

The Effects of Exergaming on Executive Functions in Children with ADHD: A Protocol of Systematic Review and Meta-Analysis

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Abstract: Background: Attention-deficit/hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders that affect children. Symptoms of ADHD have been associated with reduced executive functions (EFs). Physical activity (PA) was suggested as an optional treatment; however, adherence to PA in children with ADHD is low. Exergaming has shown the beneficial effects on EFs; however, the evidence-base results were varied. This study will review primary studies investigating the effects of exergaming to increase EFs. Methods: This protocol of systematic review and meta-analysis is developed following the PRISMA guidelines. The study protocol has been registered in PROSPERO (CRD42024549395). Studies from eleven databases, published articles from the same authors, forward and backward, and co-citing and co-cited citation searches will be screened by two researchers based on inclusion and exclusion criteria. Two researchers will assess the risk of bias using The Cochrane Risk of Bias 2. Narrative synthesis will be presented, and meta-analyses will be performed on EF outcomes using random-effect meta-analyses. GRADE will be used to assess the quality of evidence by two researchers. Conclusion: This study will be the first systematic review and meta-analysis which offer insights on the effects of exergaming on EFs and adherence to PA in children with ADHD.

1 INTRODUCTION


Attention deficit/hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders in children (Salari et al., 2023). The key symptoms of ADHD are inattention, hyperactivity/impulsivity, or combined presentation and mostly arise during school-age children (American Psychiatric Association, 2022; Colomer et al., 2017). Those symptoms have been associated with the reduction in executive functions (EFs) (Nigg et al., 2002; Willcutt et al., 2005).


EFs are meta-cognitive functions that are essential for goal orientation, behaviour flexibility, and adaptation because they control fundamental cognitive processes (Diamond, 2013). According to Biederman et al. (2004), EFs consist of three main processes which are inhibition, working memory, and cognitive flexibility. Those three processes are highly associated with learning and academic achievement


in children. Therefore, children with ADHD usually experience low performance and poor academic achievement due to problems with their EFs (Arnold et al., 2020).

Engaging in physical activity (PA) could be one of the options to deal with reducing EFs. There are substantial evidence-based studies indicating that PA has positive impacts on EFs (Welsch et al., 2021; Chan et al., 2022). However, although the positive impacts of doing PA for children with ADHD are known, children with ADHD engage in less PA (Mercurio et al., 2021). Boman & Bernhardsson (2023); Ogrodnik et al. (2023) found that one of the barriers for children with ADHD to engage in PA is low motivation and forgetfulness since PA is often perceived as fatiguing and uninteresting.

Therefore, there is a need for another approach as adjunct or independent treatment for children with ADHD. Halperin & Healey (2011) argued that combining PA with cognitive challenges might be a

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good treatment to deal with EF problems and low adherence in PA to children with ADHD. This combination approach could be implemented through exergaming.

Exergaming is an innovation that combines exercise with gaming; therefore, players should make body movements that appear on the digital games to play exergaming; by doing so, the players will get the benefits of doing PA (Wijffelaars & Markopoulos, 2023). Using game field approaches, exergaming could be fun exercises that can increase motivation, EFs, and adherence to PA in children (Staiano & Calvert, 2011; Primack et al., 2012).

There are growing numbers of studies that examine the effects of exergaming on the EFs in children with ADHD and found the beneficial effects (Chang et al., 2022; Benzing & Schmidt, 2019). However, the effects of the outcomes of those studies are varied from moderate effects (Benzing & Schmidt, 2019) to large effects (Chang et al., 2022). Therefore, it could be suggested to conduct a systematic review to solve the gaps in understanding the effects of exergaming to increase EFs in children with ADHD.

To the best of our knowledge, this will be the first systematic review and meta-analysis exploring the effects of exergaming on EFs in children with ADHD. This systematic review and meta-analysis aim to review primary studies that have investigated the effects of exergaming on EFs in children with ADHD and to summarise their findings.

1.1 Research Questions

1. What is the effectiveness of exergaming on executive functions in children with ADHD compared with the control group?
2. What is the adherence of children with ADHD in exergaming interventions?

