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Current Evidence on Exergaming Interventions for Children and Adolescents with Attention-Deficit/Hyperactivity Disorder

Dikkat-Eksikliği/Hiperaktivite Bozukluğu Tanılı Çocuk ve Ergenlerde Exergaming Kullanımına İlişkin Güncel Kanıtlar

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ÖZ

Dikkat-eksikliği/hiperaktivite bozukluğu çocuk ve ergenlerde işlevsel bozulmaya yol açan belirtiler ile karakterizedir. Bu durumun klinik yönetiminde, ilaç tedavisi ve/veya davranışsal müdahalelerin kullanıldığı olağan tedaviye ek olarak fiziksel aktivitenin artırılması önerilmektedir. Exergaming ekrandaki hareketlerin kontrolü için tüm beden hareketleri yapılmasını gerektiren, fiziksel aktivitenin oyun bağlamıyla bütünleştirildiği aktif video oyunu şeklidir. Dikkat-eksikliği/hiperaktivite bozukluğu olan çocuk ve ergenlerde motivasyon, dürtü kontrolü ve odağını sürdürme zorlukları nedeniyle klasik egzersizlerin sürdürülmesi zor olabilmektedir. Exergaming oyun-temelli ödüller ve oyunlaştırılmış bileşenler ile fiziksel aktiviteyi sürdürülebilir yapan ilgi çekici etkinlikler aracılığıyla bu zorlukların aşılmasını kolaylaştırabilir. Bu makalede mevcut literatür gözden geçirilerek, DEHB tanılı çocuk ve ergenlerde fiziksel aktivitenin artırılması için exergaming uygulanabilirliği ve yararlı yönlerinin değerlendirilmesi amaçlanmaktadır.

Anahtar kelimeler: dikkatsizlik; dürtüsellik; exergaming; hiperaktivite; yürütücü işlevler

ABSTRACT

Attention-deficit/hyperactivity disorder is characterized by symptoms causing functional impairment in children and adolescents. For the clinical management of this condition, increasing physical activity is recommended in addition to the usual treatment with medication and/or behavioral interventions. Exergaming is active video gaming that requires full-body movements to control on-screen actions, integrating physical activity into the gaming context. For children and adolescents with attention-deficit/hyperactivity disorder, traditional forms of exercising can be challenging to sustain due to challenges with motivation, impulse control, and maintaining focus. Exergaming might address these challenges by incorporating game-based rewards and appealing activities with gamified elements that can make physical activity sustainable. By reviewing currently available research, this paper aims to evaluate the feasibility and benefits of exergaming as a way to promote physical activity among children and adolescents with ADHD.

Keywords: executive functions; exergaming; hyperactivity; inattention; impulsivity

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INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by symptoms of hyperactivity/impulsivity and inattention, causing significant functional impairment. Inattention may manifest with impairing symptoms in school and home settings, such as the inability to sustain attention in classes and during long reading tasks, impairing academic functioning, or during extended conversations with other people, impairing social functioning. Children and adolescents with ADHD usually have difficulty following directions and completing responsibilities in school and home settings. They dislike and avoid work requiring extended mental effort, such as homework. Other symptoms of inattention include planning and organizing consequent tasks, disorganized work, poor time management, loss of materials essential for completing tasks and activities, distractibility, and forgetfulness. Hyperactivity/impulsivity symptoms include fidgetiness, inability to keep seated during classes, running and climbing inappropriately, inability to keep busy silently, being on the move constantly, talking excessively, difficulty waiting for their turns in a line, replying questions before they are finished, interrupting others' while talking or playing, and using others' materials without asking permission. ADHD is usually associated with emotional dysregulation, causing anger and being annoyed or offended easily, which may manifest in excessive reactions due to emotional impulsivity. Moreover, executive function impairments are common in working memory, shifting attention, reaction time, response inhibition, and planning/organization.

