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Physical fitness and executive functions in early childhood: A systematic review of recent evidence

Nemanja Lakicevic [a,b,*], Marko Manojlovic [c], Elena Chichinina [a], Apollinaria Chursina [a], Kristina Tarasova [a], Ewan Thomas [d], Yuming Zhong [e], Antonino Bianco [d], Patrik Drid [c]

[a] Faculty of Psychology, Lomonosov Moscow State University, Moscow, Russia
[b] Federal Scientific Center of Psychological and Interdisciplinary Research, Moscow, Russia
[c] Faculty of Sport and Physical Education, University of Novi Sad, Novi Sad, Serbia
[d] Department of Psychology, Educational Science and Human Movement, University of Palermo, Palermo, Italy
[e] School of Medical and Health Sciences, Edith Cowan University, Joondalup, WA, Australia

A R T I C L E I N F O

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A B S T R A C T

Background: Optimizing physical fitness (PF) and developing executive functions (EFs) is of great importance in preschool children. The link between PF, obtained through repetitive physical activity, and EFs is gaining increasing attention in recent years and we sought to systematically search the literature on the relationship between PF and EFs in preschool children published in the last five years.
Methods: Web of Science, Scopus, and PubMed were databases searched for the relevant literature. Original studies written in English and published in peer-reviewed journals including healthy children aged 3–6 years who were simultaneously tested for PF and EFs were considered eligible. To ensure transparent and accurate reporting we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Investigation was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO) database (CRD420251072802).
Results: A total of 20 studies (n = 3117, age=4.9 ± 2.5 years) were included in the final analysis. Aerobic fitness was consistently associated with better EF outcomes. Body composition, muscle strength, and flexibility were not associated with aspects of EF. Agility, speed, and power were positively associated with the parameters of working memory. The dynamic component of balance was correlated with enhanced inhibitory control. The link between agility, speed, power, and the static component of balance with inhibitory control was quite inconsistent. Similarly, conflicting evidence was observed regarding the association between dynamic and static balance with working memory aspects.
Conclusion: Aerobic fitness appears to play a significant role in enhancing EF development while the relationship between other components of PF and EFs seems less clear. Kindergartens are uniquely positioned to nurture children, making them ideal for promoting the development PF and EF through intentional, play-based, and developmentally aligned experiences.

1. Introduction

Establishing the health benefits of physical activity (PA) in preschool children (3–6 years) is challenging given the sparse evidence currently available in this population and the fact that risk factors for non-communicable disease do not appear until adulthood.[1] However, a limited number of available studies have repeatedly shown that regular PA increases bone health and prevents weight gain in preschool children, while evidence pertaining to cardiometabolic health and cognition is insufficient.[1] The current World Health Organization (WHO) guidelines on PA in preschool children recommend no less than 180 min of PA per day, of which at least 60 min should be moderate-to-vigorous intensity (MVPA).[2] A recent systematic review of accelerometer studies on the adherence of preschool children to the WHO daily PA guidelines outlined that 60 % of preschoolers adhered to the overall PA recommendation, 78 % adhered to the total PA aspect of the recommendation, and 90 % adhered to the MVPA factor of the recommendation.[3] Within an even more recent systematic review, 7 studies showed below 30 %

* Corresponding author at: Faculty of Psychology, Lomonosov Moscow State University, Moscow, Russia.
E-mail address: lakinem89@gmail.com (N. Lakicevic).

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compliance with the overall PA guidelines, 19 below 70 %, and 22 from 70 % to 100 %, with boys being consistently more active than girls.[4]

At a fundamental level, PA can be seen as a means to achieve physical fitness (PF) which has profound and far-reaching effect on nearly every endeavor that children will face in their life. Yet, PF does not pertain solely to the capacity to function efficiently and effectively in a physical sense, but supports a host of other vital functions for children such as brain development (attention, memory, and problem-solving),[5,6] bone and muscle development,[7,8] emotional well-being,[9] social skills development[10] and establishing life-long healthy habits.[11] Given that during preschool years children undergo rapid growth and physical, mental and emotional development, setting PF as the pedestal of development plays a crucial role in shaping their overall health and future habits. For a majority of children, the most optimal place where they would engage in their daily PA (and improve their PF) is kindergarten, as they spend majority of their waking time within this environment.[12,13] When compared across different environments, the total daily PA levels of preschool children show measurable variation, especially in kindergartens where many preschoolers are highly sedentary, spending up to ~56 min/hr physically inactive in some settings.[14] While this sedentary time might be used for various cognitive tasks, in ideal circumstances, kindergarten should be a place where preschoolers develop both physically and cognitively, given the intrinsic link between the two.[15] Indeed, supervised PA lasting 3–24 weeks, ~30 min/session, ~2 sessions/week led to significant improvements in attention, inhibitory control (IC), working memory (WM), cognitive flexibility (CF) and vocabulary in preschoolers.[16]

Developing executive functions (EFs) like IC, WM and CF in preschoolers is also of great importance as these skills determine later academic readiness,[17,18] predict math success[19] and influence learning related behavior in general.[20] Furthermore, a large meta-analysis (55 studies, n = 215212) delineated that well developed EFs i.e., self-regulation skills at age 4 were positively associated with social and school engagement and better academic performance, and negatively associated with internalizing problems, peer victimization, and externalizing problems, in early school years (~age 8) which subsequently led to a whole cascade of positive effects in multiple domains of life in later stages.[21]

Based on the available evidence, it follows that higher physical fitness (PF) might lead to better executive functions (EFs) in preschool children. While some individual studies suggested positive effects of PF on IC and WM, available evidence published up to 2022 seems narrow, mixed, and often methodologically weak.[1,22,23] Furthermore, to the extent currently known, no systematic review has been published studying the relationship between PF and EFs in preschool children. Therefore, we sought to thoroughly search the literature published in 2020 onwards to investigate the relationship between PF (not daily or weekly PA levels) and EFs in preschool children. We hypothesized that preschoolers with greater PF will have greater EF scores.