2 METHODS

A systematic review will be conducted to answer the research questions. The review protocol was written based on the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) statement (Moher et al., 2015; Shamseer et al., 2015) and the Cochrane Handbook (Higgins et al., 2023). The protocol has been registered in the International Prospective Registers of Systematic Reviews (PROSPERO) (CRD42024549395; Pradana et al., 2024).

2.1 Eligibility Criteria

Studies will be selected based on the following inclusion and exclusion criteria using Population, Intervention, Control, Outcomes, and Study design (PICOS) framework: (1) Population: children aged 4 – 12 years of age who have been diagnosed as having ADHD symptoms using the standardised diagnostic tool, for instance the International Classification of Diseases (ICD) criteria or the Diagnostic and Statistical Manual of Mental Disorder (DSM); (2) Intervention: studies that used exergaming as at least one of their interventions. All exergaming domains, structured or semi-structured, and indoors or outdoors will be included. However, studies using single-bout interventions will be excluded.; (3) Control: control groups with no treatment or using waiting list or using non-active treatment, such as usual care and cognitive training; (4) Outcomes: EFs (inhibition, working memory, and cognitive flexibility) and the adherence on exergaming interventions; (5) study design: Randomized Controlled Trials (RCTs). Only English-language published articles with no date and location restriction will be included to identify relevant studies (Lefebvre et al., 2023).

2.2 Information Sources

A systematic search will be conducted on the 11 electronic databases to identify published literature which will be included in the review: MEDLINE (Ovid); CINAHL (EBSCO); CENTRAL; Embase (Ovid); SPORTDiscus (EBSCO); PsycINFO (Ovid); Scopus (Elsevier); Web of Science (Clarivate); ACM Digital Library; IEEE Xplore Digital Library; and Sport Medicine & Education Index.

2.3 Search Strategy

The search strategy will be developed based on 5 categories from the PICOS (Table 1). The search strategy for the MEDLINE database is provided in Table 1 and will be adapted for other databases. Moreover, the researchers will search for additional papers by the same author and perform forward and backward, and co-cited and co-citing citation searches of all eligible studies.

Table 1: Search strategies.

Categories	Terms
Children	child* OR kid* OR youth OR pediatric
ADHD	ADHD OR “attention deficit hyperactivity disorder” OR “attention deficit disorder” OR “attention deficit-hyperactivity disorder” OR “attention-deficit/hyperactivity disorder” OR “hyperactivity disorder” OR “hyperkinetic syndrome” OR “minimal brain damage” OR “minimal brain dysfunction” OR “neurodevelopmental disorder”
Exergame	exergam* OR video gam* OR game* OR gaming OR “active video games” OR “computer games” OR “online gam*” OR “internet gam*” OR “virtual reality” OR vr OR “augmented reality” OR “immersive virtual reality” OR “immersive vr” OR ivr OR wii OR “nintendo wii” OR “wii gam*” OR “wii fit” OR “virtual cycl*” OR “xbox kinect” OR “physical action gam*” OR “serious game”
Executive functions	“executive function*” OR “executive dysfunction” OR “cognitive function*” OR “executive abilit*” OR “cognitive ability*” OR “cognitive control” OR “executive process*” OR cognit* OR memor* OR vigilance OR distractibility OR “cognitive flexibility” OR impulsiv* OR inhibit* OR “dual task” OR “inhibitory control” OR “working memory” OR “short term memory” OR “interference control” OR “speed reaction” OR “processing speed” OR “cognitive dysfunction” OR “cognition disorders”
RCTs	“randomized controlled trial” OR rct OR “randomised controlled trial

2.4 Data Management

The researchers will use the Covidence tool (<https://www.covidence.org/>) to automatically remove duplicates and to improve efficiency in time. Moreover, the PRISMA diagram will be used to manage records of every process (Page et al., 2021).

