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Executive Dysfunction in Adolescents with Obesity: A Systematic Review

Alteraciones del Desempeño Ejecutivo en Adolescentes con Obesidad: Una Revisión Sistemática

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Obesity has been linked to low cognitive performance throughout the human life span. Alterations relate to attention, memory, language, and executive function. However, the obesity-executive function association remains unclear in adolescents. This study presents a systematic review of executive function alterations in adolescents with obesity. A search equation was proposed (Executive dysfunction AND Obesity AND Adolescents), with sixty studies meeting the inclusion criteria in the Clarivate Analytics Web of Science Core Collection database. A bibliometric analysis was conducted to identify the importance of the research topic and a citation network was built to establish the lines of research. Finally, the citation network was exported to Gephi to visualize the research groups studying the topic. Findings suggest 4 lines of research: (a) structural and functional brain abnormalities in adolescents with obesity, (b) inhibitory control alterations in adolescents with obesity, (c) effects of physical and cognitive activity on the executive function of adolescents with obesity, and (d) working memory alterations in adolescents with obesity. Obese adolescents were found to prefer immediate rewards to long-term ones. Nevertheless, effective interventions increase the intake of fruit and vegetables and reduce that of calorie-dense food. The authors recommend additional longitudinal studies to assess whether executive function alterations are either a cause or a consequence of adolescent obesity.

Keywords: adolescent, executive function, obesity, working memory, physical exercise

La obesidad se relaciona con bajo desempeño cognitivo a lo largo del desarrollo vital. Las alteraciones se relacionan con la atención, memoria, lenguaje y con el funcionamiento ejecutivo. Sin embargo, la relación obesidad-funcionamiento ejecutivo no es clara en adolescentes. Este estudio presenta una revisión sistemática sobre las alteraciones del funcionamiento ejecutivo en adolescentes con obesidad. Se propuso una ecuación de búsqueda (Disfunción ejecutiva Y Obesidad Y Adolescentes) y 60 estudios cumplieron los criterios de inclusión en la base de datos de Clarivate Analytics Web of Science Core Collection. Un análisis bibliométrico identificó la importancia del tema de investigación y se construyó una red de citas con el propósito de establecer las líneas de estudio. Finalmente, se exportó la red de citaciones a Gephi para visualizar los grupos de investigación en la temática. Los hallazgos sugieren 4 líneas de estudio: (a) anormalidad cerebral a nivel estructural y funcional en adolescentes con obesidad, (b) alteraciones en el control inhibitorio en adolescentes con obesidad, (c) efectos de la actividad física y cognitiva en el funcionamiento ejecutivo de adolescente con obesidad y (d) alteraciones en la memoria de trabajo en adolescentes con obesidad. Se encontró que los adolescentes prefieren recompensas inmediatas en comparación con recompensas a largo plazo. Sin embargo, las intervenciones efectivas aumentan el consumo de frutas y verduras y reducen la ingesta de comida con alto contenido calórico. Se recomiendan estudios longitudinales adicionales para evaluar si las alteraciones en el funcionamiento ejecutivo es una causa o consecuencia de la obesidad en adolescentes.

Palabras clave: adolescente, función ejecutiva, obesidad, memoria de trabajo, ejercicio físico

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Obesity is a chronic metabolic disease characterized by an increase of body fat stores (Goossens, 2017). It is partly caused by elevated energy intake, which often includes a disproportionate amount of refined carbohydrates and/or processed foods (increasing insulin release and fat storage) and decreased physical activity (PA) (Ruiz et al., 2019). It is also promoted by environmental, behavioral, biological, and genetic factors, whose interactions have driven the current levels of worldwide obesity (Di Cesare et al., 2019). Recent studies indicate that 17% of all adolescents in the United States are obese (Mangone et al., 2018) but Hispanic and African-American youth have even higher rates, with over 20% being considered obese (Ogden et al., 2014).

In Latin America, the prevalence of overweight is of 62% and 26% for obesity in the population over the age of 20, being Mexico and Chile countries in which 7 out of 10 people are overweight or obese (Organización Panamericana de la Salud, 2014). According to a study, the prevalence of global obesity in Latin American girls increased and went from 0.7% in 1975 to 5.6% in 2016, and in boys, it went from 0.9% to 7.8%, respectively. Moreover, the prevalence of low weight in girls decreased from 9.2% in 1975 to 8.4% in 2016, and in boys from 14.8% to 12.4% in the same period (NCD Risk Factor Collaboration, 2017).