In current clinical practice, ADHD is treated effectively with medications such as psychostimulants, selective norepinephrine reuptake inhibitor atomoxetine, and alpha-2 agonists, in addition to behavioral management strategies. The array of non-pharmacological treatment modalities is expanding for ADHD (e.g., behavioral interventions and parental training), although pharmacological treatment continues to be the most effective approach.[1] Increasing physical activity is recommended in addition to the usual treatment of children and adolescents with ADHD, as the integration of exercise into their regular routines may yield beneficial effects.[2-5] Even a single-session exercise can benefit core symptoms and executive functions in ADHD.[6] For long-lasting benefits, reports indicate moderate to high-intensity exercise over an extended period is advisable.[7,8] However, currently available research indicates that exercise should not be viewed as a substitute for the primary treatment of ADHD but as an adjunct to the treatment strategy.[9]

The utilization of continuously advancing technology has also garnered attention as a method of treatment delivery for ADHD. Research so far indicates that technological interventions possess the potential to alleviate the challenges of children and adolescents with ADHD.[10] However, despite the generally optimistic outcomes, higher-quality research is needed to understand the efficacy of technology-based treatment in treating symptoms of ADHD.[11] The most contemporary technology-driven interventions that have been examined for children and adolescents diagnosed with ADHD include delivery of the usual treatment remotely (i.e., telepsychiatry), cognitive training, neurofeedback, and integrative approaches, including exercise and cognitive engagement (i.e., exergames).[11]

Exergaming is active video gaming that requires full-body movements to control on-screen actions, integrating physical activity into the gaming context. Consequently, it involves elements of cognitive training and physical exercise. Evidence suggests that affect-based exercise interventions with enjoyable components can help increase adherence to physical activity.[12] By providing exercise in a gamified manner (e.g., scoring, visual rewards, and real-time feedback), exergaming has the potential to be an enjoyable option for increasing physical activity. In addition to physical health benefits, exergaming can be beneficial for mental and social well-being, which may be of particular value for children and adolescents.[13,14]

For children and adolescents with ADHD, traditional forms of exercising can be challenging to sustain due to challenges with motivation, impulse control, and maintaining focus. Exergaming might address these challenges by incorporating game-based rewards and appealing activities with gamified elements that can make physical activity sustainable for children and adolescents with ADHD. By reviewing currently available research on this issue, this

paper aims to evaluate the feasibility and benefits of exergaming as a way to promote physical activity among children and adolescents with ADHD.

Methodology for Literature Review

For this narrative review, a literature search was conducted on the PubMed database to review the current evidence on exergaming to promote physical activity among children and adolescents with attention-deficit/hyperactivity disorder, searching with terms "exergaming" and "ADHD"; "exergaming" AND "attention"; "exergaming" AND "hyperactivity"; "exergaming" AND "executive"; "exergaming" AND "children" AND "; "exergaming" AND "children" AND "mental health"; "exergaming" AND "children" AND "well-being"; "exergaming" AND "children" AND "quality of life." The search revealed ninety-nine articles published between 2010 and 2024, while 60 remained after removing duplicates from search results.

Articles were initially reviewed regarding the study population, intervention used, and primary outcomes. Thirty-three articles were excluded due to participant characteristics (i.e., including children and adolescents with physical disabilities or health conditions including chronic health conditions, primary ciliary dyskinesia, spina bifida, chronic kidney disease, renal transplant recipients, cerebral palsy, acute lymphoblastic leukemia, pediatric cancer survivors, chronic ankle instability, tennis players or including adult participants) and due to study or intervention design (i.e., protocols reporting study designs, virtual reality for diagnostic purposes, cyber cycling without exergaming effects, digital motor interventions for physical rehabilitation purposes). Articles conducted on children and adolescents with developmental disabilities, autism spectrum disorder, and neurodevelopmental disorders in general, which have high co-occurrence rates with ADHD, were retained in the review due to clinical implications. A total number of 27 articles remaining after the aforementioned exclusions are included in this study. A flowchart diagram of the reviewing process can be seen in Figure 1. A summary of the reviewed articles can be seen in Supplement Table 1.

