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Original

Analysis of cognitively loaded physical tasks and active breaks for the improvement of executive functions in the school context. A systematic review and meta-analysis

Félix Zurita-Ortega, Gabriel González-Valero, José Luis Ubago-Jiménez*, and Eduardo Melguizo-Ibáñez

Department of Didactics of Musical, Plastic and Corporal Expression, University of Granada, Granada, Spain

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A B S T R A C T

In the school environment, young people show a high level of sedentary behaviour. Physical activity has been shown to be beneficial in improving students' quality of life. Moreover, physical activity with cognitive challenges and the implementation of active breaks are effective tools to work on the cognitive development of students in the school environment. The overall aim of this study was to analyse and compare the effect of interventions based on active breaks and cognitively challenging physical tasks to improve executive functions. The search for research was carried out in Web of Science, ERIC, Scopus, PsycINFO, Pubmed and Cochrane Library from May to August 2024. It has been considered studies that applied a physical activity programme with cognitive demands or application of active breaks and that used a randomised controlled trial or controlled trial design. The quantitative synthesis consisted of 22 studies. Two moderating variables were established: physical activities with cognitive demands and the use of active breaks. The application of physical activities with cognitive demands was more effective for working on cognitive flexibility (g = 1.47, CI = [0.70, 2.25]), fluency (g = 1.71, CI = [1.16, 2.27]) and updating (g = 1.05, CI = [-0.96, 3.06]). *The application of active breaks* was more efficient for attention work (g = 0.74, CI = [0.01, 1.47]), inhibition (g = 1.24, CI = [0.56, 1.92]) and working memory (g = 1.00, CI = [-0.54, 2.55]). It has been concluded that the presence of cognitive load in school physical activities condition the work of different executive functions.

Análisis de las propuestas educativas basadas en ejercicios con demandas cognitivas y descansos activos para la mejora de las funciones ejecutivas. Una revisión sistemática y meta-análisis

Palabras clave:
Metodologías activas
Funciones ejecutivas
Educación

R E S U M E N

En el entorno escolar los jóvenes muestran un elevado nivel de sedentarismo. Se ha demostrado que la actividad física es beneficiosa para mejorar la calidad de vida de los estudiantes. Asimismo, la actividad física con retos cognitivos y la aplicación de descansos activos son herramientas eficaces para trabajar el desarrollo cognitivo de los estudiantes en el centro educativo. El objetivo general de este estudio ha sido el de analizar y comparar el efecto de las intervenciones basadas en descansos activos y las tareas físicas con demandas cognitivas para mejorar las funciones ejecutivas. La búsqueda de investigaciones se ha llevado a cabo en Web of Science, ERIC, Scopus, PsycINFO, Pubmed y Cochrane Library desde mayo hasta agosto de 2024. Se han tenido en cuenta los estudios que han aplicado un programa de actividad física con demandas cognitivas o descansos activos y que hayan seguido un diseño de ensayo controlado aleatorizado o ensayo

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* Corresponding author.
E-mail address: jlubago@ugr.es (J.L. Ubago-Jiménez).

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controlado. La síntesis cuantitativa ha quedado formada por 22 estudios. Se han establecido dos variables moderadoras: actividades físicas con demandas cognitivas y aplicación de descansos activos. La aplicación de actividades físicas con demandas cognitivas ha sido más efectiva para trabajar la flexibilidad cognitiva (g = 1.47, IC = [0.70, 2.25]), fluidez (g = 1.71, IC = [1.16, 2.27]) y actualización (g = 1.05, IC = [−0.96, 3.06]). La *aplicación de descansos activos* ha sido más eficiente para el trabajo de la atención (g = 0.74, IC = [0.01, 1.47]), inhibición (g = 1.24, IC = [0.56, 1.92]) y memoria de trabajo (g = 1.00, IC = [−0.54, 2.55]). Se ha concluido que la presencia de carga cognitiva en las actividades físicas escolares condiciona el trabajo de diferentes funciones ejecutivas.

Introduction

Numerous research studies affirm that regular physical activity has a beneficial impact on human health (Gasana et al., 2023; Martínez-Heredia et al., 2020). Despite a wide range of scientific studies that empirically demonstrate the benefits of regular physical activity, there are very worrying data related to the level of sedentary lifestyles in the youth population (Li et al., 2022). According to the World Health Organization (2019), excessive sedentary behaviour among young people is considered a serious health problem. Studies show that primary and secondary school students spend a high proportion of the school day engaging in sedentary behaviour (Cain, 2022; Kuzik et al., 2022). Specifically, in the academic environment, adolescents and pre-adolescents spend 209 minutes a day in sedentary activities and only 16 minutes a day in physical activities (de Greeff et al., 2016; Egan et al., 2019). Such attitudes affect the quality of life, well-being and development of young people (Cain, 2022; Kuzik et al., 2022). Increased time spent in regular physical activity at school is positively related to improved cognitive performance (Watson et al., 2017). Research has shown that the implementation of physical activity-based programmes during lectures leads to the activation of selective parts of the brain's structural network (de Greef et al., 2018). This activation leads to improvements in the cognitive functions of the learners (Álvarez-Bueno et al., 2017).

Executive functions are advanced cognitive functions that are responsible for initiating, controlling, regulating and monitoring human information and behavioural processes (Luo et al., 2023). These develop throughout childhood and adolescence coinciding with periods of growth in the maturation of the frontal lobes (Jurado & Rosselli, 2007). These developmental periods have been identified from 6 to 16 years of age (Jurado & Rosselli, 2007). This developmental period coincides with the stages of elementary and secondary education. These functions can be classified according to how they operate (Egger et al., 2019). The first of these focuses on updating and storing information (Miyake et al., 2000). The second one relates to the ability to inhibit and control impulsive responses (Egger et al., 2019). The last one refers to the ability to switch between different operations, perspectives, tasks and rules (Egger et al., 2019). These variables have a high degree of relevance for successful outcomes related to the teaching-learning process (Gilmore et al., 2024).

One of the most used strategies for working on executive functions in the academic environment is active breaks (Müller et al., 2021; Muñoz-Parreño et al., 2021). This learning strategy is characterised by interrupting the sedentary teaching-learning process by using physically active academic classes (Contreras-Jordán et al., 2020; Melguizo-Ibáñez, Zurita-Ortega et al., 2024). The application of active breaks is effective in working on inhibition, attention, working memory and cognitive flexibility from 5 to 17 years of age (Graham et al., 2021; Melguizo-Ibáñez, Puertas-Molero et al., 2024; Muñoz-Parreño et al., 2021; Ruiz-Ariza et al., 2021). When planning an intervention based on active breaks it is necessary to consider the intensity of the activity along with its duration (Contreras-Jordán et al., 2020; Melguizo-Ibáñez, Zurita-Ortega et al., 2024; Pastor-Vicedo et al., 2021). Active breaks lasting between 10 and 20 minutes and performed at a moderate-vigorous intensity have better results on executive functions (Contreras-Jordán et al., 2020; Melguizo-Ibáñez, Zurita-Ortega et al., 2024).