2. Methods

2.1. Study design and protocol registration

The present literature review with narrative synthesis was conducted in accordance with the guidelines highlighted in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[24] All the relevant aspects of the PRISMA checklist are provided as online Supplementary Material 1. The protocol of the investigation was prospectively registered using the International Prospective Register of Systematic Reviews (PROSPERO) database (registration number, CRD420251072802). There were no substantial modifications with respect to the study methodology following the completion of the registration process.

2.2. Search strategy

An extensive search of the existing literature was carried out via primary and secondary sources of scientific evidence. The relevant databases, including the Web of Science, Scopus, and PubMed, referred to the primary sources of evidence. Taking into account the growing evidence regarding the examined topic and that previously published systematic review covered the evidence published up to 2022, only studies available from January 1, 2020, to June 1, 2025, in the English language were assessed for eligibility. The overall search strategy was developed by analyzing the relevant systematic reviews with meta-analyses and employing the MeSH expressions. The Boolean search syntax with operators "AND" and "OR" with keywords referring to the categories of "physical fitness," "executive functions," and "preschool children" were implemented in all the mentioned databases. The comprehensive literature search strategy is demonstrated in Supplementary Material 2. The secondary sources of the existing evidence pertained to backward citation tracking, forward citation tracking, and the checking of the references of the systematic reviews closely related to the current overall content. Three reviewers (NL, MM, and ET) independently searched the emphasized sources of potentially relevant investigations. Finally, to ensure that all studies are encompassed, an updated search of each electronic database using the already highlighted strategy was performed on July 1, 2025.

2.3. Selection process

The selection of the available investigations comprised the three crucial phases. Firstly, the analysis of titles and abstracts of the scientific literature was carried out. Secondly, the full-text studies were sought for retrieval. Thirdly, the studies were subjected to a comprehensive assessment in the context of the inclusion and exclusion criteria. Two independent reviewers (NL and MM) were involved in all phases of the study selection. All inconsistencies between reviewers were resolved after a discussion; however, regarding the potential disagreement among the reviewers following the discussion, the third investigator (ET) clarified all controversies.

2.4. Eligibility criteria

The PECOS (P – population, E – exposure, C – comparison, O – outcome, and S – study design) framework for observational studies[25] has been implemented with respect to the overall eligibility procedure. (P) preschool children between 3 and 6 years old; respondents with disabilities were not considered for inclusion. In addition, there were no restrictions regarding the sex, body mass index (BMI), and PA level of the addressed population; (E) PF, including all the well-known and established components of health-related PF and skill-related PF among the preschool children;[26] (C) no comparison was performed in the current systematic review with narrative synthesis; (O) core EFs, such as aspects of the WM, CF, and IC; and (S) observational studies, including prospective and retrospective cohort, cross-sectional, and case-control. Publications such as editorials, systematic reviews and meta-analyses, books, case reports, conference papers, and non-peer-reviewed journal articles were not considered appropriate for inclusion.

2.5. Data extraction

Data extraction was performed using a Microsoft Excel sheet which was conducted independently by two reviewers (NL and MM), and all discrepancies were resolved after an extensive discussion. The extracted data were divided into the following categories:[1] authors with year of the study's publication, country, study design, and level of evidence;[2] sample size and demographic characteristics of the analyzed population, such as sex. mean age, age range, and BMI;[3] parameters of PF with all applied tests;[4] EFs components and measuring tools that assessed each variable; and[5] crucial findings concerning the studies that satisfied the PECOS requirements. More specifically, the values of the correlation coefficients (r, Pearson, and Spearman correlation coefficients, as well as partial correlation), beta coefficients (β, regression analyses), Cohen's *d*, and chi-square were retrieved from the existing literature. If the emphasized data were missing from certain investigations, the corresponding authors were contacted via email. If no adequate response was obtained from the authors, the studies were excluded. Since all data were available in the tables and text of the articles, the extraction from the figures was not performed.

2.6. Study quality appraisal

The National Heart, Lung, and Blood Institute (NHLBI) Quality Assessment Scale for Observational Cohort and Cross-Sectional Studies evaluated the methodological quality of the studies included in the qualitative analysis.[27] The NHLBI tool consists of 14 items referring to the population characteristics, exposure, outcome, and confounding variables. In addition, the items are also related to the blinding and follow-up period of the investigations. Each aspect of the scale is rated as 1 ("Yes") and 0 ("No"/or "cannot determine," "not applicable," and "not reported"), providing a possible score between 0 and 14 for all studies. The overall scores of 0–3 indicated the "poor" quality, 4–6 indicated the "fair" quality, 7–10 indicated the "good" quality, and 11–14 indicated the "excellent" quality.[28] The assessment of the methodological quality was performed independently by two reviewers (NL and MM). Disagreements between the reviewers were resolved via a discussion or following a consultation with the third investigator (ET).

