and hand-held implements) for participants as they matriculated through the 6-weeks of 12 sessions. For an objective measure of exercise intensity, a forearm-worn optical heart rate monitor (Rhythm+™ 2.0, Scosche Industries, Oxnard, California) was used to monitor % time in heart rate (HR) zones. This was synchronously and graphically displayed using a fitness app (iCardio®) via Bluetooth to an iPad mounted on a stand to be clearly viewed. Heart rate zones were arbitrarily defined in 20 bpm ranges so that <109 bpm = Zone 1, 110-129 bpm = Zone 2, 130-149 bpm = Zone 3, 150-169 bpm = Zone 4, and >170 bpm = Zone 5 (Figure 2). This enabled both participant and research facilitator real-time feedback and subsequent adjustments in gameplay so that higher heart rate zones (i.e., low-to-moderate-to-vigorous intensities) were encouraged throughout both intra-sessions and between sessions.

Figure 2: Sample screenshot of iCardio® app heart rates (left) and % time in heart rate zone after a 1-hr session of Obie® gameplay.

Familiarization: In the first visit to the lab, participants (i) were instructed on how the device functioned, (ii) were demonstrated on how to play Obie, and (iii) played an array of different exergames for 3-5 min each over an hour period to become acquainted with gameplay. Thereafter, they were measured for the following baseline and post-measures:

Anthropometry: Body mass was measured in duplicate on a calibrated medical scale (accuracy ± 0.1kg), and height was determined using a precision stadiometer (Seca, Hanover, MD, USA; accuracy ± 0.01 m). For mass, participants removed unnecessary clothing and accessories. For height, participants were instructed to stand as straight as possible with unshod feet flat on the floor.

Six Minute-Walk-Test (6MWT): The six-minute walk test has become a widely used reliable and valid measure for assessing functional exercise capacity at a submaximal level from pediatric to older populations (20). It is inexpensive, safe, and self-paced assessment tool for populations such as this cohort (41). Conversely, there is still debate concerning the minimal age for performing a cardiopulmonary exercise test to determine the VO_{2max}, the gold standard measure of aerobic fitness, as there are large interindividual differences and children may not be able to understand instructions and cooperate according to strict instructions (40). Therefore, we chose the 6MWT which was conducted according to standardized procedures provided by the American Thoracic Society (4). Briefly, it was conducted in an indoor corridor, with the course marked by two cones 30 m apart. The research examiner demonstrated the walking form and provided notifications of foul (i.e., both feet off the ground) prior to the test. After the participants quietly rested seated for 5 minutes, they were asked to walk at their maximal pace to cover as much ground as possible over a 6-minute period. Standardized encouragement ("keep going," "you are doing well," and "everything is going fine") was provided by the examiner during the test; other words were not allowed. The walking distance covered in meters after 6 min was recorded. The following sex, age and weight adjusted prediction equation for VO_{2max} estimation was also calculated and recorded (18):

VO_{2max} estimation = 61.1 – 11.1 x sex (male=1, female=2) – 0.4 x age – 0.2 x weight – 0.2 x (distance walked x 10^{-1}).

Statistical Analysis

Baseline and post-6-week data are reported with descriptive statistics (presented as mean (SD)). Changes in the primary and secondary outcome variables were assessed by dependent t-tests. Statistical significance was accepted at $p<0.05$.

RESULTS

Eight study participants with an average age of 11.4±1.4 yr (ranging from 9 to 13 years old), weight 36.2±3.1 kg, height 141±2.1 cm and a BMI of 21.5±3.9 kg/m^2 successfully completed the 6-week training program without injuries or serious adverse events. However, three participants required an additional 1-2 weeks to complete the program due to minor illness or vacation. Participants significantly improved 6MWT from baseline to week 6 (575.4±55.0 m to 732.8±58.9 m; $P<0.01$) which conferred a 31% improvement in estimated VO_{2max} (31.5±5.5 ml/kg/min to 40.9±5.9 ml/kg/min), respectively.