Among the relevant findings in Latin America was an increase of 1 kg/m^2 by decade in females of Central and Andean Latin America, while, in the same region, males didn't show any significant changes. Furthermore, a major body mass index variation in children and adolescents as opposed to adults was detected. One of the most alarming statistics is that for 2016, the average body mass index in Chile was of 22-24 kg/m^2, increase seen in other 10 countries (Campos Rodríguez et al., 2021).

Chronic weight problems pose serious health risks, including metabolic syndromes and cardiovascular diseases (Piché et al., 2020). These issues usually develop at an early age and often continue into adulthood, with 60% of the individuals who were overweight at 11 years old growing up to be overweight adults (Naets et al., 2018). However, research shows that studies on neuropsychological characteristics of adolescent obesity have focused primarily on an undifferentiated comparison between obese and non-obese samples (Rankin et al., 2016). Additionally, theories of the association between obesity and executive function (EF) may agree that excessive weight should be associated with impairments in EF but the exact reason for this association is still unclear (Yang et al., 2018).

There is growing evidence that obesity is not only an increased calorie intake and weight management problem, but it is also linked to adverse neurocognitive outcomes, including decreased performance on attention, shifting, abstract reasoning, and visuospatial organization tasks (Donofry et al., 2020). Obese adolescents also show impairments in executive functioning, problems regulating behavior, emotion, and thought processes (Gowey et al., 2018). Although theories converge in positing that obesity should be associated with greater impairments in executive functioning, it is also possible that differences on EF could predispose individuals to excessive weight (Favieri et al., 2019). In the case of excessive weight, coupled with a strong automatic approach response to high-calorie food and food cues, people who show low levels of executive control are susceptible to obesity-related behaviors (e.g., increased intake of fatty foods, weight gain), whereas those with effective cognitive control may be protected (van Meer et al., 2016). However, results are inconsistent in studies examining these associations (Kamijo et al., 2014).

Executive dysfunction commonly associated with adolescent obesity include impulsivity, poor inhibitory control (IC), impaired working memory (WM), and poor cognitive flexibility (CF), but also planning and problem solving deficits (Qavam et al., 2015). Although these processes are frequently included in conceptualizations of EF, there are competing frameworks for describing how these processes are integrated (Ardila, 2018; Baddeley, 2018; Best & Miller, 2010; Friedman & Miyake, 2017; MacPherson et al., 2017; Zelazo & Müller, 2010), which may reflect the relatively recent and innovative nature of EF research in adolescents. These frameworks range from those that conceptualize it in childhood as operating effectively as an integrated whole (e.g., central executive framework), a small number of sub-systems (e.g., dual-process framework), to an array of relatively distinct processes (Baddeley & Hitch, 2019; Carroll, 2007). In this systematic review, EF are understood as high-level cognitive processes that, through their influence on lower-level processes, enable individuals to regulate their thoughts and actions during goal-directed behavior (Friedman & Miyake, 2017).

Research has focused primarily on three EF: WM, shifting, and inhibition (Daucourt et al., 2018). Inhibiting tasks require avoiding a dominant or prepotent response (eye movements, categorization, or word reading for antisaccade, stop-signal, and Stroop, respectively). Updating tasks require continuously updating the contents of WM, adding new information and removing no-longer relevant information (with category exemplars, letters, or spatial locations for keep track, letter memory, and spatial 2-back, respectively).

Shifting tasks require switching between two subtasks, according to a cue that appears before each trial (between categorizing numbers as odd/even or letters as consonant/vowels, shapes as red/green or circle/triangle, or words as living/nonliving or big/small for the number letter, color shape, and category-switch tasks, respectively (Friedman & Miyake, 2017; Theodoraki et al., 2020).