2.7. Data synthesis

Considering a high level of methodological heterogeneity observed among included studies, the meta-analysis was precluded. Specifically, substantial heterogeneity was recorded with respect to the tests that evaluated the PF and outcome variables. Hence, the qualitative synthesis approach has been applied for the current systematic review. The relevant data were presented in a tabular format and narratively synthesized in the text. Additionally, the interpretation of the obtained results primarily relied on the values of the previously highlighted effect sizes from the involved investigations.

3. Results

3.1. Study selection

The results referring to the comprehensive search of electronic databases and the aspects of the selection of the existing studies are given in Fig. 1. A total of 1.157 records were identified via the primary sources of evidence, while 461 duplicates were removed using the Zotero software. After the screening of the titles and abstracts, 612 records were eliminated; therefore, 84 full-text reports were included in the third phase of the literature selection process. The available studies were most frequently excluded due to the inappropriate population (n = 23) and examined exposure variables (n = 15). Moreover, several studies were also eliminated due to the missing the age range of the addressed population (n = 2). Regarding the secondary sources of evidence, backward citation tracking yielded 1 additional record. Overall, 20 studies fulfilled all highlighted PECOS criteria and were involved in the qualitative analysis.

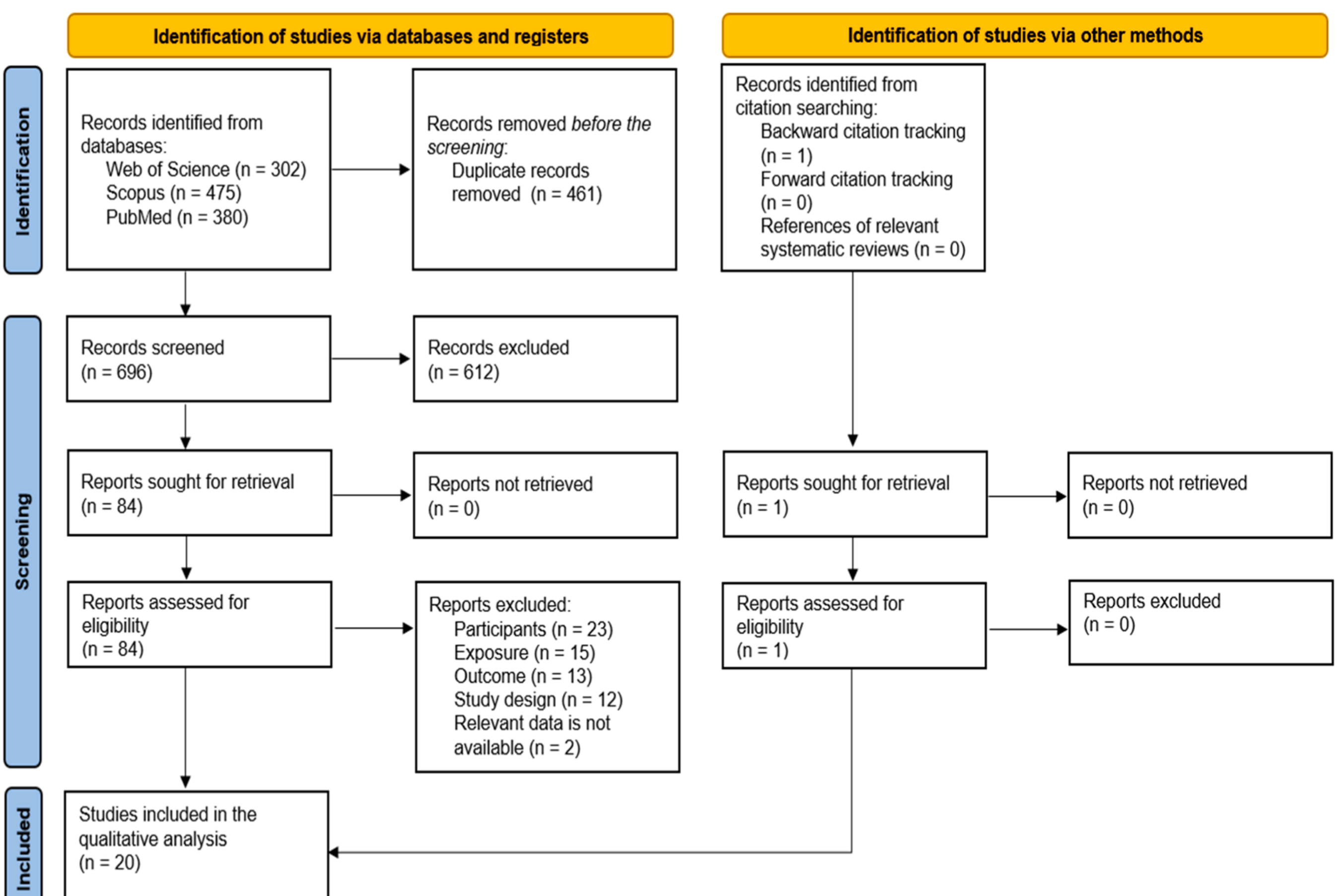

Fig. 1. PRISMA flow diagram demonstrates the databases search and the relevant aspects of the study selection process.