Another strategy that uses physical activity to improve executive functions is physical tasks that require cognitive demands (de Greeff et al., 2018). These types of activities involve tasks that require a large amount of cognitive effort to comprehend new information and activities in which complex motor skills are practised (Wang et al., 2024). Cognitive physical activities require an adaptive capacity of the brain to constantly respond to changing demands, which promotes brain neuroplasticity (de Greeff et al., 2018). They activate similar brain areas and networks, helping to improve different cognitive functions (Raichlen & Alexander, 2017).

The study by Mazzoli et al. (2021) found that there are differences in brain activation between cognitive physical activities and active breaks. The results indicated more efficient neural activity in the dorsolateral prefrontal cortex of the students who followed the cognitive physical activity programme (Mazzoli et al., 2021). Physical activities with high cognitive engagement are more effective on executive functions than those with relatively low cognitive engagement (de Greeff et al., 2018, 2016). The effects of physical activity on improving attention and executive functions in young people depend on the type of activity chosen and the cognitive load (Pastor-Vicedo et al., 2021). Despite the results found by Mazzoli et al. (2021) intervention programmes have found that active breaks without cognitive load are effective tools to improve cognitive functions (Muñoz-Parreño et al., 2021; Pastor-Vicedo et al., 2024). Therefore, this study aims (1) to identify research based on the application of active breaks and physical tasks with cognitive demands to improve executive functions in primary and secondary education; (2) to analyse the effect of interventions based on active breaks and physical tasks with cognitive demands to improve executive functions; and (3) to compare the effects of interventions on different executive functions.

Method

Design

The study has been conducted in accordance with the criteria set out in the latest update of the PRISMA declaration (Page et al., 2021). This research has been registered in PROSPERO to allow comparison of the review and meta-analysis with what was foreseen in the initial protocol. The registration code for this research has been CRD42024567627.

Search strategy for research

The research has been conducted between May and August 2024. Web of Science, ERIC, Scopus, PsycINFO, PubMed and Cochrane Library have been the databases consulted to search for scientific studies. Based on the search criteria, the following structure has been used: *"Physical Activity"* OR *"Physical Break"* AND *"Cognition"* OR *"Executive functions"* AND *"Educat*"*. The search in Web of Science has been limited to the following branches of knowledge: *"Sport Sciences"*, *"Psychology Applied"*, *"Psychology Educational"* and *"Education Educational Research"*. The following areas have been consulted in Scopus: *"Social Sciences"* and *"Psychology"*. The time range for the search has been defined as 2014 to 2024. Previously, a study of the scientific production in the databases has been carried out. This analysis shows that most of the research has been published since 2014. References of systematic reviews and meta-analysis studies have also been consulted to find another research related to the topic.

In the case of research that provided data with more than one executive function, the research team has been asked to classify the data for each executive function in isolation. In this way, several groups of executive functions have been created. The variables given the highest priority have been *attention, inhibition, working memory, cognitive flexibility, fluency* and *updating*. To define the study sample, inclusion criteria have been established. The PICOT strategy has been used to establish these criteria (Riva et al., 2012). Through this strategy, inclusion criteria have been established according to the following dimensions: population, intervention, comparison, outcomes, time, context, language and other characteristics of the studies (Riva et al., 2012). Chart 1 provides a description of the inclusion criteria together with the reasons for exclusion.

Chart 1

Inclusion and exclusion criteria based on PICOT strategy

Area	Inclusion criteria	Exclusion criteria
Population	Elementary and secondary students	Not be students in elementary and secondary school
	Students aged between 6 and 16 years old	Not be between the ages of 6 and 16 years old
Intervention	Have carried out interventions of active breaks or physical activities with cognitive demands on executive functions	Do not apply active breaks or physical exercise programmes with cognitive loads
Comparison	Implementation of a trial control and randomised controlled trial design	Failure to present a control trial or randomised control trial design
	Compilation of pre-test and post-test results for the control and experimental groups	
	Interventions where the control group has not applied active breaks and has performed physical activities without cognitive demands	
Outcomes	Assessment of executive functions	Do not analyse executive functions
Time	Research published between 2014 and 2024	Unpublished studies between 2014 and 2024
Context	Proposals developed at schools	Studies carried out outside the school
Language	Writing in Spanish or English	Studies not written in English or Spanish
Other characteristics of the studies	Use of validated instruments and effective data collection techniques	Not using validated instruments and effective techniques for data collection
	Provision of the following statistics: mean values, standard deviations and number of participants in the control and experimental groups	Not providing the following statistics: mean values, standard deviations and number of participants in the control and experimental group.
	Open Access studies	Not available in open access

Research selection strategies

Figure 1 presents the research flowchart. The process of identifying scientific research has been executed through database consultation and through identification by other methods. Initially, 102614 studies have been obtained. After applying the first exclusion criteria, the sample has been reduced to 3323 scientific articles. Subsequently, studies not written in English or Spanish and research that was not open access have been discarded. The application of these criteria has reduced the sample to 236 scientific studies. The sample has then been screened based on the design of the studies and the presence of statistical data. Through this identification method, the sample has been reduced to 18 studies. A top-down search has also been carried out by examining the bibliographic references of the included articles. This resulted in the incorporation of four new studies. Finally, the final quantitative synthesis consisted of 22 studies.

Analysis of the level of research bias

To analyse the level of bias in the selected studies, the Cochrane risk of bias tool has been used (Higgins et al., 2011). This analysis has been carried out to check for any biases that may have influenced the effects of the different studies. The risk of bias has been analysed by three researchers according to the dimensions set out in the Cochrane manual (Higgins et al., 2011). When assessing the level of agreement between researchers, a value for Cohen's Kappa of .823 has been obtained.

Calculation of effect size

The Review Manager 5.3 software was used. To calculate the effect size, mean values, number of participants and standard deviations have been considered. All these data have been extracted from the original investigations by the research team. The calculation is based on the difference of the standardised mean values, adjusted for sample size (Sánchez-Meca & Botella-Ausina, 2015). The size of the effect has been classified into four levels: nil ($\leq$0.20), small (0.21-0.49), moderate (0.50-0.79) and large ($\geq$0.80) (Cohen, 1998). The results have been classified according to the technique used to improve executive functions: *Physical activities with cognitive demands* and *implementation of active breaks*.

Codification of research

The quantitative synthesis studies have been codified by each of the researchers. This has been done to check the researchers' agreement in extracting data from the studies and calculating effect sizes. The authors' level of agreement has been 85.7%. The effect size of each study has been calculated by three authors. The Fleiss Kappa index has been used to evaluate the methodological quality of the research (K_F) (Fleiss, 1981). Cohen's Kappa index has been used to assess the quality of coding (K_C) (Cohen, 1960). For the first index a value of K_F = .715 has been obtained and for the second a value of K_C = .885 has been achieved. The results obtained have shown a high degree of agreement among the research team (Landis & Koch, 1977). For the extraction of the data from the studies, the researchers have used the following coding process (Table 1): (1) Author/s (Year); (2) Research design; (3) Sample; (4) Educational stage; (5) Technique used for the improvement of executive functions; (6) Executive functions analysed; (7) Instruments used for data collection; (8) Effect size [Confidence Interval 95%].