Although WM, shifting, and inhibition are important aspects of EF, they may not be the only components (Daucourt et al., 2018). Indeed, several other EF domains have been well defined in the literature (Antón et al., 2019), including (a) decision making (DM) (Mansur et al., 2019), defined as the cognitive process that occurs whenever an individual has to make a choice from several alternative possibilities; (b) verbal fluency (VF) (Gustavson et al., 2019), defined as the ability to generate as many words as possible from a semantic category (or that start with certain letters) in a given time; and (c) planning (Dassen et al., 2018), defined as formulating, evaluating, and selecting a sequence of thoughts and actions to achieve a goal.

Despite this continuing debate, research demonstrates that impulsive adolescents have poorer weight outcomes in behavioral obesity treatment programs (Walø-Syversen et al., 2019), less IC, and smaller orbitofrontal cortex volume than healthy weight peers (Pehlivanova et al., 2018). Body mass index was also found to be inversely related to performance in attention, IC, and WM tasks, even after controlling for intelligence quotient (Faul et al., 2019). Perhaps, these studies focused solely on behaviors such as eating well and exercise. Most likely, it is not sufficient to focus only on how children eat and move, but it is necessary to build on how they think. It is still necessary to design a program that focuses on the improvement of EF, with emphasis on the IC domain and healthy behaviors (Reinert et al., 2013)

Research investigating the associations between EF and eating behavior in obese samples is growing; yet there are still limitations to be addressed. Extant studies have often relied on a limited number of tasks, such as single informant report of eating behaviors or specific domains of EF (Goldschmidt et al., 2015). Yet, the high rate of adolescent-caregiver disagreement on reports of disordered eating suggests that a multi-informant method likely remains the most useful approach (Bartholdy et al., 2017). Thus, it remains a challenge to consolidate and generalize these findings to provide a comprehensive understanding of the EF –eating behavior association in adolescent obesity (Gowey et al., 2018).

However, other studies reported no statistically significant differences in EF between obese adolescents and their healthy counterparts (Mamrot & Hanć, 2019). This lack of consistency is due to studies not reporting medical conditions of hypertension, type II diabetes, and obstructive sleep apnea, which leads to indicate that false positive and false negative rates are to be found in these trials (Landínez Martínez et al., 2019).

Researchers have consequently reached a wide range of conclusions about the relationship between excess weight and EF, ranging from impairments on neuropsychological tasks (Cohen et al., 2011) to no apparent executive dysfunction (Lawyer et al., 2015). In sum, although weight-related impairments in inhibition, CF, WM, DM, VF, and planning are often reported, a systematic review is needed to assess the consistency and magnitude of such deficits. This review sought to appraise the existing literature to investigate the relationship between executive dysfunction and adolescent obesity.

Method

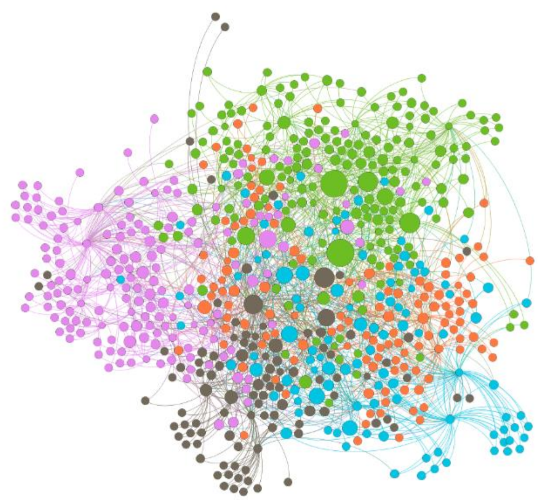
A bibliometric analysis was performed on 144 manuscripts extracted from the Clarivate Analytics Web of Science Core Collection database to observe the evolution of the scientific literature and identify specific characteristics of the related knowledge domain. The bibliometric analysis was integrated with a literature review using a method comparable to the method employed in another study (Valencia-Hernández et al., 2020). The rationale behind this approach is to use scientometric techniques and citation analysis.