3.2. Study characteristics

All included studies were published between 2020 and 2025 and were conducted in China,[29–33] the USA,[34–38] Spain,[39–41] Russia.[42,43] Finland,[44] Japan,[45] the Netherlands,[46] Turkey,[47] and Brazil.[48] There were 18 cross-sectional[6,7,9,10,12–17,19,20–26] and 2 cohort[8,11] studies, all indicating level III of evidence. A total of 3117 preschool children (1619 boys and 1498 girls) were represented across the studies included in this systematic review. The examined population was, on average, 4.9 ± 2.5 years old with a BMI of 15.6 ± 1.8 kg/m^2 (Table 1). Aerobic fitness was assessed in 6 studies,[6,7,11,13,17,19] commonly implementing the multi-stage 20-meter shuttle-run test, while body composition[7,10,12,14,26] was addressed only through body mass index (BMI). Muscle strength was evaluated in 3 studies[7,17,19] using the handgrip strength test whereas flexibility was tested in 3 studies,[8,10,20] most frequently with the sit-and-reach test. Regarding the skill-related PF, agility, and speed were assessed in 7 studies,[7,10,17,19,20,23,25] while the standing broad jump commonly referred to the power testing.[7,8,10,17,19,20,25] Dynamic[8,10,15,16,22,24] and static[7,9,21–24] components of balance were independently examined in 6 studies with a one-leg balance test and balance beam, respectively. One study[33] evaluated the coordination by applying the double-leg timed hop.

As for EF, the aspects of WM were analyzed in 12 investigations,[6,8,10,11,14,15,17,20–24] with various tests emphasized in Table 2. The CF was measured in 12 studies[8,10–15,17,19–21,24] via dimensional change card sort test. The 19 studies[6–14,16,17,19–26] addressed IC, commonly employing the "Go & No-Go" and Flanker tasks.

3.3. Results of syntheses

The higher levels of overall PF score were associated with improved EF parameters, including WM, CF, and IC. The increased aerobic fitness was consistently and weakly to moderately associated with the superior values of IC. The range of the revealed effect size was between r = 0.2 and r = 0.4. Still, the other evaluated variables of health-related PF, such as body composition, muscle strength, and flexibility, were not associated with the EF aspects. Agility, speed, and power were positively associated with the parameters of WM. In addition, the increased values of the dynamic component of balance were correlated with enhanced IC. The recorded effect size was weak to moderate (r = 0.2, r = 0.49, respectively). The relationship between agility, speed, power, and the static component of balance with IC was quite inconsistent (Table 2). Similarly, conflicting evidence was observed regarding the association between dynamic and static balance with WM aspects. One study[33] indicated that coordination was inversely correlated with WM, CF, and IC.

3.4. Quality assesment of studies

The assessment of the study methodological quality is demonstrated in Table 3. A total of 15 studies[6,7,9,10–14,17,19,21–23,25,26] had "good" quality and 5 studies[8,15,16,20,24] were rated as "fair." The range of the methodological quality was between 5 and 10 for all included studies. The overall mean score of the current systematic literature review was 7.2, indicating the "good" quality. Score 1 was commonly given to the

Table 1
Characteristics of studies that fulfilled all eligibility criteria.

Authors and year of the study's publication	Country	Study design	Level of evidence	Sample size and sex	Age (years)	BMI (kg/m^2)
Aoyama et al. 2020[23]	Japan	Cross-sectional	III	N = 43; B/G = 25/18	Age range = 4–6; mean age = 5.6 ± 7.7	NR
Becker and Nader 2021[11]	USA	Cohort	III	N = 81; B/G = 42/39	Age range = 3–5; mean age = 4.3 ± 6.6	NR
Beck et al. 2020[12]	USA	Cross-sectional	III	N = 85; B/G = 43/42	Age range = 4–5; mean age = 5 ± 6.9	15.9 ± 1.4
Canli et al. 2025[25]	Turkey	Cross-sectional	III	N = 139; B/G = 78/61	Age range = 4–6; mean age = 6 ± 1	16.1 ± 1.9
Chichinina et al. 2025[21]	Russia	Cross-sectional	III	N = 272; B/G = 147/125	Age range = 5–6; mean age = 5.1 ± 4.1	NR
Chou et al. 2022[8]	China	Cohort	III	N = 273; B/G = 141/132	Age range = 4–5; mean age = 4.6 ± 0.4	NR
Escolano-Pérez et al. 2022[16]	Spain	Cross-sectional	III	N = 43; B/G = 15/28	Age range = 5–6; mean age = 5.8 ± 3.5	NR
García-Alonso et al. 2025[17]	Spain	Cross-sectional	III	N = 241; B/G = 121/120	Age range = 3–6; mean age = 4.8 ± 0.8	16.1 ± 1.4
Keye et al. 2021[13]	USA	Cross-sectional	III	N = 59; B/G = 34/25	Age range = 4–6; mean age = 5 ± 0.6	NR
Li et al. 2022[7]	China	Cross-sectional	III	N = 120; B/G = 66/54	Age range = 3–6; mean age = 4.9 ± 0.3	15.8 ± 1.8
Luo et al. 2023[6]	China	Cross-sectional	III	N = 127; B/G = 74/53	Age range = 3–6; mean age = 4.4 ± 0.7	15.4 ± 1.3
Martins et al. 2020[26]	Brazil	Cross-sectional	III	N = 42; B/G = 24/18	Age range = 3–5; mean age = 3.7 ± 0.7	15.4 ± 1.5
Nieto-López et al. 2020[19]	Spain	Cross-sectional	III	N = 362; B/G = 179/183	Age range = 5–6; mean age = 5.3 ± 3.5	15.5 ± 3.3
Rhee et al. 2021[14]	USA	Cross-sectional	III	N = 92; B/G = 50/42	Age range = 4–6; mean age = 5.1 ± 0.7	16.5 ± 2.5
Stuhr et al. 2020[15]	USA	Cross-sectional	III	N = 41; B/G = 18/23	Age range = 5–6; mean age = 5.9 ± 0.3	15.4 ± 1.9
Van Der Veer et al. 2020[24]	Netherlands	Cross-sectional	III	N = 198; B/G = 102/96	Age range = 3–5; mean age = NR	NR
Vanhala et al. 2022[22]	Finland	Cross-sectional	III	N = 214; B/G = 104/110	Age range = 3–5; mean age = 3.9 ± 0.6	NR
Veraksa et al. 2021[20]	Russia	Cross-sectional	III	N = 261; B/G = 130/131	Age range = 5–6; mean age = 5.7 ± 0.3	NR
Zhang et al. 2024[9]	China	Cross-sectional	III	N = 153; B/G = 80/73	Age range = 3–6; mean age = 4.9 ± 0.7	15.2 ± 1.7
Zhou et al. 2024[10]	China	Cross-sectional	III	N = 271; B/G = 146/125	Age range = 3–6; mean age = 4.6 ± 9.9	15.2 ± 1.7