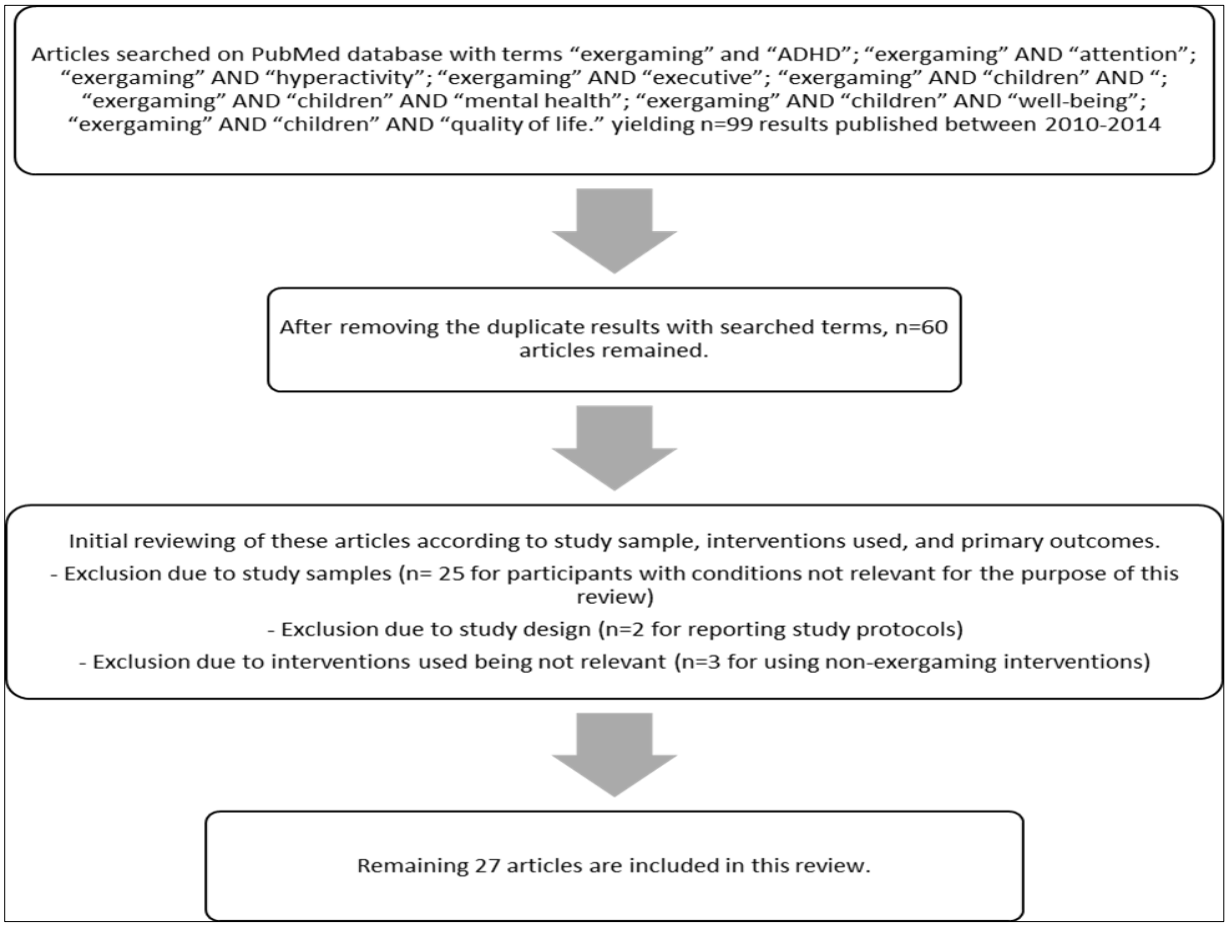

Figure 1. Flowchart diagram of the article reviewing process.