Table 1
Analysis of the sample characteristics and effect sizes for each of the executive functions analysed

Author/s (Year)	Research design	Sample	Educational Stage	Technique	Executive functions	Instruments	Effect Size [CI 95%]
Kolovelonis and Goudas (2023)	Randomized Controlled Trial	102 students (56 boys and 46 girls) (10.13 ± 0.57)	Elementary Education	Physical activities with cognitive demands	Fluency	Design fluency test	1.71 [1.16; 2.27]
					Inhibition		1.17 [0.66; 1.68]
					Cognitive Flexibility		1.45 [0.92; 1.98]
Robinson et al. (2022)	Randomized Controlled Trial	97 students (53 boys and 44 girls) (15.78 ± 0.44)	Secondary Education	Active Breaks	Inhibition	Toolbox Cognition Battery	3.16 [2.55; 3.77]
					Cognitive Flexibility		0.08 [−0.38; 0.53]
Kolovelonis and Goudas (2022)	Randomized Controlled Trial	140 students (71 boys and 69 girls) (10.97 ± 0.51)	Elementary Education	Physical activities with cognitive demands	Attention	Design fluency test	0.40 [−0.07; 0.86]
Bulten et al. (2022)	Randomized Controlled Trial	38 students (15 boys and 23 girls) (11.95 ± 0.49)	Elementary Education	Physical activities with cognitive demands	Working Memory	Leiter International Performance Scale	0.71 [−0.10; 1.52]
					Inhibition	The Stroop Task	0.20 [−0.58; 0.99]
					Cognitive Flexibility	Trail Making Test	0.17 [−0.61; 0.96]
Muñoz-Parreño et al. (2021)	Controlled Trial	166 students (92 boys and 74 girls) (10.90 ± 0.70)	Elementary Education	Active Breaks	Working Memory	NIH-EXAMINER Battery	0.21 [−0.09; 0.52]
					Inhibition		0.57 [0.26; 0.88]
					Cognitive Flexibility		0.35 [0.04; 0.66]
Müller et al. (2021)	Randomized Controlled Trial	241 students (114 boys and 127 girls) (-)	Elementary Education	Active Breaks	Attention	D2 Test	1.01 [0.68; 1.34]
Graham et al. (2021)	Controlled Trial	116 students (58 boys and 58 girls) (12.19 ± 0.93)	Secondary Education	Active Breaks	Inhibition	Stroop Task	0.56 [0.18; 0.93]
					Cognitive Flexibility	Trail Making Test	0.30 [−0.07; 0.67]
					Updating	Forward Memory Span	0.46 [0.09; 0.83]
de Bruijn et al. (2021)	Controlled Trial	62 students (30 boys and 32 girls) (9.20 ± 0.61)	Elementary Education	Physical activities with cognitive demands	Working Memory	Spatial Span task	0.48 [−0.11; 1.07]
Ruiz-Ariza et al. (2021)	Controlled Trial	136 students (59 boys and 77 girls) (12.92 ± 0.43)	Secondary Education	Active Breaks	Attention	D2 Test	− 0.11 [−0.51; 0.30]
Layne et al. (2021)	Randomized Controlled Trial	40 students (31 boys and 9 girls) (8-9 years old)	Elementary Education	Active Breaks	Inhibition	Go/No-Go test with signals	0.60 [−0.04; 1.23]
Vazou, Klesel, Lakes and Smiley (2020)	Controlled Trial	39 students (21 boys and 18 girls) (7.69 ± 1.52)	Elementary Education	Physical activities with cognitive demands	Attention	SWAM scale	0.24 [−0.39; 0.88]
					Inhibition	Flanker test	−0.33 [−0.97; 0.30]
van den Berg et al. (2019)	Randomized Controlled Trial	512 students (273 boys and 239 girls) (9-12 years old)	Elementary Education	Active Breaks	Attention	D2 Test	1.56 [1.37; 1.76]
					Inhibition	Stroop Color-Word Task	1.79 [1.58; 1.99]
					Working Memory	Verbal Fluency task	1.79 [1.53; 2.05]

Table 1
(*Continued*)

Author/s (Year)	Research design	Sample	Educational Stage	Technique	Executive functions	Instruments	Effect Size [CI 95%]
Egger et al. (2019)	Randomized Controlled Trial	142 students (64 boys and 78 girls) (7.91 ± 0.40)	Elementary Education	Active Breaks	Fluency	Backwards Colour Recall task	1.36 [0.91; 1.82]
					Inhibition	Flanker task	0.25 [−0.16; 0.55]
					Cognitive Flexibility		0.47 [0.06; 0.88]
Egger et al. (2018)	Randomized Controlled Trial	216 students (110 boys and 106 girls) (7.94 ± 0.44)	Elementary Education	Active Breaks	Inhibition	Flanker task	0.44 [0.05; 0.83]
					Cognitive Flexibility	Flanker task	0.36 [−0.02; 0.75]
Dalziell, Boyle and Mutrie (2016)	Randomized Controlled Trial	46 students (22 boys and 24 girls) (9-10 years old)	Elementary Education	Physical activities with cognitive demands	Working Memory	Lucid Assessment System for Schools (LASS 8–11)	0.21 [−0.37; 0.79]
de Greeff et al. (2016)	Randomized Controlled Trial	499 students (226 boys and 273 girls) (8.1 ± 0.70)	Elementary Education	Physical activities with cognitive demands	Working Memory	Digits backward and Visual span backward	0.23 [0.05; 0.40]
Koutsandréou, Wegner, Niemann and Budde (2016)	Randomized Controlled Trial	71 students (32 boys and 39 girls) (9.35 ± 0.60)	Elementary Education	Physical activities with cognitive demands	Working Memory	The Letter Digit Span	0.99 [0.40; 1.58]
Pesce, Masci et al. (2016)	Randomized Controlled Trial	920 students (480 boys and 440 girls) (5-10 years old)	Elementary Education	Physical activities with cognitive demands	Inhibition	Random Number Generation task,	0.39 [0.20; 0.57]
					Working Memory		0.14 [−0.04; 0.32]
					Attention	Cognitive Assessment System	0.80 [0.61; 0.99]
Pesce, Marchetti et al. (2016)	Randomized Controlled Trial	90 students (57 boys and 33 girls) (14.50 ± 0.50)	Secondary Education	Physical activities with cognitive demands	Inhibition	Random Number Generation	0.14 [−0.28; 0.55]
					Updating		0.02 [−0.39; 0.44]
Schmidt et al. (2016)	Randomized Controlled Trial	92 students (50 boys and 42 girls) (11.77 ± 0.41)	Elementary Education	Active Breaks	Attention	D2 Test	0.16 [−0.45; 0.77]
Schmidt et al. (2015)	Randomized Controlled Trial	181 students (82 boys and 99 girls) (10-12 years old)	Elementary Education	Physical activities with cognitive demands	Updating	E-Prime Software (Psychology) Software Tools, Pittsburgh, PA	2.08 [1.64; 2.52]
					Inhibition	Flanker task	2.08 [1.64; 2.52]
					Cognitive Flexibility		2.13 [1.68; 2.57]
Chen, Yan, Yin, Pan and Chang (2014)	Randomized Controlled Trial	98 students (56 boys and 42 girls) (9-11 years old)	Elementary Education	Physical activities with cognitive demands	Inhibition	Flanker task	−0.54 [−1.19; 0.10]
					Working Memory	N-back (2-back)	1.74 [0.99; 2.50]
					Cognitive Flexibility	The more-odd task	2.03 [1.24; 2.82]