First, the Web of Science database was selected to identify articles that describe the proposed search equation: TOPIC:(executive dysfunction) AND TOPIC: (obesity) AND TOPIC: (adolescents) from January 2001 to December 2019 (Vallaster et al., 2019). The search equation file was then converted to txt for further analysis. Then, a bibliometric analysis identified the importance of the research topic in the current literature (Zupic & Čater, 2015). To do this, the bibliometrix tool was used (http://www.bibliometrix.org). Third, a citation network was built in order to establish the study research lines. This algorithm is based on the graph theory, where studies are represented as nodes and citations as links. So, every node is a knowledge unit in the network. The citation network was built through Sci2 tool software and then every referenced citation was chosen to identify articles with a 95% similarity through the Jaro-Wikker algorithm and to be able to remove duplicates (Prasetya et al., 2018). Finally, the citation network was updated through merge node.

Overall, the search equation was converted in a citation network that comprises both the selected articles and its references (Gomez, 2020).

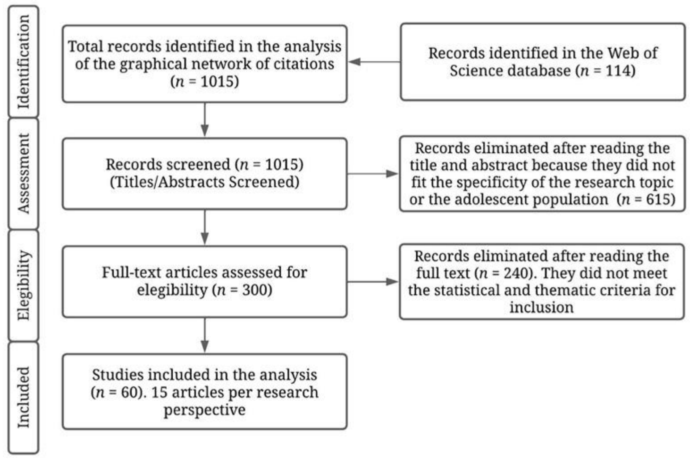
Lastly, the citation network was exported to Gephi (Bastian et al., 2009) to be visualized into groups (author communities). Besides, in-degree, out-degree, and betweenness filters were analyzed to investigate the structure of the network and to calculate the main parameters (node connectivity, positioning, and citation). Then, the giant component was computed. This is a group of nodes (articles) that are all connected to each other. Disconnected nodes from the main network were removed (Gomez, 2020). Finally, both a clustering algorithm (Blondel et al., 2008) and the modularity index were applied to the final citation network. This approach assembled densely-connected nodes to the main research perspectives. In Figure 1 the final citation network composed by four clusters is shown. These represent 62.37% of the final graph. Every cluster depicts a group of references linked to a research perspective. The node size depicts the amount of received citations. The final citation network is composed by 1015 articles (nodes) and 3043 links (edges or citations).

Figure 1
Final Citation Network (Research Communities)



The PRISMA strategy has been applied for article eligibility (Page et al., 2021) (see Figure 2). Selection criteria were: (a) articles with less than 95% similarity through the Jaro-Wikker algorithm, (b) clusters with 10% or higher visibility nodes, and (c) eligible articles with the highest statistical parameters (in-degree, out-degree and betweenness filters) in the research perspectives (main clusters), (d) longitudinal and cross-sectional studies, (e) experimental and quasi-experimental designs, (f) clinical and non-clinical studies of obese/healthy adolescents, (g) studies about executive dysfunction in obese adolescents, and (h) studies about orbito-frontal cortex dysfunction in obese adolescents. This segmentation is based on node connectivity, positioning, and citation in the final network (Valencia-Hernández et al., 2020)

Figure 2
PRISMA Flow Diagram Showing Selection Methodology



Selected Studies and Potential Conflict of Interest

Four clusters complied with selection criteria (b). These are the research perspectives that led to the incorporation of 60 published and peer-reviewed papers. Fifteen works assessed the structural and functional brain abnormalities in adolescent obesity, 15 assessed IC dysfunctions, 15 assessed the effects of physical and cognitive activity on executive functioning, and 15 assessed WM dysfunctions.

Variables

EF tasks are shown as assessing inhibition, CF, WM, DM, and VF, shifting or planning based upon previous empirical or theoretical evidence, suggesting that a given task primarily utilized the particular coded EF. Neuroimaging techniques are also shown in 15 studies that assessed the structural and functional brain abnormalities in adolescent obesity (see Table 1).