2.5 Selection Process

Two researchers will independently screen articles based on the eligibility criteria. Firstly, the reviewers will conduct an initial search followed by two-step screening processes which are screening the titles and the abstracts to exclude studies that do not meet the eligibility criteria. The reviewers will choose ‘yes’ to

the eligible study and “no” to the study which is not meet a particular criterion. If the reviewers are unsure about the decision, the reviewers will follow through to the next step which is screening the full text.

Secondly, the reviewers will screen the full text of selected studies to identify the final eligible studies to be included in the synthesis. If there are disagreements during abstract and full-text screening, they will be resolved through discussion. If there are any disagreements that cannot be resolved, the arbiter from the third author will mediate the discussion of the discrepancies.

2.6 Data Collection Process and Data Items

The data collection process will be performed by two independent researchers who will collect the data of following study characteristics in the Excel: the reference, study location, participant characteristics (age, gender, type of ADHD), intervention details (type of exergame, exergame features, dose, setting, delivery mode, theoretical frameworks), and outcomes (measurement tool, unit of measurement, EFs domains, adherence) from included studies based on the Consolidated Standards of Reporting Trial-EHEALTH checklist (Eysenbach & CONSORT-EHEALTH Group, 2011) and the Consensus on Exercise Reporting Template (CERT) (Slade et al., 2016). The author will contact the study authors if there are missing or unclear data. Discussion will be conducted to resolve discrepancies between reviewers. If conflicts cannot be resolved, the third author will conduct mediation.

2.7 Outcomes and Prioritization

The primary outcome of this study is EFs (inhibition, working memory, and cognitive flexibility). Studies exploring changes in EFs between baseline and the end of interventions which used standardized outcome measures assessing either EFs or any specific domain of EFs as a continuous outcome will be included. For instance, Chang et al. (2022) used The Wisconsin Card Sorting Test, while Benzing & Schmidt (2019) used computer-based tests using E-Prime Software.

The secondary outcome of this systematic review and meta-analysis is the adherence to the exergaming interventions which will be measured through the drop-out rate.

2.8 Risk of Bias in Individual Studies

The risk of bias (RoB) in the included studies will be independently assessed by two researchers using the Cochrane RoB 2 tool for RCT. The authors will present RoB table for all included studies. Conflicts between reviewers will be resolved through discussion. The third author will conduct mediation if there are discrepancies that cannot be resolved.

The researchers will assess RCTs on the allocation concealments, sequence generation, blinding of outcome assessments, incomplete outcome data, reporting bias, and validity of outcome measures (Higgins et al., 2011). Blinding of participants and personnel to the group allocation will not be assessed since this would not be suitable for the exergaming intervention study. Rating as “low” or “some concerns” or “high” risk of bias will be used.

2.9 Data Synthesis

A narrative synthesis of the results in EFs outcome will be presented. A meta-analysis will be conducted where possible by pooling the appropriate data using Review Manager 2014. The authors will use random-effects meta-analysis since high variance of the unit of measurement and intervention design. The authors will use outcome data which reported using the change from baseline to calculate the standardised mean difference (SMD) and 95% confidence intervals (CIs). The authors will conduct imputation on *p*-value to obtain the standard deviation (SD) of the change from baseline if the studies did not report using change from baseline (Deeks et al., 2019).

The authors will calculate the I^2 statistics to assess heterogeneity (Higgins, 2002) and will be depicted as part of the forest plots in Review Manager. Where possible, the authors will independently perform subgroup analyses on the type of ADHD and exergame, the measurement methods between studies, and male versus female. Moreover, the authors will perform sensitivity analyses.

2.10 Publication Bias

The authors will utilize a funnel plot when the meta-analysis contains at least 10 studies.

2.11 Confidence in Cumulative Evidence

Two reviewers will use the Grading of Recommendation, Assessment, Development and Evaluation (GRADE) tool by Higgins & Green (2008) to independently assess the quality of

evidence. Disagreements between reviewers will be solved through discussion. If discrepancies cannot be resolved, the third author will conduct mediation.