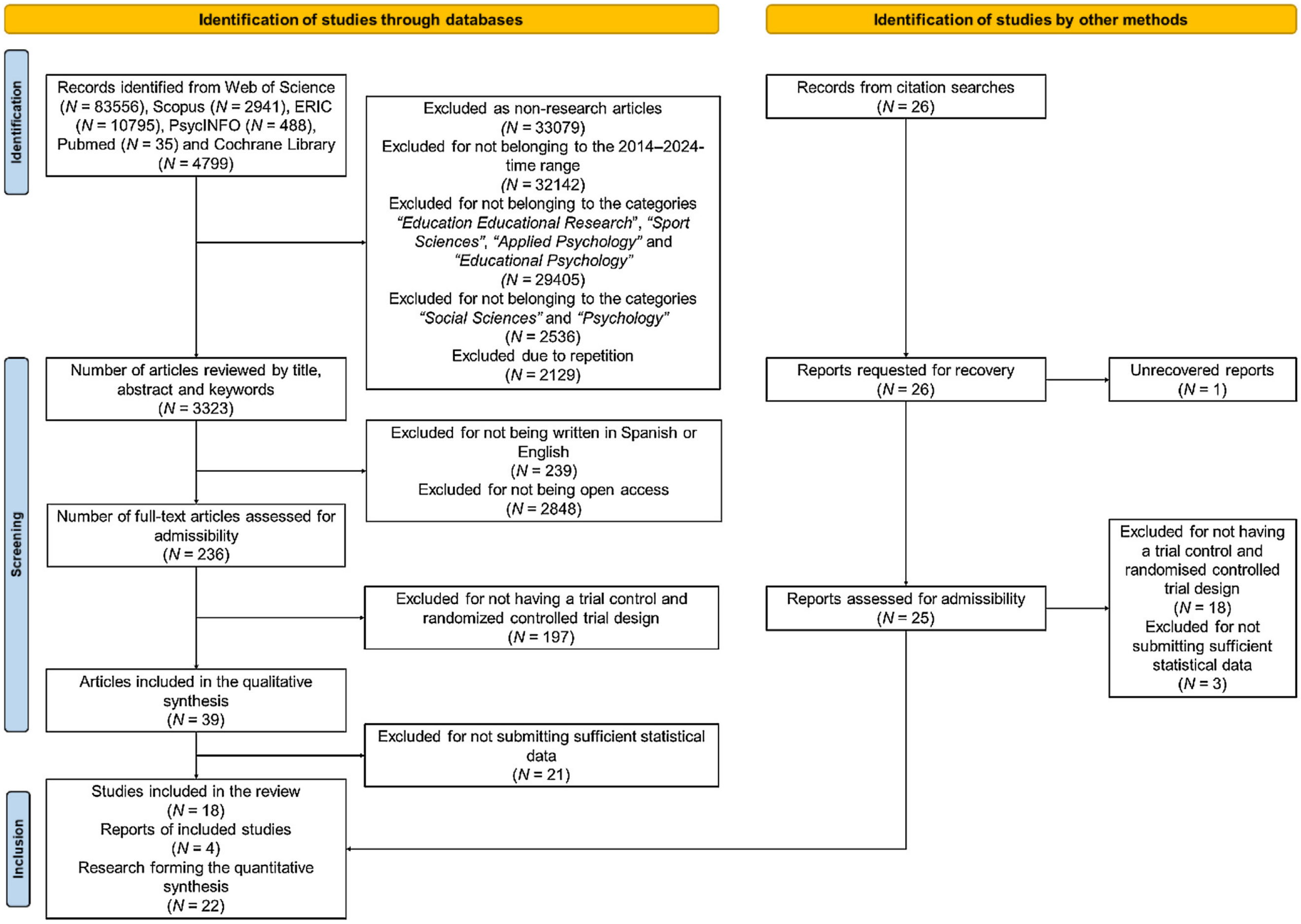

Figure 1. Research flowchart.

Statistical analysis of the meta-analysis

A random effects meta-analysis has been carried out to combine the effect sizes of each study. The impact of the type of strategy used to work on executive functions has been analysed through subgroup analysis. Specifically, this variable has been subdivided into two sub-variables: *Physical activities with cognitive demands* and *implementation of active breaks*. Egger's regression test (Egger et al., 1997) has been used to investigate publication bias. This test has been shown to be more effective than the Begg test in detecting possible asymmetries (Fernández-Castilla et al., 2021). In addition, Egger's test is characterised by its high specificity (Rubio-Aparicio et al., 2018), with the effect being statistically significant if $Z \geq 1.96$ or $Z \leq -1.96$ (Fernández-Castilla et al., 2021; Sánchez-Meca & Botella-Ausina, 2015). To determine the level of heterogeneity, the Q statistic has commonly been used (Sánchez-Meca & Botella-Ausina, 2015). It considers the deviations between the results of each investigation according to the contribution of each one and the overall result of all the investigations (Borenstein et al., 2021; Molina-Arias, 2018). Some authors have claimed that the *Q*-statistic is conservative, hence the statistical significance value has been set at $p < .1$ (Borenstein et al., 2021). In addition, it does not facilitate group diversity and becomes less accurate when little research is available (Borenstein et al., 2021; Molina-Arias, 2018).

For the above contextualisation, the I^2 statistic has also been used for the heterogeneity analysis. Through the value obtained for this index, it has been possible to estimate the total variability (Molina-Arias, 2018). The value of I^2 is between 0 and 100 (Molina-Arias, 2018). The heterogeneity classification thresholds have been 25%, 50% and 75% to establish low, moderate or high heterogeneity respectively (Borenstein et al., 2021; Molina-Arias, 2018).

Results

Analysis of the studies in the sample

The sample of this meta-analysis study consists of 22 scientific studies. A total of 4044 students have participated in this study. Specifically, 50.74% ($n = 2052$) are boys and 49.26% ($n = 1992$) are girls. Continuing with the distribution of participants according to educational stage, 89.14% ($n = 3605$) belong to elementary education and 10.86% ($n = 439$) to secondary education. In terms of the techniques used to improve executive functions, 12 studies presented *physical activities with cognitive demands* and 10 *implemented active breaks*.

Risk of bias of the study sample

Figure 2 presents the risk of bias for the different dimensions analysed. For this research, low risk of bias is shown for random sequence generation ($n = 15$, 68.18%), allocation concealment ($n = 20$, 90.90%), blinding of participants and staff ($n = 17$, 77. 27%), blinding of outcome assessment ($n = 16$, 72.72%), incomplete results ($n = 18$, 81.81%), selective reporting ($n = 15$, 68.18%) along with other sources of bias ($n = 11$, 50.0%). High risk of bias is denoted for random sequence generation ($n = 1$, 4.54%), blinding of outcome assessment ($n = 1$, 4.54%) and for other sources of bias ($n = 4$, 18.18%).