Table 1
Studies Included in the Systematic Review

Study	Subject (sample size)	Female %	Mean age (years)	Mean BMI kg/m²)	EF studied/structural-functional brain abnormalities	Task/s used/neuroimaging technique
Miller et al. (2009)	OB (12) NW (15)	66.0% 66.0%	9.3 12.1	36.0 19.0	Inhibition, WM, CF/OB showed smaller cerebellar volumes than NW.	WJIII-Cog, WJA/MRI.
Rofey et al. (2015)	OB (5) NW (5)	80.0% 50.0%	15.4 14.5	34.3 18.6	OB showed smaller caudate nucleus and thalamus volume than NW.	MRI.
Alarcón et al. (2016)	OB (18) OW (46) NW (88)	33.3% 45.6% 45.4%	14.4 13.8 14.2	30.9 24.2 20.3	WM/OB showed reduction in fractional anisotropy in LSLF/LILF.	WAIS-IV/fMRI.
Pearce et al. (2017)	OB (10) NW (12)	60.0% 50.0%	17.0 16.5	47.2 21.6	DM/OB showed lower left PFC activation than NW in a reward related DM task.	MIDT/fMRI.
Sweat et al. (2017)	OB (108) NW (54)	63.0% 53.7%	19.6 19.3	35.5 21.4	Inhibition, CF/OB showed smaller corpus callosum.	Stroop, TMT, COWAT, TOL/MRI.
de Groot et al. (2017)	OB (23) NW (19)	N.R N.R	N.R N.R	N.R N.R	DM, Inhibition/OB had greater pallidum volume.	Choice delay task. SST/MRI.
Yau, Kim et al. (2014)	OB (30) NW (30)	57.0% 63.3%	17.6 17.2	35.4 21.1	WM, CF/OB showed reduced OFC, ACC, and major cerebral WHM tracts.	WCST. TMT B/MRI.
Yau et al. (2010)	OB-T2D (18) OB (18)	N.R N.R	16.4 17.1	37.7 36.8	WM, planning, VF/ OB-T2D showed reduced WHM volume and enlarged CSF in frontal lobe.	WCST. TOL. COWAT/MRI.
Chen et al. (2018)	OB (22) NW (18)	60.0% 60.0%	16.9 15.1	32.0 21.0	Inhibition/OB showed larger No-Go N2 amplitude relative to the Go N2 amplitude.	Go/No-go/EEG.
Maayan et al. (2011)	OB (54) NW (37)	63.6% 56.8%	17.5 17.3	39.8 21.6	VF, CF, WM/OB showed lower OFC volume.	COWAT, TMT, Stroop, WRAML/MRI.
Moreno-López et al. (2012)	OB (36) NW (16)	72.2% 56.2%	14.2 14.1	32.6 20.2	Impulsivity, inhibition/OB showed increased gray matter in right hippocampus.	SPSRQ, Stroop/MRI.
Jastreboff et al. (2016)	OB (24) NW (14)	54.1% 29.0%	15.3 15.8	34.4 21.8	OB showed decreased perfusion in the PFC and increased perfusion in the hypothalamus and striatum.	fMRI.
Yau et al. (2012)	OB-MS (49) OB (62)	63.2% 54.8%	17.7 17.4	38.4 30.0	WM, VF, planning, CF/OB-MS showed reduced hippocampal volumes, increased overall CSF volume, and compromised WHM microstructural integrity.	WCST, TOL, COWAT, and TMT B/MRI.
Ross et al. (2015)	OB (79) NW (51)	64.6% 49.0%	19.6 19.4	35.6 22.9	CF, WM, planning/OB showed significantly thinner OFC.	TMT, LNS, WM scale, TOL/MRI.
Yau, Kang et al. (2014)	OB (39) NW (51)	61.5% 55.0%	17.8 17.3	38.8 26.5	OB showed reductions in retinal arteriolar diameter and WHM tracts relative to NW.	MRI.
Kulendran et al. (2014)	OB (53) NW (50)	60.3% 60.0%	14.2 13.8	33.7 20.6	Inhibition, DM.	SST, Delayed discounting task.
Chen et al. (2018)	OB (22) NW (18)	60.0% 60.0%	16.9 16.0	30.0 21.0	Inhibition.	Go/no-go.
Kittel et al. (2017)	OB (22) NW (22)	81.0% 81.0%	14.8 15.2	34.0 23.0	Inhibition, CF, DM.	Stroop, TMT, IGT.
Lokken et al. (2009)	OB (25)	60.0%	15.8	54.0	Inhibition, CF.	Go/no-go, TMT.
Delgado-Rico et al. (2013)	OW (42) NW (21)	66.0% 47.0%	14.1 14.1	29.1 19.8	Inhibition.	Stroop.
Tee et al. (2018)	OB (74) OW (93) NW (311)	58.0% 55.0% 60.0%	14.8 14.8 14.8	30.0 26.0 21.0	Inhibition, WM, CF.	Stroop, Digit Span, TMT.