Feasible Exergaming Interventions in Structured Settings: School-Based Exergaming, Family Exergaming, Remotely Delivered Coaching

Current evidence suggests that exergaming can be a school-based intervention for children and adolescents with ADHD. According to Fogel et al. (2010), physically inactive children and their teachers find exergaming socially acceptable, increasing the duration of physical activity in PE classes.[15] While improving physical fitness in addition to specific motor skills, such as balance, agility, and postural stability in children, exergaming can contribute to better physical coordination and control of movements.[16] Motor impairments related to comorbidities or developmental delay are frequent in children with ADHD, which can negatively impact their functioning. Engaging in structured exergaming in school settings can increase body awareness and control, helping them overcome challenges in physical coordination.[17]

Besides the physical benefits, studies conducted on healthy or overweight samples suggest that exergaming at school may enhance attention, decrease problem behaviors, and lead to long-term psychosocial improvement among children and adolescents. Brief exergaming sessions can be helpful as a part of the school schedules, providing acute cognitive enhancement through physiological mechanisms such as increased cerebral blood flow.[2] These sessions may help manage difficulties related to focusing and sustaining attention in ADHD. Fogel et al. (2010) suggest that exergaming may also help decrease problem behaviors during classes, which can be particularly relevant for ADHD, as it channels energy constructively while reducing impulsivity and off-task behaviors.[15] Long-term psychosocial gains from classroom-based exergaming routines are also exhibited, including increased enjoyment and social support from teachers.[18]

Exergaming can also be used in the home setting as a family intervention or a component of a remotely delivered treatment. Parents also find family exergaming feasible as it can serve as a valuable indoor physical activity alternative, especially when outdoor activity is not applicable.[19] For children and adolescents with ADHD, exergaming with family may be a suitable, structured, and cooperative activity with a positive and socially supportive environment. Parents still favor real-world physical activities over exergaming but see the potential for positive behavior changes through productive screen time.[20] Family exergaming can also help replace other sedentary activities, such as problematic use of technology among children and adolescents with ADHD. Parents' role may be crucial in helping children with ADHD to participate in family exergaming sessions, including sports or dance.

Bowling et al. (2021) reported the feasibility of a remotely delivered health behavior intervention to promote a healthy lifestyle using exergames in adolescents with neurodevelopmental disorders, including ADHD.[21] Their intervention improved sleep duration and reduced screen time, which is crucial for children and adolescents with ADHD, who commonly suffer from sleep disturbances and elevated screen time. According to Bowling et al. (2021), exergaming may offer a healthier alternative to passive screen-based activities, especially when combined with health coaching with consistent encouragement and structured guidance to children with neurodevelopmental disorders.[21]

McMichael et al. (2020) reported that parental perspectives on adolescent exergaming are generally positive.[20] While parents acknowledge the benefits of exergaming for adolescent physical activity, several concerns were raised, including gaming addiction, violent content, and social isolation in virtual reality.[20] In this respect, parents of children and adolescents with ADHD may even be more concerned. Nevertheless, these issues may be alleviated through judicious game selection and regulated screen time.

Interventional Studies Conducted In Children and Adolescents with ADHD So Far Show Promising Results

Exergaming sessions before starting homework at home or during recess in school settings could offer practical solutions for some of the difficulties experienced by children with ADHD. The immediate positive impact of exergaming on executive functions observed in a study by Benzing et al. (2018) suggests a promising potential for it to be used as a preparatory activity for attention-demanding situations.[22] However, another study by Benzing & Schmidt

(2019) did not find significant improvement in hyperactivity/impulsivity or inattention symptoms, highlighting the need for exergaming interventions targeting core symptoms of ADHD.[23] More recent studies demonstrated improvements in ADHD symptoms with exergaming interventions in children.[24,25] A study by Ji et al. (2023) exhibited that both exergaming and traditional physical activity are associated with attention improvements, while exergaming had a more substantial effect on attention-related brain functions.[24] They explained this finding by exergaming requiring players to involve multiple cognitive functions to perform physical activity.[24]