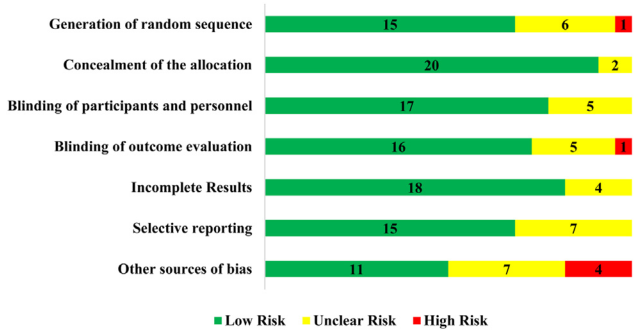

Figure 2. Analysis of sample bias levels.

Influence of the type of intervention on executive functions

Figure 3 presents the effects for *cognitively demanding physical tasks* and *active breaks* for *attention*. A positive and moderate effect of both interventions on the improvement of this executive function is denoted ($g = 0.65$, CI = [0.22, 1.09] $p <$ .00001, $Q = 72.70$, $I^2 = 92\%$, $Z = 2.93$, $p =$ .003) however, the differences between groups are not statistically significant ($Q = 0.17$, $df = 1$, I^2 = 0%, p = .68).

Figure 4 highlights the results of both intervention programmes on *inhibition*. It shows a large and positive effect of both techniques on this executive function ($g = 0.81$, CI = [0.36, 1.26] $p <$ .00001, $Q = 252.32$, $I^2 = 95\%$, $Z = 3.52$, $p =$ .004). Differences between groups are statistically significant ($Q = 4.24$, $df = 1$, I^2 = 76.4%, p = .04). Studies that *implement active breaks* ($g = 1.24$, CI = [0.56, 1.92] $p <$ .00001, $Q = 135.99$, $I^2 = 96\%$, $Z = 3.58$, $p =$ .0003) show greater effectiveness than proposals based on *physical activities with cognitive demands* ($g = 0.38$, CI = [−0.08, 1.84] $p <$ .00001, $Q = 46.72$, $I^2 = 87\%$, $Z = 1.60$, $p =$ .11).

Figure 5 provides the results of the intervention programmes on *working memory*. Specifically, both work methodologies are adequate and present a moderate effect for working on this executive function ($g = 0.70$, CI = [0.24, 1.16] $p <$ .00001, $Q = 133.54$, $I^2 = 94\%$, $Z = 2.99$, $p =$ .003). The differences between the groups are not statistically significant ($Q = 0.36$, $df = 1$, I^2 = 0%, p = .55).

Figure 6 presents the findings on cognitive *flexibility*. A positive and moderate effect of both interventions on this executive function is obtained ($g = 0.79$, CI = [0.32, 1.27] $p <$ .00001, $Q = 80.12$, $I^2 = 90\%$, $Z = 3.27$, $p =$ .001). The differences between the groups are statistically significant ($Q = 8.02$, df = 1, I^2 = 87.5%, p = .005). It is observed that *physical activities with cognitive demands* ($g = 1.47$, CI = [0.70, 2.25] $p =$ .0002, $Q = 19.34$, $I^2 = 84\%$, $Z = 3.72$, $p =$ .0002) are more effective than the *application of active breaks* ($g = 0.32$, CI = [0.16, 0.49] $p =$ .0002, $Q = 1.66$, $I^2 = 0\%$, $Z = 3.78$, $p =$ .0002) to improve this executive function.

Figure 7 presents a large and positive effect of active breaks and cognitively demanding physical tasks on *fluency* ($g = 1.50$, CI = [1.15, 1.85] $p <$ .00001, $Q = 0.92$, $I^2 = 0\%$, $Z = 8.42$, $p <$ .00001). The differences between the groups are not statistically significant ($Q = 0.92$, $df = 1$, I^2 = 0%, p = .34).

Finally, Figure 8 indicates that research combining *physical activity with cognitive load* and *active breaks* has a positive and moderate effect on *updating* ability ($g = 0.85$, IC = [−0.32, 2.02] $p <$ .00001, $Q = 48.91$, $I^2 = 96\%$, $Z = 1.43$, $p =$ .15) nevertheless, the differences between the groups are not statistically significant ($Q = 0.32$, $gl = 1$, I^2 = 0%, p = .57).

Discussion

Once the main results have been presented, they are then compared with those of another similar research that has been carried out. The application of active breaks and cognitively demanding physical activities are favourable strategies to successfully work on students' executive functions. These improvements in executive functions through physical activity are thought to result in neurophysiological arousal, leading to an increase in neurotransmitters (de Greeff et al., 2018; Dishman et al., 2006). In addition, the practice of any physical activity enhances angiogenesis and neurogenesis in areas of the brain during the teaching-learning process (de Greeff et al., 2018; Mavilidi et al., 2020; Ruiz-Ariza et al., 2021).

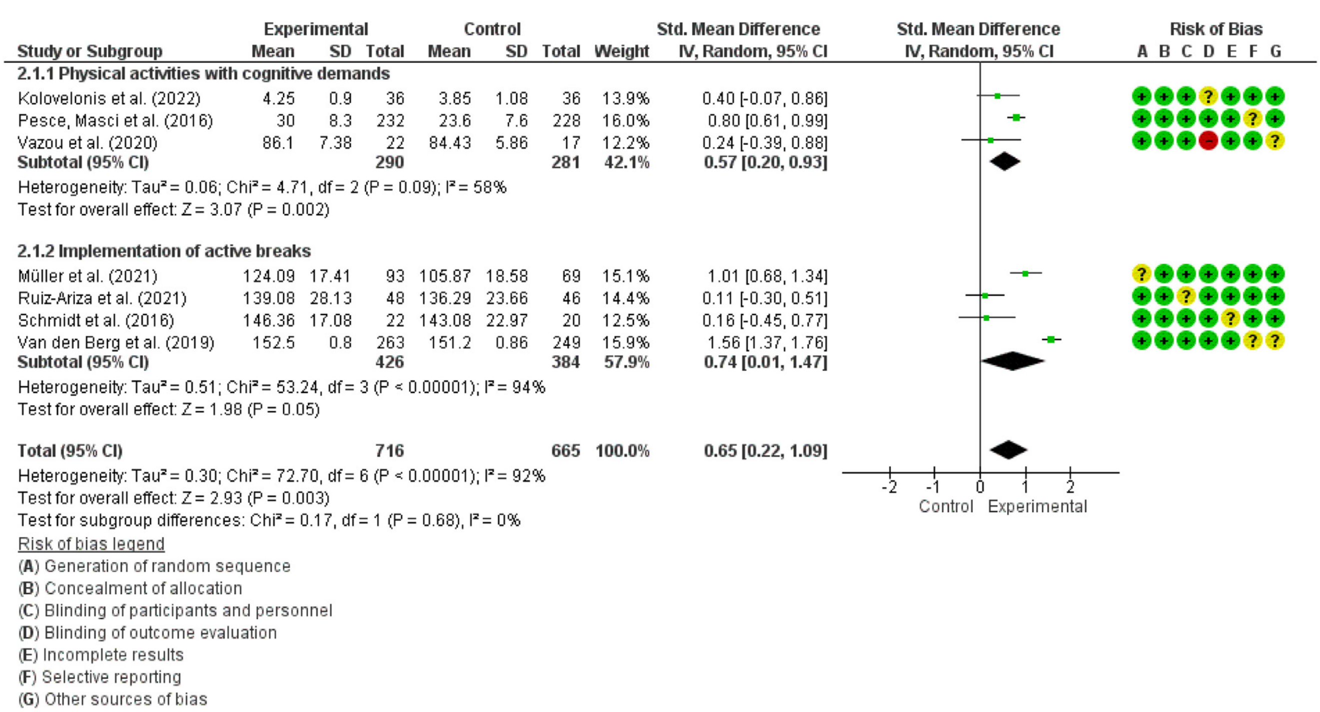

Figure 3. Forest plot for *attention*.