(continues)

Table 1 (Continuation)
Studies Included in the Systematic Review

Study	Subject (sample size)	Female %	Mean age (years)	Mean BMI kg/m²)	EF studied/structural-functional brain abnormalities	Task/s used/neuroimaging technique
Batterink et al. (2010)	OW (29)	100%	15.7	25.0	Inhibition.	Go/no-go.
Huang et al. (2019)	OB (38)	36.8%	15.8	31.2	Inhibition.	Stroop.
Pauli-Pott et al. (2010a)	OW (177)	54.2%	12.0	29.2	Inhibition.	Go/no-go.
Pauli-Pott et al. (2010b)	OW (111)	56.7%	12.0	29.1	Inhibition.	Go/no-go.
Jensen et al. (2019)	OB (23) NW (29)	46.0% 46.0%	15.9 15.6	> 30 18.5-24.9	Inhibition.	Go/no-go.
Moreno-Lopez et al. (2016)	OW (30) NW (30)	53.3% 63.3%	15.3 15.4	28.5 20.0	WM, Inhibition.	LNS, Five-digit test.
Verbeken et al. (2018)	OB (36)	44.0%	12.0	30.0	Inhibition.	Go/no-go.
Bauer, & Houston (2017)	OB (92) NW (96)	100% 100%	15.9 15.9	> 30 18.5-24.9	Inhibition.	Go/no-go, Stroop.
Halberstadt et al. (2017)	OB (120)	57.5%	14.8	40.2	Inhibition.	SST.
Tarp et al. (2016)	OB (89) NW (543)	51.6% 51.0%	13.2 12.9	> 30 18.5-24.9	Inhibition.	Flanker task.
Watach et al. (2019)	OB (20)	0%	13.4	36.0	Inhibition, WM, planning.	Brief-2.
Chen et al. (2016)	OB (50)	44.0%	12.7	> 30	Set-shifting.	WCST.
Borkertienė et al. (2019)	OW (10) NW (10)	0%	18.7 18.1	27.4 21.7	Choice reaction time, inhibition.	ANAM4.
Chen et al. (2017)	OB (66)	42.4%	14.0	> 30	Planning.	TOL.
Huang et al. (2015)	OB (74)	14.3%	13.0	> 30	Inhibition.	Flanker task.
Staiano et al. (2012)	OB (54)	57.4%	16.4	33.1	task switching, CF.	D-KEFS.
Flynn et al. (2014)	OB (7) OW (14) NW (49)	50.0% 50.0% 50.0%	13.2 14.9 11.7	> 30 25.0-29.9 18.5-24.9	task switching, CF, inhibition.	D-KEFS.
Naar-King et al. (2016)	OB (181)	76.0%	14.2	> 30	Inhibition, WM, planning.	Brief-Parent Report.
Booth et al. (2013)	OB (279)	50.0%	13.0	> 30	task switching.	opposite-worlds task
Verbeken et al. (2013)	OB (44)	45.0%	12.0	> 30	Inhibition, WM.	Corsi Block-Tapping Task, SST.
Xiang et al. (2019)	OB (36)	44.4%	12.8	> 30	Inhibition.	Stroop.
Gowey et al. (2018)	OB (195)	60.0%	12.9	33.9	Inhibition, WM, planning.	Brief-Parent Report.
Warschburger et al. (2018)	OB (232)	53.9%	13.0	> 30	Inhibition.	Stroop.
Wu et al. (2016)	OB (44) OW (23) NW (92)	31.8% 26.0% 56.5%	12.0	> 30 25.0-29.9 18.5-24.9	WM.	Digit Span.
Padilla et al. (2019)	OB (30) NW (30)	49.0% 51.0%	15.3	> 30 18.5-24.9	WM.	LNS.