A recent meta-analysis by Kou et al. (2024) reported that exergaming interventions lead to moderate improvement in inhibitory control in ADHD without publication bias, indicating its potential to help manage impulsivity.[25] Currently, available research shows no superiority of exergaming over traditional physical exercises. However, there is comparable effectiveness regarding ADHD symptom control and executive function improvement.[26] In addition, exergaming interventions may alleviate mental health issues experienced by children with ADHD, as Benzing & Schmidt (2019) observed a reduction in general psychopathology from clinically elevated to borderline level.[23]

Factors to Consider For Optimizing Benefits of Children and Adolescents with ADHD from Exergaming Interventions

Children with ADHD may need additional incentives to get engaged and to maintain focus in physical activities that are not enjoyed, which exergaming may facilitate. Sun (2012) emphasized that exergaming generates instant, positive emotions fostering intrinsic motivation, and it can elicit higher situational interest than traditional exercise due to its novelty and interactive nature.[27] This motivational appeal of exergaming may be helpful in ADHD interventions by encouraging children to stay engaged without external reinforcement. However, a critical issue with adherence to exergaming intervention is the motivational decline usually seen in children after the initial exposure.[28] While exergaming may initially engage children and adolescents, strategies to maintain their interest over time are critical. For children and adolescents with ADHD, maintaining motivation through exergaming interventions that are both enjoyable and gradually adjusted to keep interest may be warranted.

Like other treatment approaches, the duration and frequency of exercise interventions are crucial factors in effectiveness. Anzeneder et al. (2023) found that a 15-minute exercise is optimal for acute cognitive gains, while Chen et al. (2023) reported that sessions lasting at least 20-30 minutes and interventions lasting more than six weeks are ideal for long-term improvements.[29,30] Considering these findings with Benzing et al. (2018), it is plausible to suggest that although acute beneficial effects may also help function in structured settings such as school, regular and extended sessions may be necessary to achieve meaningful, long-lasting gains from exergaming interventions.[22] Also, trends in the positive effects of exergaming may plateau after a period, suggesting a need for adaptations in further studies to maintain their effectiveness.[18]

Exergaming may lead to varying levels of cognitive engagement, and the dose of cognitive challenge during exergaming can also influence its beneficial effects. Anzeneder et al. (2023) found that a higher level of cognitive engagement during physical activity can enhance cognitive functioning outcomes.[31] Their research suggests that exergaming involving focus and strategy may aid children and adolescents with ADHD in improving attention and executive functioning. However, a study by Best (2012) pointed out that physiological arousal provided by physical activity primarily drives executive functioning improvements rather than cognitive engagement.[32] These findings suggest that while a higher cognitive engagement may not be necessary for the acute beneficial effects of exergaming, it may be favorable in the long term.

Exergaming as a Social Experience: Pros and Cons of Social Play for Children and Adolescents

Since exergaming may be a social experience in specific settings, the advantages and risks of social play must also be considered for children and adolescents with ADHD. Although some results suggest that social gaming may be associated with increased adherence to sustained exergaming, others imply that intrinsic motivation may be more important for continued use among children than social

play.[14,28] Verhoeven et al. (2015) reported that, surprisingly, social play is not associated with higher enjoyment during exergaming among adolescents.[33] However, individual motivations should also be considered while choosing appropriate exergames to enhance adherence of children and adolescents with ADHD.

Social aspects of exergaming can include competitive or cooperative elements. Competitive exergaming may be associated with short-term physical arousal and more significant energy expenditure, which makes it appealing to those with ADHD. However, this type of exergaming may not be ideal for children prone to impulsivity or emotional dysregulation due to the risk of increased aggression.[14] Importantly, competitive play can sometimes lead to demotivation due to consistently comparing themselves to others. Tailoring exergames to include cooperative rather than competitive elements may help foster long-term participation and improve psychosocial well-being in children and adolescents.[14]

Cognitive outcomes can also be affected by the type of exergaming. Nekar et al. (2023) found that cooperative, competitive, and solitary exergames can all enhance memory, attention, and visual perception among children with developmental disabilities.[34] However, cooperative and competitive exergames may lead to better improvements in attention than solitary ones, possibly due to better cognitive engagement. Moreover, according to Nekar et al. (2023), cooperative exergaming may provide a safe and supportive environment while promoting social interactions and reducing anxiety in multiple dimensions.[34] These results suggest that in addition to the physical and cognitive benefits, specific types of exergames may also provide social and emotional improvements among children and adolescents with ADHD.