B boys, *BMI* body mass index, *G* girls, *N* number, *NR* not reported

Table 2
Analyzed PF components, EF parameters, and obtained results of all involved investigations.

Authors and year of the study's publication	Health-related PF	Skill-related PF	Assessed outcomes	Essential findings
Aoyama et al. 2020[23]	NA	Agility - side-hop repetition task; static balance - closed one-legged task	Spatial WM - the hand movement task; auditory WM - the backward digit span subtest; IC - fruit/vegetable stroop task	Values recorded at the agility test positively correlated with spatial and auditory WM ($r = 0.30$ and $r = 0.39$, respectively). Greater balance was associated with increased results on the auditory WM test ($r = 0.31$).
Becker and Nader 2021[11]	Aerobic fitness - multistage 20-meter shuttle-run test	NA	EFs, including WM, CF, and IC - head-toes-knees-shoulders; IC - day-night stroop	The examined exposure variable positively correlated with the head-toes-knees-shoulders ($r = 0.31$) and day-night stroop ($r = 0.24$) tests.
Beck et al. 2020[12]	Body composition - BMI	NA	CF - dimensional change card sort test; IC - delay choice (self and other)	A statistically significant positive relationship was revealed between BMI and IC task ($r = 0.21$).
Canli et al. 2025[25]	NA	Agility - 20-yard shuttle test; balance - SensBalance MiniBoard; dy - countermovement jump test	IC - "Go & No-Go" tasks, including the accuracy number of "Go", the accuracy number of "No-Go," and reaction time parameters	Higher levels of balance were associated with increased values of accuracy number of the "Go" task ($\beta = 0.08$), while a negative relationship was observed between the mentioned parameter of PF and reaction time ($\beta = -1.32$). In addition, the lower time necessary to complete the administered agility test correlated with greater results of the accuracy "Go" test ($\beta = -1.98$).
Chichinina et al. 2025[21]	NA	Static balance - one-leg balance test	Verbal WM - NEPSY-II "Sentences Repetition" test; visual WM - NEPSY-II "Memory for Designs" test; CF - dimensional change card sort test; IC - NEPSY-II "Inhibition" test; IC - NEPSY-II "Statue" test	The increased values recorded at the one-leg balance test were associated with the superior results of tasks referring to the visual VM ($r = 0.17$), IC ("Statue," $r = 0.25$), and CF ($r = 0.13$).
Chou et al. 2022[8]	Flexibility - sitting body flexion	Dynamic balance - balance beam; power - standing long jump, tennis ball throw length, and both leg successive jumping; speed - 10-meter run	EF aspects, including WM, CF, and IC - head-toes-knees-shoulders	The overall score referring to the evaluated PF components was positively associated with EF parameters ($r = 0.19$).
Escolano-Pérez et al. 2022[16]	NA	Dynamic balance - walking heel-to-toe test	IC - "Childhood Executive Functioning Inventory " questionnaire, items pertaining to the IC	Participants with increased results concerning the dynamic balance had higher values of the evaluated EF parameter ($d = 0.76$).
García-Alonso et al. 2025[17]	Aerobic fitness - multistage 20-meter shuttle-run test; muscle strength - handgrip strength	Agility and speed - 4 × 10-meter shuttle-run test; power - standing long jump	Visual-spatial WM - "Mr. Ant" task; phonological WM - "Not This" test; CF - card sorting; IC - "Go & No-Go" tasks	Each of the applied parameters of PF, including the overall PF score, was positively associated with the WM aspects, CF, and IC, except in the context of aerobic fitness, phonological WM, and CF. The range of the recorded effect sizes was between $\beta = 0.2$ and $\beta = 0.4$.
Keye et al. 2021[13]	Aerobic fitness - six-minute walk test	NA	CF - hearts and flowers task; IC - Eriksen Flanker task	Higher values of the recorded distance walked with respect to the implemented aerobic fitness test correlated with the increased CF ($r = 0.39$). Additionally, an inverse relationship was found between aerobic fitness and IC, evaluated using the reaction time ($r = -0.26$).
Li et al. 2022[7]	Aerobic fitness - multistage 20-meter shuttle-run test; body composition - BMI; muscle strength - handgrip strength	Agility and speed - 2 × 10-meter shuttle-run test; static balance - one-leg balance test; power - standing long jump	IC - Flanker task expressed as accuracy and reaction time	A statistically significant negative association was observed between the overall PF score, aerobic fitness, balance, and reaction time as a measure of the Flanker task ($\beta = -2.49$, $\beta = -23.28$, $\beta = -12.04$, respectively).
Luo et al. 2023[6]	Aerobic fitness - multistage 20-meter shuttle-run test	NA	WM - "Mr. Ant" task; IC - "Go & No-Go" tasks	Higher values of aerobic fitness correlated with superior results of the WM test ($r = 0.25$). In addition, a positive relationship between the examined parameter of PF and various aspects of the IC task, including impulse control ($r = 0.41$), "Go" accuracy ($r = 0.37$), and "No-Go" accuracy ($r = 0.36$), was also revealed.
Martins et al. 2020[26]	Body composition - BMI	NA	IC - "Go & No-Go" tasks	There was no statistically significant relationship between BMI and the addressed variable of EF.
Nieto-López et al. 2020[19]	Aerobic fitness - multistage 20-meter shuttle-run test; muscle strength - handgrip strength	Agility and speed - 4 × 10-meter shuttle-run test; power - standing broad jump	CF - dimensional change card sort test; IC - an adapted version of the Eriksen Flanker task	Only increased values of aerobic fitness were associated with greater levels of the IC outcome ($r = 0.23$).