(continues)

Table 1 (Conclusion)
Studies Included in the Systematic Review

Study	Subject (sample size)	Female %	Mean age (years)	Mean BMI kg/m²)	EF studied/structural-functional brain abnormalities	Task/s used/neuroimaging technique
Verdejo-García et al. (2010)	OB (19) OW (8) NW (34)	31.8% 26.0% 56.5%	15.3	28.1-51.0 24.0-28.0 17.5-23.9	WM.	LNS.
Narimani et al. (2019)	OB (15) NW (76)	58.0% 55.0%	19.9	30.0 18.0-23.0	WM.	CANTAB, Spatial WM (SWM) Spatial Span (SSP).
Schwartz et al. (2013)	NW (983)	N.R	15.0	NR	WM.	Digit-span (F-B) SOPT.
Li et al. (2008)	OW (360) NW (1716)	N.R	N.R	28.0	WM.	Digit-span and Arithmetic test.
Alarcon et al. (2016)	OW (46) NW (88)	N.R	14.1	28.0	WM.	Verbal WM accuracy, Spatial WM.
Brady et al. (2017)	OW (20) NW (20)	N.R	16.7	28.0 24.0	WM.	WISC/WM (WAIS).

Note. N.R = not reported; OB = Obesity group; OB-T2D = Obesity-type 2 diabetes group; OB-MS = Obesity-metabolic syndrome; OW = Overweight group; NW = normal weight group; WHM = White matter; WRALM = Wide Range assessment of learning and memory; WJIII-Cog = Woodcock-Johnson Tests of Cognitive Abilities (third edition); WJA = Woodcock-Johnson Tests of Achievement; MRI = Magnetic Resonance Imaging; fMRI = Functional Magnetic Resonance Imaging; EEG = Electroencephalogram; Brief-2 = Behavior Rating Inventory of Executive Function-2; D-KEFS = Delis-Kaplan Executive Function System; SPSRQ = Sensitivity to Punishment and Sensitivity to Reward Questionnaire; TMT = Trail Making Test; TMT B = Trail Making Test part B; COWAT = Controlled Oral Word Test; TOL = Tower of London; WCST = Wisconsin Card Sorting Test; LNS = Letter Number sequencing; CANTAB = Cambridge Neuropsychological Test Battery; SST = Stop signal task; WAIS = Wechsler Adult Intelligent Scale; IGT = Iowa Gambling Task; SOPT = Self-ordered pointing task; MIDT = Monetary incentive delay task; ANAM4 = Automated Neuropsychological Assessment Metrics version 4; LSLF = left superior longitudinal fasciculus; LILF = left inferior longitudinal fasciculus; PFC = prefrontal cortex; CSF = cerebrospinal fluid; ACC = anterior cingulate cortex; OFC = Orbitofrontal Cortex.

Results

Bibliometric Analysis

Research databases show an evolution of the number of papers per year available in Web of Science on executive dysfunction in adolescents and obesity. The first publication, according to Web of Science data, was in 2006. From this moment on, the number of papers has grown on an annual percentage rate of 34%.

In Table 2 an overview of the most important journals according to their number of papers in the search is provided. In this table OBESITY (ranked as Q1) is presented as the most influential journal in this topic with eight articles that were cited 425 times. Most journals are both in quantile Q1 or Q2, showing the quality and importance of the research topic. Additionally, their impact factor is greater than 1.

Table 2
The Most Important Journals on Research Topic According to the Number of Published Papers

Journal	Papers	Quantile	IF^5	TC	> 100
Obesity	8	Q1	4.505	425	2
International Journal of Obesity	6	Q1	5.544	231	1
Appetite	5	Q1	4.077	66	0
Journal of Pediatrics	5	Q1	4.250	145	0
Childhood Obesity	4	Q2	3.022	27	0
Journal of Pediatric Psychology	4	Q2	3.609	12	0

Note. IF^5 = Impact factor (last 5 years); TC = Times cited; > 100 = Number of papers with > 100 citations. Based on Web of Science database.