Feasibility of Exergaming among Different Age Groups and Children with Developmental Disabilities

Exergaming interventions can be feasible for children as young as preschoolers by integrating fun and motivational elements with improvements in social and cognitive functioning.[35-37] This feasibility offers an optimistic outlook on early intervention strategies for treating preschool children with ADHD as behavioral interventions since non-medication treatments are usually the first choice in this age group. Exergaming can also apply to children with developmental disabilities in which ADHD is a frequent comorbidity. For instance, a six-week exergaming intervention program was found feasible and safe among children with fetal alcohol syndrome and comorbid ADHD diagnosis.[38] Children and adolescents with disabilities may not be able to participate in regular ways of exercising and require more individualized and assisted physical activity interventions, which may be facilitated with exergaming. Moreover, structured exergaming interventions can be feasible for children with autism spectrum disorder, which is another neurodevelopmental disorder frequently co-occurring with ADHD.[39,40] Tailored exergames are warranted according to the needs of children with developmental disabilities in future studies.[41]

Potential Risks and Harms of Exergaming Interventions for Children and Adolescents

Besides the strengths and opportunities associated with exergaming interventions, the weaknesses and threats should also be considered for children and adolescents.[42] General weaknesses of exergaming interventions are economical burdens and technical restrictions. For children and adolescents, one of the most important risks associated with exergaming may be the replacement of the traditional physical activity. Moreover, principles related to the healthy use of technology should not be neglected, although it is not clear whether exergaming causes increased screen time.[42] Children and adolescents should always be supervised by adults (i.e., parents at home, teachers at school) in an effort to create a balance between virtual and real-world activities.

Conclusion

In conclusion, studies conducted among children and adolescents with ADHD so far indicate that exergaming interventions provide acute enhancement of executive functions and attention and moderate improvement in inhibitory control, as well as a decline in general psychopathology symptoms. There is a need to improve the effectiveness of exergaming interventions on specific ADHD

symptoms. Exergaming can be especially helpful for children and adolescents who struggle with adherence to regular exercise routines, offering an enjoyable way to address both physical and cognitive needs. Further studies should focus on optimizing exergaming sessions' duration, frequency, and intensity as further developments in exergaming technology may also be needed to keep children with ADHD motivated and maintain their interest in play. Multidisciplinary experimental studies including experts from medicine, technology, education, and sport sciences are needed to develop better interventions targeting difficulties of children and adolescents with ADHD.

Conflict of Interest

The authors declare that there is not any conflict of interest regarding the publication of this manuscript.

Ethics Committee Permission

Ethical approval is not relevant since the publication is a literature review.

Authors' Contributions

Concept/Design: Sİ. Data Collection and/or Processing: Sİ. Data analysis and interpretation: Sİ. Literature Search: Sİ. Drafting manuscript: Sİ.