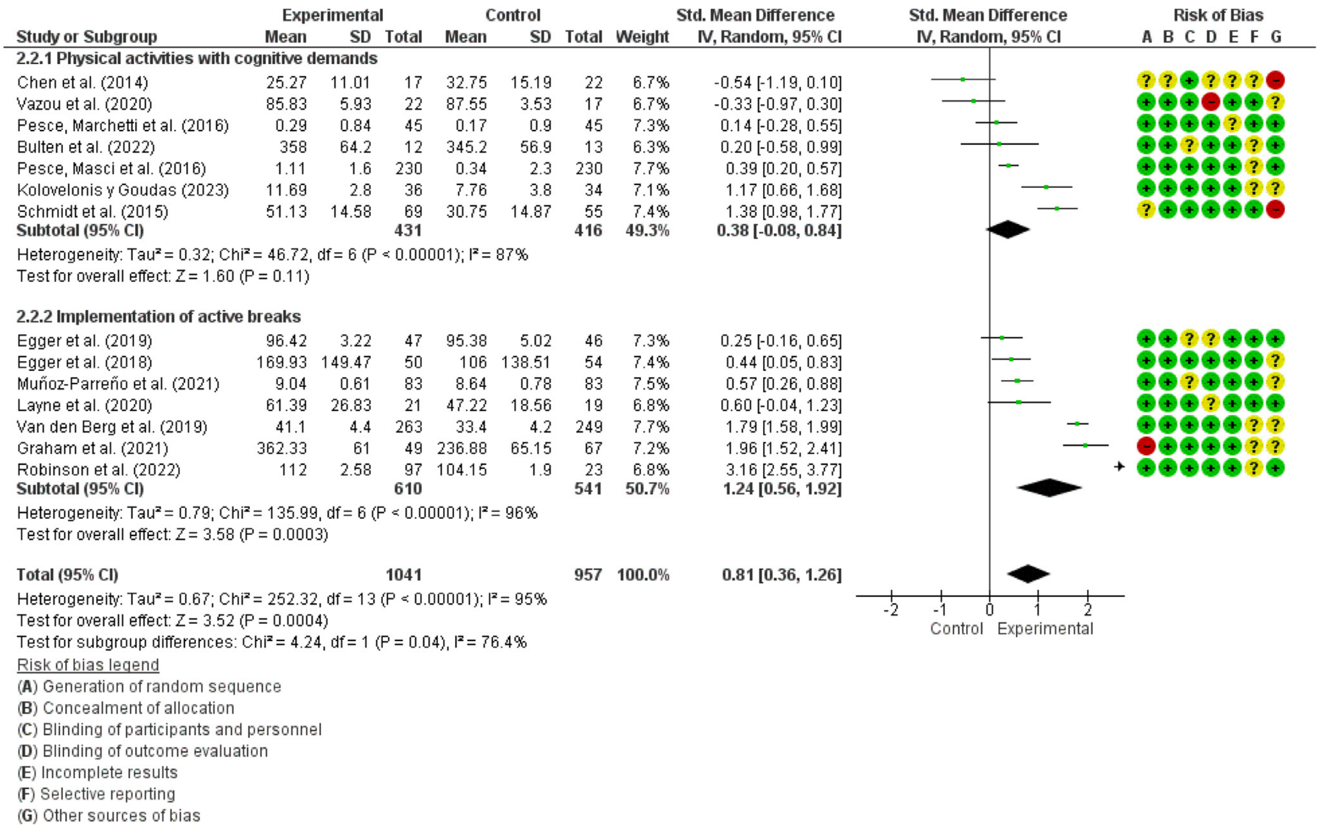

Figure 4. Forest plot for *inhibition.*

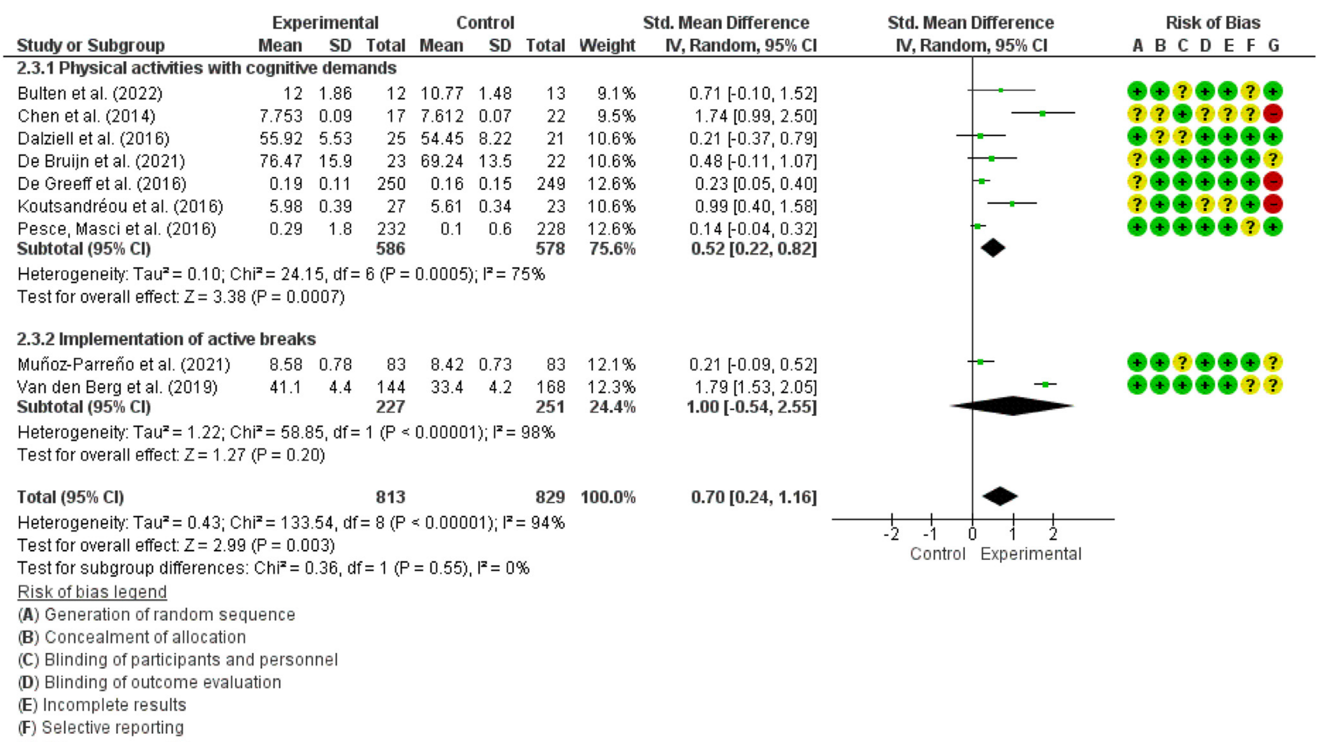

Figure 5. Forest plot for *working memory*.