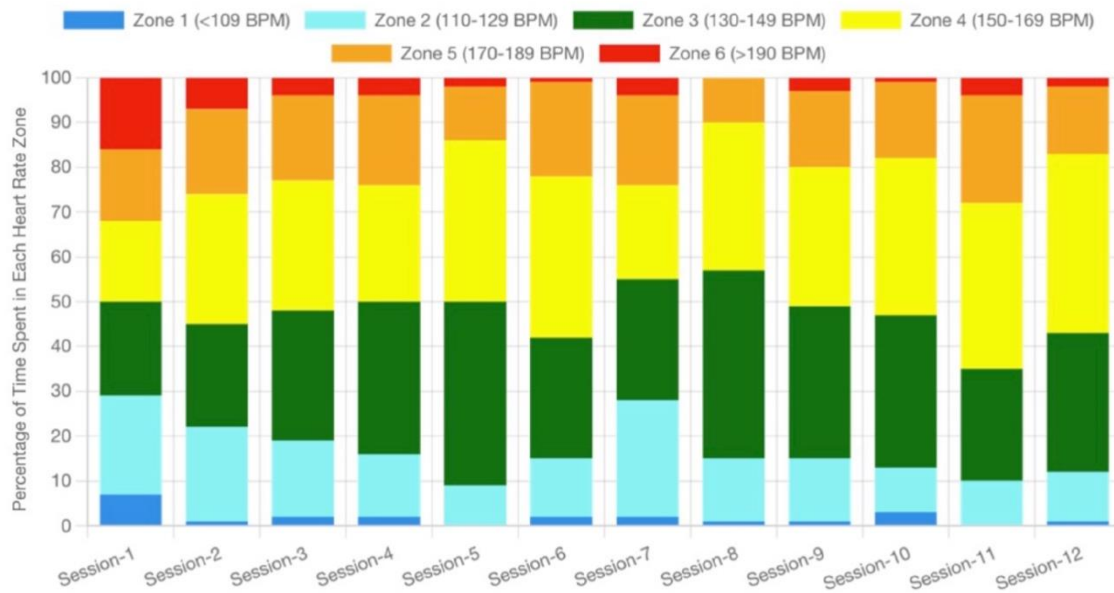

Figure 3: Mean percentage of time spent in each of the six heart rate zones during each of the twelve sessions for all eight participants.

As shown in Figure 3, there was an upward trend of the mean percentage of time spent in the intermediate HR zones (3 and 4). The mean percentage of time spent in HR zones 3 and 4 through sessions 7-12 was approximately 10% higher than that of the first six sessions (38.6% versus 29.1%, respectively). Conversely, the mean percentage of time spent in the lower HR zones (1 and 2) abated over the same span, as the last six sessions of the intervention yielded a 17% decrease of time spent in these HR zones compared to the first six sessions (7.8% versus 9.2%, respectively). Time spent in the highest HR zones (5 and 6) remained relatively unchanged.

DISCUSSION

The benefits of exercise, while well documented for other disease models (31,11), have not been examined in the context of exergaming with children diagnosed with FASD and ADHD. To our knowledge, our study is among the first to examine the effects of a long-term exergaming intervention on cardiovascular measures of fitness in children with FASD and ADHD. Accordingly, this study provided a preliminary understanding of the efficacy that exergaming platforms have as an adjunct intervention for these clinical populations.

Over the six-week training period, there was over a 23% increase in aerobic capacity as measured via 6MWT. Moreover, 85% of HR_{max} was achieved for at least 3-14 minutes each session (or 6-28% of the total session time) for every participant. Participants were encouraged to spend progressively more time in HR zones above 1 & 2 over the period of the exergaming sessions. It became apparent to us that by spending more time in intermediate HR zones, as opposed to higher heart rate zones (5 & 6), participants were able to better acclimate to the difficulty of the training sessions. In fact, this could have worked to the benefit of overall adherence, as spending too much time in the higher heart rate zones may have been prohibitive for engagement and enthusiasm. Higher intensity resistance and aerobic exercise, when positively correlated with higher perceived exertion, has been reported to be less enjoyable (15). In addition, it may have been possible that the more participants became more proficient with playing the games, the more immersed they became. Exergaming can divert a user's attention away from the exercise and exercise intensity being performed and focus it on the gameplay itself (28). These overall findings are consistent with trends of improved cardiovascular fitness in preschool children that participated in a 12-week exergaming intervention (11). However, a significant difference between these studies is that the participants in our study donned a heart rate monitor throughout their exergaming sessions.