3 DISCUSSION

The needs of optional approaches to treat executive dysfunctions in children with ADHD are crucial. Exergaming has shown beneficial effects to increase EFs in children with ADHD (Chang et al., 2022; Benzing & Schmidt, 2019). As far as authors concerned, this will be the first systematic review and meta-analysis investigating and summarising the evidence on the effects of exergaming on EFs in children with ADHD.

This proposed systematic review and meta-analysis may introduce some limitations. Since our topic is specific and the exergaming interventions to treat EFs in children with ADHD is relatively new, the results of eligible studies may be limited. Those can affect the possibility to conduct meta-analysis, sub-group analysis, and sensitivity analysis (Higgins et al., 2023). However, to address those limitations, the authors will use 11 databases and comprehensive search strategies which have been consulted with an academic librarian. Another potential limitation is the possibility of bias in the included studies; therefore, the authors will use the RoB 2 tool to assess the risk of bias of eligible studies.

On the other hand, there are some potential strengths of our study. Two reviewers and one arbiter will involve in the screening, data extraction, and RoB and GRADE assessments. Those approaches can minimize the selection bias (Stoll et al., 2019). Moreover, the authors will adhere to the PRISMA guideline to implement robust and rigorous systematic review and meta-analysis (Page et al., 2021).

4 CONCLUSION

This study will be the first systematic review and meta-analysis which will synthesis primary studies and summarise their findings on the effects of exergaming on EFs and adherence to PA in children with ADHD.

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REFERENCES

- American Psychiatric Association. (2022). *Diagnostic and statistical manual of mental disorders (5th ed., text rev.)*.
- Arnold, L. E., Hodgkins, P., Kahle, J., Madhoo, M., & Kewley, G. (2020). Long-term outcomes of ADHD: academic achievement and performance. *Journal of attention disorders, 24*(1), 73-85.
- Benzing, V., & Schmidt, M. (2019). The effect of exergaming on executive functions in children with ADHD: A randomized clinical trial. *Scandinavian journal of medicine & science in sports, 29*(8), 1243-1253.
- Biederman, J., Monuteaux, M. C., Doyle, A. E., Seidman, L. J., Wilens, T. E., Ferrero, F., Morgan, C.L., & Faraone, S. V. (2004). Impact of executive function deficits and attention-deficit/hyperactivity disorder (ADHD) on academic outcomes in children. *Journal of consulting and clinical psychology, 72*(5), 757.
- Boman, C., & Bernhardtsson, S. (2023). Exploring needs, barriers, and facilitators for promoting physical activity for children with intellectual developmental disorders: A qualitative focus group study. *Journal of Intellectual Disabilities, 27*(1), 5-23.
- Chan, Y. S., Jang, J. T., & Ho, C. S. (2022). Effects of physical exercise on children with attention deficit hyperactivity disorder. *Biomedical journal, 45*(2), 265-270.
- Chang, S. H., Shie, J. J., & Yu, N. Y. (2022). Enhancing executive functions and handwriting with a concentrative coordination exercise in children with ADHD: A randomized clinical trial. *Perceptual and Motor Skills, 129*(4), 1014-1035.
- Colomer, C., Berenguer, C., Roselló, B., Baixauli, I., & Miranda, A. (2017). The impact of inattention, hyperactivity/impulsivity symptoms, and executive functions on learning behaviors of children with ADHD. *Frontiers in psychology, 8*, 540.
- Deeks, J. J., Higgins, J. P., Altman, D. G., & Cochrane Statistical Methods Group. (2019). Analysing data and undertaking meta-analyses. *Cochrane handbook for systematic reviews of interventions, 241-284*.
- Diamond, A. (2013). Executive functions. *Annual review of psychology, 64*, 135-168.
- Eysenbach, G., & Consort-EHEALTH Group. (2011). CONSORT-EHEALTH: improving and standardizing evaluation reports of Web-based and mobile health interventions. *Journal of medical Internet research, 13*(4), e1923.
- Halperin, J. M., & Healey, D. M. (2011). The influences of environmental enrichment, cognitive enhancement, and physical exercise on brain development: can we alter the developmental trajectory of ADHD?. *Neuroscience & Biobehavioral Reviews, 35*(3), 621-634.
- Higgins, J. P., Altman, D. G., Gotzsche, P. C., Jüni, P., Moher, D., Oxman, A. D., & Sterne, J. A. (2011). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ, 343*.
- Higgins, J. P., & Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Statistics in medicine, 21*(11), 1539-1558.
- Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). (2023). *Cochrane Handbook for Systematic Reviews of Interventions version 6.4 (updated August 2023)*. Cochrane. Available from www.training.cochrane.org/hanbook
- Lefebvre, C., Glanville, J., Briscoe, S., Littlewood, A., Marshall, C., Metzendorf, M. I., Noel-Storr, A., Paynter, R., Rader, T., Thomas, J., & Wieland LS. (2019). Chapter 4: Searching for and selecting studies. *Cochrane Handbook for systematic reviews of interventions*. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). *Cochrane Handbook for Systematic Reviews of Interventions version 6.4 (updated October 2023)*. Cochrane, 2023. Available from www.training.cochrane.org/handbook
- Mercurio, L. Y., Amanullah, S., Gill, N., & Gjelsvik, A. (2021). Children with ADHD engage in less physical activity. *Journal of attention disorders, 25*(8), 1187-1195.
- Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., & Prisma-P Group. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic reviews, 4*, 1-9.
- Nigg, J. T., Blaskey, L. G., Huang-Pollock, C. L., & Rappley, M. D. (2002). Neuropsychological executive functions and DSM-IV ADHD subtypes. *Journal of the American Academy of Child & Adolescent Psychiatry, 41*(1), 59-66.
- Ogrodnik, M., Karsan, S., Malamis, B., Kwan, M., Fenesi, B., & Heisz, J. J. (2023). Exploring Barriers and Facilitators to Physical Activity in Adults with ADHD: A Qualitative Investigation. *Journal of Developmental and Physical Disabilities, 1-21*.
- Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., & McKenzie, J. E. (2021). PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ, 372*.
- Pradana, F. G. A., Baker, G., Wibowo, R. A. (2024). The effects of exergaming on executive functions in children with ADHD: A systematic review and meta-