The comparative analysis shows that active breaks are more effective in working on attention, inhibition and working memory. There are other techniques not based on physical activity, such as mindfulness. The study by Müller et al. (2021) has highlighted that active breaks are more effective than these techniques and that this is mainly due to physical movement. Physical activity without cognitive load is related to the inverted U hypothesis (Pastor-Vicedo et al., 2021). The level of arousal for attention enhancement is

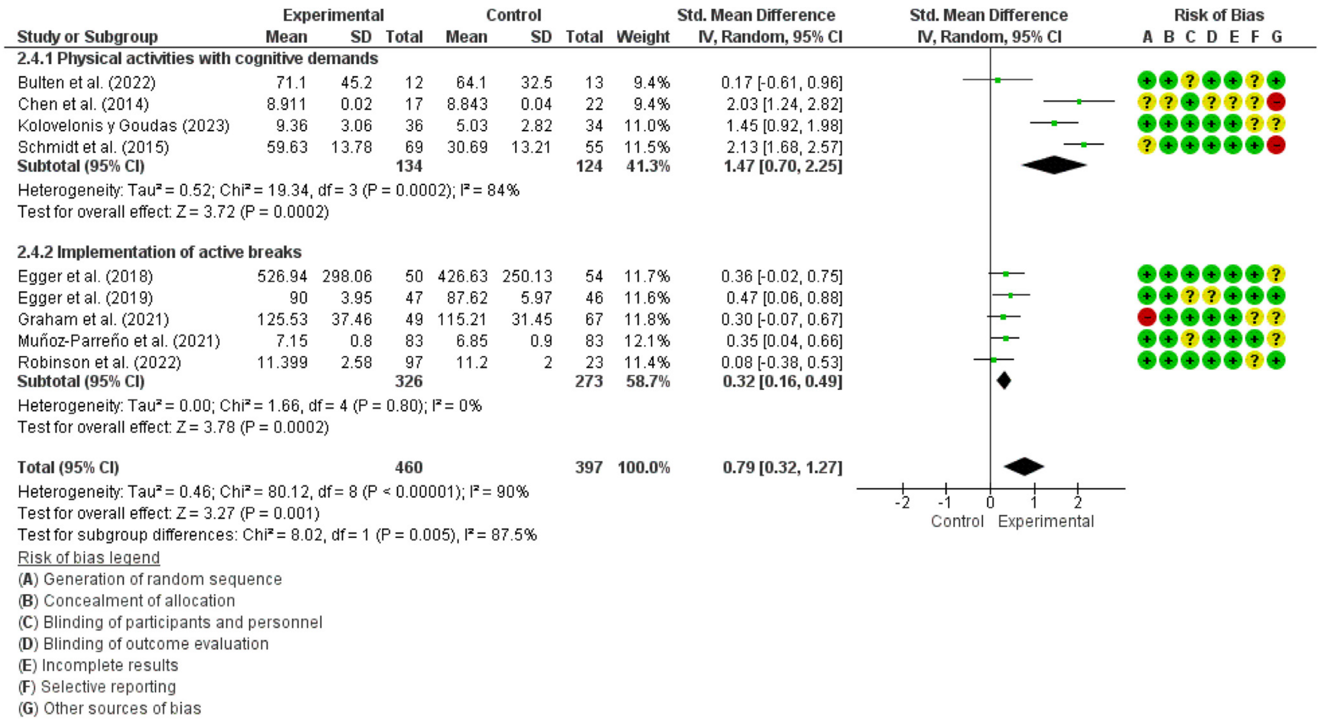

Figure 6. Forest plot for *cognitive flexibility*.

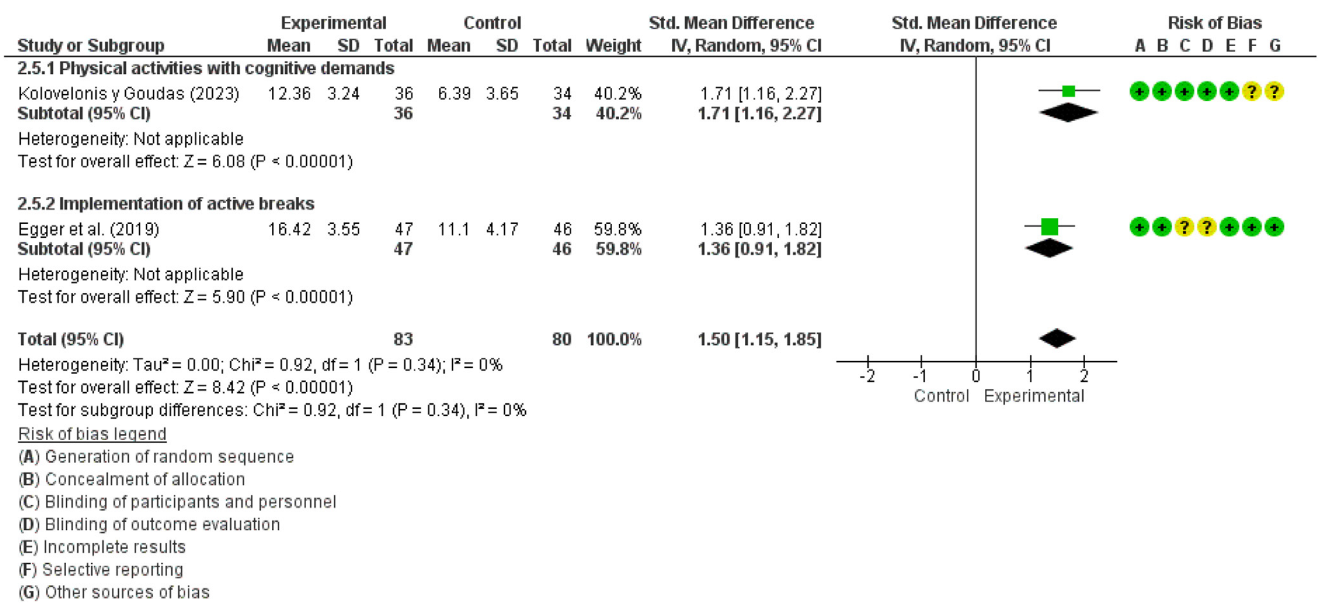

Figure 7. Forest plot for *fluency*.

achieved once a period of moderate intensity physical activity has been applied (Pastor-Vicedo et al., 2021). Improved cardiorespiratory fitness leads to activation of cerebral angiogenesis resulting in improved cerebral vascularisation (Pastor-Vicedo et al., 2021). The benefits of this active methodology may be due to physiological and socio-behavioural factors (de Greeff et al., 2016, 2018; Ruiz-Ariza et al., 2021).