We believe the success in this exergaming feasibility study was bolstered using two distinct factors. The first was an individualized exercise intensity prescription tailored to each participant's capabilities based on their baseline cardiovascular assessment. The second was the implementation of a wrist-worn optical heart rate monitor, which ensured that activity minimally met the CDC recommendations for aerobic exercise in children and adolescents (43). Facilitators of the exergaming sessions were able to prompt the participants to reach higher heart rate zones using the instantaneous feedback from the heart rate monitors. Utilizing feedback from heart rate monitors during exercise with elementary-aged children has been shown to improve aerobic fitness (9). This could be due to the finding that monitoring heart rate measurements can increase intrinsic motivation during physical activity (33). Aiming for higher target heart rate zones can modulate effort and perceived exertion, which is a notable benefit of incorporating the heart rate data with our exergaming sessions.

Among the eight participants in the study, there was 100% compliance with all 12 sessions completed. This trend differs from longitudinal patterns of moderate attrition and a plateau effect of physical activity from a seven-week school trial of exergaming in which participants experienced boredom with the exergame after the novelty wore off (25). Similarly, children have expressed less interest in exergaming when the platform itself is no longer considered a novelty (5). Contrariwise, the exergaming platform used in our study had over a hundred games that incorporated a myriad of movements, objectives, and cooperative play using colorful interactive animations and surround sound. In addition, the incorporation of in-game incentives may have further contributed to the perfect compliance rate. Elementary-aged children with FASD have reported enjoyment while using exergaming interventions that have built-in reward systems (37). In-game interactive challenges and incentives, all found within our platform, have been shown to increase the motivation and satisfaction of exercise (23). The compelling design of this exergaming platform was likely a significant factor in the enjoyment and subsequent compliance of participants.

While the physical benefits of exergaming have been established (15, 38), the social and mental benefits warrant further consideration. Social exergaming, especially in light of the recent COVID-19 pandemic that this study occurred during, can ameliorate the detriments of social isolation among children (36). By providing opportunities to communicate and engage with others during social exergaming, children can participate in significant dyadic interactions that encourage socialization (8). The variety of games that allow cooperative and competitive play gives parents, educators, and peers the opportunity to enhance the social exergaming experience. Having another participant present has been shown to increase intrinsic motivation and effort (10). In terms of the impact on mental health, exergames have demonstrated a positive effect on self-esteem and mood in elementary school children (2). Research also suggests that exergaming can yield the same acute psychological benefits, such as positive affect and enhanced short-term memory, associated with traditional exercise (35). In conjunction with our training paradigm, which harnessed relevant constructs identified in Social Cognitive Theory and the Self-Determination Theory (29), exergaming served to enhance participants' motivation and resistance to relapse. It may have also strengthened perceived self-efficacy, competence, and commitment by providing them with progressively challenging mastery experiences in an interactive environment. Given that the full effects of the global COVID-19 pandemic on the mental states and social skills of children are unknown, social exergaming may be a viable tool to mitigate the possible effects.

There are several limitations to this study. The exergaming intervention was conducted with co-participants (e.g., research facilitators) and non-participants (e.g., a parent or friend) present. Both of these groups could have encouraged the participants throughout the intervention. While social encouragement can yield positive short-term effects on exercise performance (42), verbal encouragement can yield even higher maximum effort during exercise (3). It may be possible that the presence of encouragement could have contributed to a higher exertion of effort. Further research should be conducted to determine if independent exergaming can yield the same benefits as social exergaming. To that end, research facilitators were responsible for selecting the exergames for every training session in order to keep the participants engaged. The variability of choosing which games to play may have yielded different results if, for example, the participants were given the autonomy to pick. Additionally, given that this was a feasibility study, the sample size was a significant limiting factor. Future studies should aim to examine if the trends identified from this study would be replicated across a larger sample.

Conclusion: Given the multimodal nature of the Obie platform which provides hundreds of games that draws the player into a physical environment that is perceptually rich, cognitively challenging, physically and socially inviting, while safe, has huge promise in improving cardiovascular fitness in children with FASD and other developmental challenges. More collaboration between gaming designers, neuroscience researchers, and exercise physiologists may lead to the development of even better individualized exergaming platforms that are sustainable and reproducible in the near future.

REFERENCES

1. Anders P, Lehmann T, Müller H, Grønvik KB, Skjæret-Maroni N, Baumeister J, et al. Exergames inherently contain cognitive elements as indicated by cortical processing. Front Behav Neurosci 12: 102, 2018.