REFERENCES

1. Peterson BS, Trampush J, Maglione M, et al. Treatments for ADHD in Children and Adolescents: A Systematic Review. Pediatrics. 2024;153(4):2024065787.
2. Li D, Li L, Zang W, et al. Effect of physical activity on attention in school-age children with ADHD: a systematic review and meta-analysis of randomized controlled trials. Front Physiol. 2023;14:1189443.
3. Song Y, Fan B, Wang C, Yu H. Meta-analysis of the effects of physical activity on executive function in children and adolescents with attention deficit hyperactivity disorder. PLoS One. 2023;18(8):0289732.
4. Sun W, Yu M, Zhou X. Effects of physical exercise on attention deficit and other major symptoms in children with ADHD: A meta-analysis. Psychiatry Res. 2022;311:114509.
5. Yang G, Liu Q, Wang W, Liu W, Li J. Effect of aerobic exercise on the improvement of executive function in children with attention deficit hyperactivity disorder: a systematic review and meta-analysis. Front Psychol. 2024;15:1376354.
6. Chen JW, Zhu K. Single Exercise for Core Symptoms and Executive Functions in ADHD: A Systematic Review and Meta-Analysis. J Atten Disord. 2024;28(4):399-414.
7. Huang H, Jin Z, He C, Guo S, Zhang Y, Quan M. Chronic Exercise for Core Symptoms and Executive Functions in ADHD: A Meta-analysis. Pediatrics. 2023;151(1):2022057745.
8. Chen JW, Du WQ, Zhu K. Optimal exercise intensity for improving executive function in patients with attention deficit hyperactivity disorder: systematic review and network meta-analysis. Eur Child Adolesc Psychiatry. 2024:1-22.
9. Sibley MH, Bruton AM, Zhao X, et al. Non-pharmacological interventions for attention-deficit hyperactivity disorder in children and adolescents. Lancet Child Adolesc Health. 2023;7(6):415-428.
10. Powell L, Parker J, Harpin V. What is the level of evidence for the use of currently available technologies in facilitating the self-management of difficulties associated with ADHD in children and young people? A systematic review. Eur Child Adolesc Psychiatry. 2018;27(11):1391-1412.
11. Guan Lim C, Lim-Ashworth NSJ, Fung DSS. Updates in technology-based interventions for attention deficit hyperactivity disorder. Curr Opin Psychiatry. 2020;33(6):577-585.
12. Klos L, Feil K, Eberhardt T, Jekauc D. Interventions to Promote Positive Affect and Physical Activity in Children, Adolescents and Young Adults-A Systematic Review. Sports (Basel). 2020;8(2):26.
13. Joronen K, Aikasalo A, Suvitie A. Nonphysical effects of exergames on child and adolescent well-being: a comprehensive systematic review. Scand J Caring Sci. 2017;31(3):449-461.
14. Marker AM, Staiano AE. Better Together: Outcomes of Cooperation Versus Competition in Social Exergaming. Games Health J. 2015;4(1):25-30.
15. Fogel VA, Miltenberger RG, Graves R, Koehler S. The effects of exergaming on physical activity among inactive children in a physical education classroom. J Appl Behav Anal. 2010;43(4):591-600.
16. Liu W, Zeng N, McDonough DJ, Gao Z. Effect of Active Video Games on Healthy Children's Fundamental Motor Skills and Physical Fitness: A Systematic Review. Int J Environ Res Public Health. 2020;17(21):8264.
17. Oppici L, Stell FM, Utesch T, Woods CT, Foweather L, Rudd JR. A Skill Acquisition Perspective on the Impact of Exergaming Technology on Foundational Movement Skill Development in Children 3-12 Years: A Systematic Review and Meta-analysis. Sports Med Open. 2022;8(1):148.
18. Fu Y, Burns RD, Gomes E, Savignac A, Constantino N. Trends in Sedentary Behavior, Physical Activity, and Motivation during a Classroom-Based Active Video Game Program. Int J Environ Res Public Health. 2019;16(16):2821.
19. Rhodes RE, Nwachukwu N, Quinlan A. Family Exergaming: Correlates and Preferences. Games Health J. 2018;7(3):188-196.
20. McMichael L, Farič N, Newby K, et al. Parents of Adolescents Perspectives of Physical Activity, Gaming and Virtual Reality: Qualitative Study. JMIR Serious Games. 2020;8(3):14920.
21. Bowling AB, Slavet J, Hendrick C, et al. The Adaptive GameSquad Xbox-Based Physical Activity and Health Coaching Intervention for Youth With Neurodevelopmental and Psychiatric Diagnoses: Pilot Feasibility Study. JMIR Form Res. 2021;5(5):24566.
22. Benzing V, Chang YK, Schmidt M. Acute Physical Activity Enhances Executive Functions in Children with ADHD. Sci Rep. 2018;8(1):12382.
23. Benzing V, Schmidt M. The effect of exergaming on executive functions in children with ADHD: A randomized clinical trial. Scand J Med Sci Sports. 2019;29(8):1243-1253.
24. Ji H, Wu S, Won J, et al. The Effects of Exergaming on Attention in Children With Attention Deficit/Hyperactivity Disorder: Randomized Controlled Trial. JMIR Serious Games. 2023;11(1):40438.