Physical activity also immediately facilitates cognitive performance by increasing the attention span of learners (de Greeff et al., 2016, 2018). Improved attention levels have had a beneficial impact on working memory and inhibition in the academic environment (van den Berg et al., 2019). In some cases, the motor development of the learners conditions the degree of cognitive load of the active breaks (van den Berg et al., 2019). High levels of motor complexity when implementing some active break activities may deplete students' different cognitive resources (van den Berg et al., 2019, 2016). This oversaturation hinders the development of attention, updating and inhibition (Egger et al., 2018; van den Berg et al., 2016; van den Berg et al., 2019).

Active breaks have been shown to be effective tools for improving executive functions (Melguizo-Ibáñez, Zurita-Ortega et al., 2024). Incorporating cognitive load into various physical tasks has also been found to be effective in improving higher order cognitive functions (Bulten et al., 2022; de Bruijn et al., 2021). These results raise a debate about which technique is more effective for working on executive functions in the academic environment. The

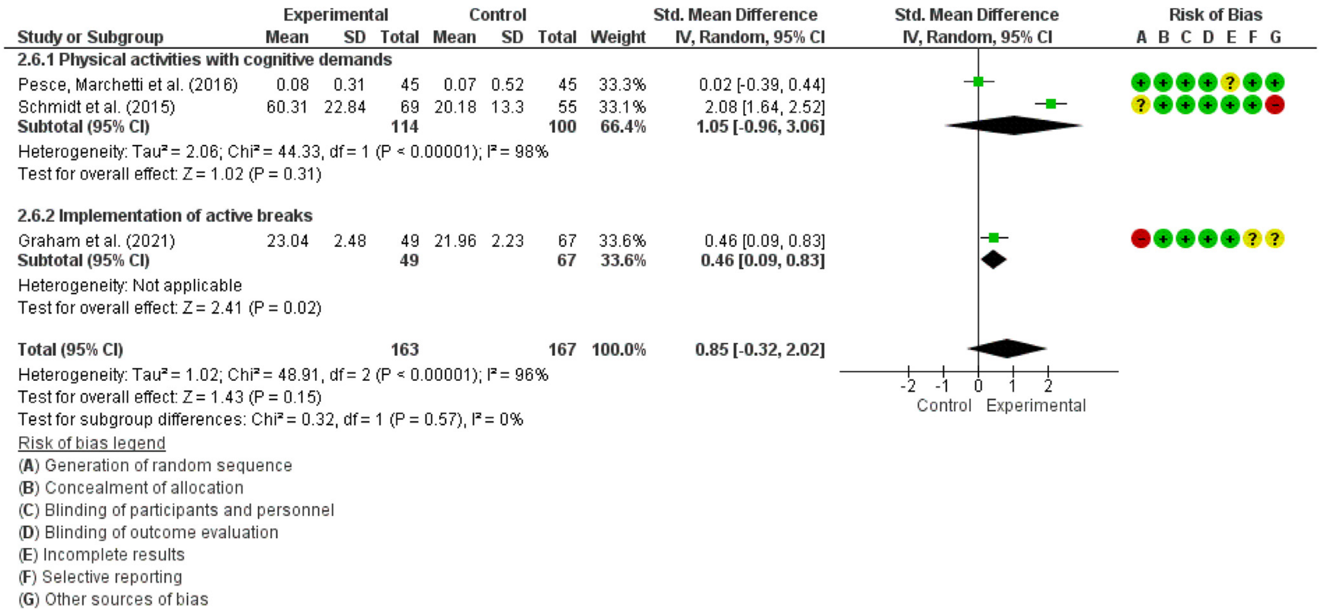

Figure 8. Forest plot for *updating*.

results of this research indicate that cognitive flexibility, fluency and updating have a greater effect when stimulated through physical activities with cognitive demands. For the work on this type of variable, it has been noted that physical activity presents higher order cognitive processes (de Bruijn et al., 2021). The acquisition of new skills during coordinative physical activity is related to increased activation in the prefrontal and parietal cortex (de Bruijn et al., 2021).

Research has found that the presence of cognitive engagement has led to an increase in attention and speed of information processing (Schmidt et al., 2016; Schmidt et al., 2015). Cognitive engagement combined with physical activity affects executive functions differently than physical exercise alone (Schmidt et al., 2015). Games that require cognitive engagement and physical effort have been found to have a greater effect on executive functions (Schmidt et al., 2015). Research that has applied physical games with cognitive loads oriented to the work of executive functions has resulted in higher academic achievement in students (Fedewa et al., 2018). In response, the study by Layne et al. (2021) found improvements in executive functions, but not in academic performance after applying an intervention programme based on active breaks without cognitive load. In contrast, the research by Fedewa et al. (2018) after applying cognitively demanding activities has led to improvements in the work on executive functions and on students' academic performance.

Limitations and practical applications of the study

It should be noted that this study has met its objectives. Nevertheless, this study has a few limitations. The first one relates to the time range. This research has only focused on studying research published in the 2014–2024-time range on participants aged between 5 and 16 years old. A meta-analytic study of the total number of studies has not been produced, but the sample has initially been divided into two subgroups. This may have led to effect sizes being estimated with few studies. In addition, studies have been extracted from specific areas of knowledge in the databases. This may have left out similar research. Another limitation is the high degree of heterogeneity obtained in some of the analyses carried out. Based on the results obtained and considering the applicability, this study shows that the practice of physical activity in the school environment is beneficial for improving the executive functions of students. As future perspectives it would be convenient to carry out a study focused on applying strategies to improve executive functions with and without cognitive load to work on the different executive functions in the different educational stages.

Conclusions

This research shows how techniques based on the practice of physical activity are effective for working on executive functions within the school itself. Differences have been found depending on the techniques used to increase the effect of executive functions. A greater effect on attention, inhibition and working memory has been obtained for research using active breaks without cognitive loads. On the contrary, it has been highlighted that the variables cognitive flexibility, fluency and updating show a greater effect when physical activities with cognitive loads are applied

CRediT authorship contribution statement

Conceptualisation: Félix Zurita-Ortega, José Luis Ubago-Jiménez; *Methodology:* Gabriel González-Valero, Eduardo Melguizo-Ibáñez; *Software:* José Luis Ubago-Jiménez, Gabriel González-Valero; *Formal Analysis:* Eduardo Melguizo-Ibáñez, Félix Zurita-Ortega; *Research:* José Luis Ubago-Jiménez, Félix Zurita-Ortega, Gabriel González-Valero; *Resources:* Félix Zurita-Ortega; *Drafting:* Eduardo Melguizo-Ibáñez; *Proofreading and editing:* José Luis Ubago-Jiménez; *Supervision:* Félix Zurita-Ortega, José Luis Ubago-Jiménez; *Project management:* Gabriel González-Valero; *Fundraising:* José Luis Ubago-Jiménez

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