- analysis of randomized controlled trials. PROSPERO: International prospective register of systematic reviews. Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42024549395
- Primack, B. A., Carroll, M. V., McNamara, M., Klem, M. L., King, B., Rich, M., & Nayak, S. (2012). Role of video games in improving health-related outcomes: a systematic review. *American journal of preventive medicine, 42*(6), 630-638.
- Salari, N., Ghasemi, H., Abdoli, N., Rahmani, A., Shiri, M. H., Hashemian, A. H., & Mohammadi, M. (2023). The global prevalence of ADHD in children and adolescents: a systematic review and meta-analysis. *Italian Journal of Pediatrics, 49*(1), 48.
- Shamseer, L., Moher, D., Clarke, M., Gherzi, D., Liberati, A., Petticrew, M., & Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ, 349*.
- Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2016). Consensus on exercise reporting template (CERT): explanation and elaboration statement. *British journal of sports medicine, 50*(23), 1428-1437.
- Staiano, A. E., & Calvert, S. L. (2011). Exergames for physical education courses: Physical, social, and cognitive benefits. *Child development perspectives, 5*(2), 93-98.
- Stoll, C. R., Izadi, S., Fowler, S., Green, P., Suls, J., & Colditz, G. A. (2019). The value of a second reviewer for study selection in systematic reviews. *Research synthesis methods, 10*(4), 539-545.
- Welsch, L., Alliot, O., Kelly, P., Fawcner, S., Booth, J., & Niven, A. (2021). The effect of physical activity interventions on executive functions in children with ADHD: a systematic review and meta-analysis. *Mental Health and Physical Activity, 20*, 100379.
- Wijffelaars, R. W., & Markopoulos, P. (2023). Collocated interactive outdoor games for children: A systematic literature review. *Entertainment Computing, 100615*.
- Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V., & Pennington, B. F. (2005). Validity of the executive function theory of attention-deficit/hyperactivity disorder: a meta-analytic review. *Biological psychiatry, 57*(11), 1336-1346.