2. Andrade A, Cruz WM, Correia CK, Santos ALG, Bevilacqua GG. Effect of practice exergames on the mood states and self-esteem of elementary school boys and girls during physical education classes: A cluster-randomized controlled natural experiment. PLoS One 15(6): e0232392, 2020.
3. Andreacci JL, Lemura LM, Cohen SL, Urbansky EA, Chelland SA, Duvillard SP. The effects of frequency of encouragement on performance during maximal exercise testing. J Sports Sci 20(4): 345-52, 2002.
4. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: Guidelines for the six-minute walk test. Am J Respir Crit Care Med 166(1): 111-7, 2002.
5. Azevedo LB, Watson DB, Haighton C, Adams J. The effect of dance mat exergaming systems on physical activity and health – related outcomes in secondary schools: Results from a natural experiment. BMC Public Health 14: 951, 2014.
6. Benzing V, Schmidt M. The effect of exergaming on executive functions in children with ADHD: A randomized clinical trial. Scand J Med Sci Sports 29(8): 1243-53, 2019.
7. Campbell TS, Donoghue KM, Ghosh U, Nelson CM, Roth TL. Early life stress affects BDNF regulation: A role for exercise interventions. Int J Mol Sci 23(19): 11729, 2022.
8. Caro K, Tentori M, Martinez-Garcia AI, Zavala-Ibarra I. FroggyBobby: An exergame to support children with motor problems practicing motor coordination exercises during therapeutic interventions. Comput Human Behav 71: 479-98, 2017.
9. Castelli DM, Hillman CH, Hirsch J, Hirsch A, Drollette E. FIT Kids: Time in target heart zone and cognitive performance. Prev Med 52(Suppl 1): S55-9, 2011.
10. Feltz DL, Forlenza ST, Winn B, Kerr NL. Cyber buddy is better than no buddy: A test of the Köhler motivation effect in exergames. Games Health J 3(2): 98-105, 2014.
11. Flentke GR, Smith SM. The avian embryo as a model for fetal alcohol spectrum disorder. Biochem Cell Biol 96(2): 98-106, 2018.
12. Fryer SL, McGee CL, Matt GE, Riley EP, Mattson SN. Evaluation of psychopathological conditions in children with heavy prenatal alcohol exposure. Pediatrics 119(3): e733-41, 2007.
13. Gao Z, Lee JE, Zeng N, Pope ZC, Zhang Y, Li X. Home-based exergaming on preschoolers' energy expenditure, cardiovascular fitness, body mass index, and cognitive flexibility: A randomized controlled trial. J Clin Med 8(10): 1745, 2019.
14. Garn AC, Baker BL, Beasley EK, Solmon MA. What are the benefits of a commercial exergaming platform for college students? Examining physical activity, enjoyment, and future intentions. J Phys Act Health 9(2): 311-8, 2012.
15. Greene DR, Petruzzello SJ. More isn't necessarily better: Examining the intensity–affect–enjoyment relationship in the context of resistance exercise. Sport Exerc Perform Psychol 4(2): 75-87, 2015.
16. Hanlon-Dearman AC, Narvey S. Approach to managing behavior in FASD. In: Chudley AE, Hicks GG (eds) Fetal Alcohol Spectrum Disorder. Neuromethods, vol 188. New York, NY: Humana; 2022.
17. Haas P, Yang C-H, Dunton GF. Associations between physical activity enjoyment and age-related decline in physical activity in children—Results from a longitudinal within-person study. J Sport Exerc Psychol 43(3): 205-14, 2021.