(continued on next page)

Table 2 (*continued*)

Authors and year of the study's publication	Health-related PF	Skill-related PF	Assessed outcomes	Essential findings
Rhee et al. 2021[14]	Body composition - BMI	NA	WM, CF, and IC - "The Behavior Rating Inventory of Executive Function Questionnaire" – Preschool Version	No statistically significant relationship was observed between the assessed component of body composition and relevant EF aspects.
Stuhr et al. 2020[15]	NA	Dynamic balance - star excursion balance test	WM - toolbox list sorting working memory test; CF - wisconsin card sorting test	Dynamic balance was not associated with the examined variables pertaining to the EF.
Van Der Veer et al. 2020[24]	NA	Dynamic balance - walking on toes; static balance - one-leg balance test	WM - forward corsi block; CF - conflict task; IC - day/night	There was no significant relationship between balance, irrespective of the analyzed components, and all relevant EF parameters.
Vanhala et al. 2022[22]	NA	Dynamic balance - balancing beam; static balance - one-leg balance test	WM - pictorial updating task; IC - Flanker task	The dynamic balance was positively associated with the WM ($r = 0.27$) and IC ($r = 0.26$). Still, no statistically significant relationship was recorded between static balance and the examined EF variables.
Veraksa et al. 2021[20]	Flexibility - sit and reach test	Agility and speed - 4 × 5-meter shuttle-run test; power - standing broad jump and throwing a tennis ball	Verbal WM - sentences repetition test; visual WM - memory for designs; CF - dimensional change card sort test; IC - the subtest inhibition	The overall score of the included PF parameters was positively correlated with the visual and verbal WM and IC.
Zhang et al. 2024[9]	NA	Static balance - one-leg balance test	IC - "Go & No-Go" tasks, including the accuracy and reaction time measures	A statistically significant positive relationship was revealed between the static balance and the accuracy aspect of IC ($\beta = 0.01$).
Zhou et al. 2024[10]	Body composition - BMI; flexibility - sit and reach test	Agility and speed - 10-meter shuttle-run test; dynamic balance - balance beam walking test; power of lower limbs - standing long jump; power of upper limbs - tennis ball throwing; coordination - double-leg timed hop	WM - digit span task; CF - dimensional change card sort test; IC - head-toe-knee-shoulder task	The following PF components were associated with the WM: power of lower limbs ($r = 0.52$), power of upper limbs ($r = 0.43$), agility and speed ($r = -0.45$), balance ($r = -0.32$), and coordination ($r = -0.50$). The PF parameters, such as the power of lower limbs ($r = 0.52$), power of upper limbs ($r = 0.46$), agility and speed ($r = -0.47$), balance ($r = -0.33$), and coordination ($r = -0.49$) correlated with the CF. The various aspects of the PF, including the power of lower limbs ($r = 0.66$), power of upper limbs ($r = 0.58$), agility and speed ($r = -0.59$), balance ($r = -0.49$), and coordination ($r = -0.54$) were significantly associated with the IC.

BMI body mass index, *CF* cognitive flexibility, *EF* executive function, *IC* inhibitory control, *NA* not applicable, *PF* physical fitness, *WM* working memory

Table 3
Evaluation of methodological quality of studies included in the qualitative analysis.