25. Kou R, Zhang Z, Zhu F, Tang Y, Li Z. Effects of Exergaming on executive function and motor ability in children: A systematic review and meta-analysis. PLoS One. 2024;19(9):0309462.
26. Zhu F, Zhu X, Bi X, et al. Comparative effectiveness of various physical exercise interventions on executive functions and related symptoms in children and adolescents with attention deficit hyperactivity disorder: A systematic review and network meta-analysis. Front Public Health. 2023;11:1133727.
27. Sun H. Exergaming impact on physical activity and interest in elementary school children. Res. Q. Exerc. Sport. 2012;83(2):212-220.
28. Rhodes RE, Kaos MD, Beauchamp MR, et al. Effects of home-based exergaming on child social cognition and subsequent prediction of behavior. Scand J Med Sci Sports. 2018;28(10):2234-2242.
29. Anzeneder S, Zehnder C, Schmid J, Martin-Niedecken AL, Schmidt M, Benzing V. Dose-response relation between the duration of a cognitively challenging bout of physical exercise and children's cognition. Scand J Med Sci Sports. 2023;33(8):1439-1451.
30. Chen J, Zhou X, Wu X, Gao Z, Ye S. Effects of exergaming on executive functions of children: a systematic review and meta-analysis from 2010 to 2023. Arch Public Health. 2023;81(1):182.
31. Anzeneder S, Zehnder C, Martin-Niedecken AL, Schmidt M, Benzing V. Acute exercise and children's cognitive functioning: What is the optimal dose of cognitive challenge?. Psychol Sport Exerc. 2023;66: 102404.
32. Best JR. Exergaming immediately enhances children's executive function. Dev Psychol. 2012;48(5):1501-1510.
33. Verhoeven K, Abeele VV, Gers B, Seghers J. Energy Expenditure During Xbox Kinect Play in Early Adolescents: The Relationship with Player Mode and Game Enjoyment. Games Health J. 2015;4(6):444-451.
34. Nekar DM, Kang HY, Lee JW, Oh SY, Yu JH. Effects of Cooperative, Competitive, and Solitary Exergames on Cognition and Anxiety Levels in Children with Developmental Disabilities. Games Health J. 2023;12(5): 405-413.
35. Xiong S, Zhang P, Gao Z. Effects of Exergaming on Preschoolers' Executive Functions and Perceived Competence: A Pilot Randomized Trial. J Clin Med. 2019;8(4):469.
36. 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. 2019;8(10):1745.
37. Gashaj V, Dapp LC, Trninic D, Roebers CM. The effect of video games, exergames and board games on executive functions in kindergarten and 2nd grade: An explorative longitudinal study. Trends Neurosci Educ. 2021;25:100162.
38. Yamamoto T, Pandit B, Viggiano M, et al. 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. Int J Exerc Sci. 2023;16(3):710-720.
39. Anderson-Hanley C, Tureck K, Schneiderman RL. Autism and exergaming: effects on repetitive behaviors and cognition. Psychol Res Behav Manag. 2011;4:129-137.
40. Hou Y, Wang Y, Deng J, Song X. Effects of different exercise interventions on executive function in children with autism spectrum disorder: a network meta-analysis. Front Psychiatry. 2024;15:1440123.
41. Lee HK, Jin J. The effect of a virtual reality exergame on motor skills and physical activity levels of children with a developmental disability. Res Dev Disabil. 2023;132:104386.
42. Benzing V, Schmidt M. Exergaming for Children and Adolescents: Strengths, Weaknesses, Opportunities and Threats. J Clin Med. 2018;7(11):422.