18. Hong SH, Yang HI, Kim D-I, Gonzales TI, Brage S, Jeon JY. Validation of submaximal step tests and the 6-min walk test for predicting maximal oxygen consumption in young and healthy participants. Int J Environ Res Public Health 16(23): 4858, 2019.
19. Hoyme HE, Kalberg WO, Elliott AJ, Blankenship J, Buckley D, Marais A-S, et al. Updated clinical guidelines for diagnosing Fetal Alcohol Spectrum Disorders. J Pediatr 138(2): e20154256, 2016.
20. Kasović M, Štefan L, Petrić V. Normative data for the 6-min walk test in 11–14 year-olds: A population-based study. BMC Pulm Med 21(1): 297, 2021.
21. Lange S, Probst C, Gmel G, Rehm J, Burd L, Popova S. Global prevalence of Fetal Alcohol Spectrum Disorder among children and youth. JAMA Pediatr 171(10): 948-56, 2017.
22. Lavie CJ, Ozemek C, Carbone S, Katzmarzyk PT, Blair SN. Sedentary behavior, exercise, and cardiovascular health. Circ Res 124(5): 799-815, 2019.
23. Lyons EJ. Cultivating engagement and enjoyment in exergames using feedback, challenge, and rewards. Games Health J 4(1): 12-8, 2015.
24. Ma Q. Beneficial effects of moderate voluntary physical exercise and its biological mechanisms on brain health. Neurosci Bull 24(4): 265-70, 2008.
25. Macvean A, Robertson J. Understanding exergame users' physical activity, motivation, and behavior over time. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, April 2013. 1251-60, 2013.
26. Mercurio LY, Amanullah S, Gill N, Gjelsvik A. Children with ADHD engage in less physical activity. J Atten Disord *25*(8): 1187-95, 2021.
27. Milbocker KA, LeBlanc GL, Brengel EK, Hekmatyar KS, Kulkarni P, Ferris CF, et al. Reduced and delayed myelination and volume of corpus callosum in an animal model of Fetal Alcohol Spectrum Disorders partially benefit from voluntary exercise. Sci Rep 12(1): 10653, 2022.
28. Mologne MS, Hu J, Carrillo E, Gomez D, Yamamoto T, Lu S, et al. The efficacy of an immersive virtual reality exergame incorporating an adaptive cable resistance system on fitness and cardiometabolic measures: A 12-week randomized controlled trial. Int J Environ Res Public Health 20(1): 210, 2022.
29. Motl RW. Theoretical models for understanding physical activity behavior among children and adolescents-Social Cognitive Theory and Self-Determination Theory. J Teach Phys Educ 26(4): 350-7, 2007.
30. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1-8, 2019.
31. Ninh VK, El Hajj EC, Mouton AJ, Gardner JD. Prenatal alcohol exposure causes adverse cardiac extracellular matrix changes and dysfunction in neonatal mice. Cardiovasc Toxicol 19(5): 389-400, 2019.
32. Ozsarfati J, Koren G. Medications used in the treatment of disruptive behavior in children with FASD – a guide. J Popul Ther Clin Pharmacol 22(1): e59-67, 2015.
33. Pascal MJ, Layne TE, Iwin CC. Analysis of a heart rate measurement system on student motivation and parent satisfaction. JTRM Kinesiol 5: 9-15, 2019.
34. Popova S, Lange S, Probst C, Gmel G, Rehm J. Global prevalence of alcohol use and binge drinking during pregnancy, and fetal alcohol spectrum disorder. Biochem Cell Biol 96(2): 237-40, 2018.

35. Russell WD, Kraft JA, Selsor CW, Foster GD, Bowman TA. Comparison of acute psychological effects from "Exergames" vs. traditional exercise. Athl Insight J 2(3): 252-67, 2011.

36. Rüth M, Kaspar K. Educational and social exergaming: A perspective on physical, social, and educational benefits and pitfalls of exergaming at home during the COVID-19 pandemic and afterwards. Front Psychol 12: 644036, 2021.

37. Schneider ALJ, Keiver K, Pritchard Orr A, Reynolds JN, Golubovich N, Graham TCN. Toward the design of enjoyable games for children with Fetal Alcohol Spectrum Disorder. Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems. CHI 2020: 1-13, 2020.

38. Staiano AE, Calvert SL. Exergames for physical education courses: Physical, social, and cognitive benefits. Child Dev Perspect 5(2): 93-8, 2011.

39. Sun H. Impact of exergames on physical activity and motivation in elementary school students: A follow-up study. J Sport Health Sci 2(3): 138-45, 2013.

40. Takken T, Bongers BC, van Brussel M, Haapala EA, Hulzebos EHJ. Cardiopulmonary exercise testing in pediatrics. Ann Am Thorac Soc 14(Suppl 1): S123-8, 2017.

41. Ulrich S, Hildenbrand FF, Treder U, Fischler M, Keusch S, Speich R, et al. Reference values for the 6-minute walk test in healthy children and adolescents in Switzerland. BMC Pulm Med 13: 49, 2013.

42. Wang L, Guo X, Wu T, Lv L, Zhang Z. Short-term effects of social encouragement on exercise behavior: Insights from China's Wanbu network. Public Health 148: 25-9, 2017.

43. Yang YJ. An overview of current physical activity recommendations in primary care. Korean J Fam Med 40(3): 135-42, 2019.