Authors and year of the study's publication	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total score	Overall rating
Aoyama et al. 2020[23]	1	1	1	1	0	0	0	1	1	0	1	0	0	0	7	Good
Becker and Nader 2021[11]	1	1	1	1	0	0	1	1	1	1	1	0	0	1	10	Good
Beck et al. 2020[12]	1	1	0	1	0	0	0	1	1	0	1	0	0	1	7	Good
Canli et al. 2025[25]	1	1	1	1	1	0	0	0	1	0	1	0	0	1	8	Good
Chichinina et al. 2025[21]	1	1	1	1	0	1	0	0	1	0	1	0	0	0	7	Good
Chou et al. 2022[8]	1	1	0	1	0	0	0	0	1	0	1	0	0	1	6	Fair
Escolano-Pérez et al. 2022[16]	1	1	0	1	0	0	0	0	1	0	1	0	0	0	5	Fair
García-Alonso et al. 2025[17]	1	1	0	1	0	1	0	1	1	0	1	0	0	1	8	Good
Keye et al. 2021[13]	1	1	1	1	1	0	0	1	1	0	1	0	0	1	9	Good
Li et al. 2022[7]	1	1	1	1	0	0	0	0	1	0	1	0	0	1	7	Good
Luo et al. 2023[6]	1	1	1	1	1	0	0	1	1	0	1	0	0	1	9	Good
Martins et al. 2020[26]	1	1	0	1	0	1	0	0	1	0	1	0	0	1	7	Good
Nieto-López et al. 2020[19]	1	1	1	1	0	0	0	0	1	0	1	0	0	1	7	Good
Rhee et al. 2021[14]	1	1	0	1	0	0	0	1	1	0	1	0	0	1	7	Good
Stuhr et al. 2020[15]	1	1	0	1	0	0	0	0	1	0	1	0	0	1	6	Fair
Van Der Veer et al. 2020[24]	1	1	1	1	0	0	0	0	1	0	1	0	0	0	6	Fair
Vanhala et al. 2022[22]	1	1	1	1	0	1	0	1	1	0	1	0	0	1	9	Good
Veraksa et al. 2021[20]	1	1	0	1	0	0	0	1	1	0	1	0	0	0	6	Fair
Zhang et al. 2024[9]	0	1	1	1	1	0	0	0	1	0	1	0	0	1	7	Good
Zhou et al. 2024[10]	1	1	1	1	1	0	0	0	1	0	1	0	0	0	7	Good

All available items are scored as 1 ("Yes") or 0 ("No"/or "cannot determine," "not applicable," and "not reported"). The existing overall rating for each study is "poor"(0−3), "fair",[4–6] "good",[7–10] and "excellent"[11–14] *1* research question or objective, *2* study population, *3* participation rate of eligible persons is at least 50 %, *4* recruitment of the respondents is from the same or similar populations, *5* power analysis, *6* exposure was assessed before the outcome, *7* sufficient timeframe regarding the association between exposure and outcome, *8* different levels of exposure, *9* exposure variables, *10* exposures were repeatedly evaluated, *11* outcome measures, *12* blinding, *13* loss to follow-up after baseline assessment was 20 % or less, *14* analysis of confounding variables

aspects with respect to the objective of the study, characteristics of the preschool children, as well as analysis of the exposure and outcome measures. Contrary, loss to follow-up and blinding were rated as 0.

4. Discussion

The goal of the present study was to synthesize a state-of-the-art evidence (2020–2025) pertaining to the association between PF components and core EFs among preschool children. The obtained results demonstrated that the overall PF score was positevely associated with the evaluated parameters of EFs. In terms of health-related PF, greater values of only aerobic fitness were associated with improved results of the IC. Agility, speed, and power positively correlated with the WM, while the higher levels of the dynamic component of balance were associated with increased values of IC. Moreover, the findings of the current study indicated that a relationship between several components of skill-related PF, including agility, speed, power, and a static component of balance, with IC, was indeed inconclusive. Finally, the assessed variables of PF did not predict CF among the examined population.

In our review, aerobic fitness has consistently been shown as the most reliable aspect of PF associated with EF performance in preschool children. Comparable observations were found in a recent meta-analysis where children who engage in aerobic exercise consistently showed considerable improvements in IC, WM and WF.[49] While biological mechanisms of aerobic exercise influencing cognition in children (and others) is multifactorial, the most important one seems to be the increased cerebral blood flow and oxygen delivery to the brain, particularly the prefrontal cortex – brain area essential for EFs.[49] Also, aerobic exercise stimulates the release of Brain-Derived Neurotrophic Factor, a neurotrophic protein that supports neuroplasticity, neurogenesis and enhanced neurotransmitter signaling[50] and is potent in enhancing EFs.[51] From psychological perspective, activities such as aerobic exercise can influence self-regulation, attention control, and motivation, through repeated practice of decision-making, rule-following, and motor planning.[52]

Being physically active has also been found to positevely affect EFs in primary school children, concurrently benefiting attention and overall academic performance.[53] Furthermore, recent evidence indicates that PA interventions improved overall EFs of children and adolescents with attention deficit hyperactivity disorder (ADHD) with moderate-to-large positive effect on IC and CF.[54] In a similar manner, novel insights show that PA interventions elicited significant benefits for CF, IC, WM, and higher-level functions in children and adolescents with neurodevelopmental disorders.[55] Similar findings have also been found in overweight and obese children where the evidence indicated that PA interventions can improve several domains of cognition, including EFs.[56] In addition, regular PA is also associated with lower levels of overweight and obesity in preschool children.[1]

In our study, skill-related PFs such as agility, speed, and power were positively associated with the parameters of WM. Although our review primaitly focused on cross-sectional studies, recently published intervention studies exploring the development of skill related PF and EF show mixed findings. Eight weeks of coordination based program performed (2x/wk, 25 min/session) in Turkish preschoolers increased vertical jump scores and balance, but showed no difference in IC compared to control group.[57] In a similar manner, another study on Turkish preschool children showed that eight weeks of structured coordinative training (2x/wk, 30 min/session) showed improvements in static balance, sideways jump and eye-hand coordination, but no changes in IC compared to control group.[58] Another study coming from China implemented a twelve-week structured motor learning training (2x/wk, 30 min/session) and compared EF outcomes in preschool children (training vs free play control group). The authors found significant improvements in WM, with no changes in CF and IC.[59] It has been postulated that interventions emphasizing both PF and EF development through cognitively enhanced PA might be the best tool available to enhance EFs in preschool children as they bring 'the best of both worlds'.[60]

Children's PA should be viewed in the light of other daily constituents such as sleep and sedentary behavior that make up the entire 24-h so a change in any behavior must be done at the expense of one of the other behaviors. Indeed, amounting evidence delineates a unique approach to foster both PF and EFs in preschool children, through cognitively enhancing PA, whereby cognitive tasks that would usually be performed sitting, are combined with some form of PA to accrue twofold advantage of being physically and cognitively active in unison while also reducing the sedentary behavior and sparing time for other daily activities.[61] Namely, cognitively engaging PA, significantly improves cognitive domains such as EFs, IF, and attention, with moderate to large effect sizes.[62] Furthermore, cognitively enhancing PA has shown to be superior in increasing EFs in over PA without cognitive task in children aged 4–12.[63,64] Nevertheless, even without cognitive elements, PA remains highly effective in improving EFs in children of various ages, especially MVPA.[65] Though, cognitively enhancing PA is particularly important in the light of findings on skill related fitness from our review where children who displayed better coordination, balance and agility showed better EF outcomes. In addition, preschool age is a period where both motor and EF skills develop rapidly.[66,67] Clearly, cognitively enhanced PA may integrate skill-focused, cognitively demanding movement activities to optimize both PF and EF outcomes.

Despite culture and country-based differences globally, available evidence shows that preschool children spend majority of their waking time in kindergartens.[13] This setting appears ideal to foster the development of multiple domains of PF and EFs while subsequently reducing the sedentary time, which is currently pervasive in kindergartens.[14] Evidence indicates that children spend 56 % of time sedentary pursuits[68] with less than 20 % of their time in PA kindergartens.[69] Though, children's PA at kindergarten is complex and should be seen through a broad lens. Namely, caregivers' behavior and children's PA levels in the kindergarten are strongly associated[70] and literature indicates that caregivers have a particularly low competence and self-efficacy pertaining to PA which directly impact their desire to foster PA in kindergartens.[70] Consequently, educators spend more than 60 % of their time being sedentary in kindergartens,[71] which directly affects children's likelihood of engaging in PA. Thus, efforts to educate parents and caregivers on PA is warranted for their own benefits and for the benefit of children they are taking care of.

Our study should be considered in the light of several limitations. First, we have included only studies published in the last five years and thus possibly omitted studies that have been published prior (reasons for this decision are given above). Next, we sought to derive evidence from studies that are published in English and possibly missed evidence data that was published in other languages. Thus, we found a rather limited number of studies that addressed the relationship between EF and PF in preschool children. Moreover, studies that we have included are mostly cross-sectional in nature, so we could not elaborate on the causal relationship between the variables of interest, but rather to describe associations and derive conclusions from these.

Strengths of our study stem primarily from following rigid protocols of accurate and transparent reporting of up-to-date studies published within the last 5 years. Furthermore, we followed stringent eligibility criteria whereby each included study was meticulously and thoroughly described in a tabular and narrative manner while performing meta-analysis was precluded due to high heterogeneity among studies. Notably, to the best of our knowledge, our study is the first systematic review ever to investigate the relationship between PF and EFs in preschool children. It must be emphasized that previously published studies have predominantly dealt with daily or weekly PA levels and EFs, but we included studies that have simultaneously measured PF and EFs in preschool children. This approach offers a different outlook on PF in the light of optimizing EFs of preschoolers and shift the paradigm from daily PA to the current PF and EFs and their potential interconnectedness. Of importance, within our study, data equally represented boys and girls coming from various countries and several continents. In addition, provided evidence might offer a direction on future development of standardized test battery for both PF and EFs ideally utilizing the most reliable and valid tools available for this population.

5. Conclusions

Aerobic fitness appears to play a significant role in enhancing EF development in preschoolers while the relationship between other components of PF and EFs seems less clear. Agility, speed, and power were positively associated with the parameters of WM. Kindergartens are uniquely positioned to nurture children, making them ideal for promoting PF and EF development through intentional, play-based, and developmentally aligned experiences. Targeted interventions designed to promote PA among girls are critically needed, as current evidence consistently demonstrates that boys engage in higher levels of PA across studies. Developing gender-responsive strategies may help address these disparities by identifying and reducing barriers that disproportionately limit girls' participation. Such efforts are essential for ensuring equitable opportunities for PA and supporting health and developmental outcomes across populations, including EF enhancement.

List of abbreviations

EF – executive functions
PA – physical activity
PF – physical fitness
WM – working memory
IC – inhibitory control
CF – cognitive flexibility

CRediT authorship contribution statement

Nemanja Lakicevic: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Marko Manojlovic:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Elena Chichinina:** Writing – review & editing, Validation, Supervision. **Apollinaria Chursina:** Writing – review & editing, Validation, Supervision. **Kristina Tarasova:** Writing – review & editing, Validation, Supervision. **Ewan Thomas:** Writing – review & editing, Validation, Supervision, Methodology. **Yuming Zhong:** Writing – review & editing, Validation, Supervision, Project administration. **Antonino Bianco:** Visualization, Supervision, Project administration. **Patrik Drid:** Validation, Supervision.

Ethics approval and consent to participate

NA

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Declaration of Competing Interest

The authors declare no competing interest associated with the presented manuscript.

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Consent for publication

NA

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ctim.2026.103321.

Data availability

The authors made their data fully available to everyone.

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