Structural and Functional Brain Abnormalities in Adolescent Obesity

The final sample consisted of 15 studies. There were 1014 individuals between obesity (540), normal weight (410), overweight (46) and type 2 diabetes Mellitus (T2DM) (18). Overall, 52.9% of the participants were female, the mean age was 16.1 years old, and the mean body mass index was 29.4. In this review, six studies have been found to report decreased microstructural integrity of white matter (WHM). Four of these studies also examined executive dysfunction. Brain imaging indicated that obese adolescents with T2DM (Yau et al., 2012; Yau, Kim et al., 2014) show reduced volume and WHM integrity compared to obese non-diabetic peers and normal-weight peers. More specifically, obese non-diabetic youth have smaller brain volumes and reduced WHM integrity in the caudate nucleus and thalamus regions compared to healthy-weight controls (Yau et al., 2010), and adolescents with T2DM have smaller brain volumes and reduced WHM integrity compared to both overweight and normal-weight control groups (Rofey et al., 2015). Also, some studies have shown that elevated body mass index is linked to reduced WHM microstructure (Yau et al., 2012; Yau, Kang et al., 2014) and broadly suggest that obesity is associated with myelin and axonal abnormalities, which makes the continued study of WHM microstructure in human obesity relevant (Alarcón et al., 2016).

On the other hand, five studies have demonstrated reductions in the cortical thickness of the orbitofrontal cortex and anterior cingulate cortex, two important regions implicated in eating behaviors and impulse inhibition (Pearce et al., 2017). Relative to lean adolescents, obese participants have significantly higher ratings of disinhibition on the three-factor eating questionnaire, lower performance on cognitive tests, and disinhibition significantly correlates with body mass index, Stroop color-word score, and orbitofrontal cortex volume (Maayan et al. 2011; Yau, Kang et al., 2014). While lean adolescents exhibit increased perfusion in regions of the brain implicated in executive tasks, behavioral choices, and DM and no change in a region vital for homeostatic appetite processes (the hypothalamus), obese subjects exhibited decreased brain perfusion in brain regions involved in EF and medial anterior cingulate cortex (Jastreboff et al., 2016; Ross et al., 2015).

Finally, others found that obese adolescents have smaller cerebellar volumes. These results raise the possibility that early childhood obesity retards both cerebellar and cognitive development (Miller et al., 2009). Similarly, it was reported that obese samples show slower cognitive processing speed, while maintaining equivalent performance on executive tasks, compared with healthy peers. This is most likely due to results that suggest a smaller anterior portion of the corpus callosum (rostrum) which is responsible for frontal lobe interhemispheric communication (Sweat et al., 2017). Neuroimaging studies also indicate that subcortical reward-related regions in obese adolescents are affected. Greater pallidum (de Groot et al., 2017) and smaller thalamus volumes were described, as well as greater and smaller hippocampal volumes (Moreno-López et al., 2012). The hippocampus is selectively engaged during gastric stimulation and this activation correlates with emotional eating and lack of control in obese adolescents.

Inhibitory Control Dysfunction in Adolescent Obesity

Obese individuals are known to be more impulsive than their normal-weight counterparts. Impulsivity has even been postulated to be a predictor of weight loss. This review found 15 studies related to IC dysfunction in adolescent obesity. There were 1564 individuals between obesity (505), normal weight (577), and overweight (482). Overall, 62.7% of the participants were female, mean age was 14.8 years old, and the mean body mass index was 28.5. Obese samples have been shown to discount more both food and monetary rewards compared with normal weight individuals, choosing a smaller and more immediate reward over a larger delayed one, also known as poor action restrain (Kulendran et al., 2014). Obese individuals showed lower accuracy compared to their normal-weight peers in No Go trials, where greater amounts of IC effort are required ($p = 0.03$). Larger No Go N2 amplitude relative to the Go N2 amplitude were also shown ($p = 0.03$), whereas this difference was not observed in healthy samples. Furthermore, a lower self-efficacy of individual's ability to control eating behaviors in challenging situations directly correlated with larger No Go N2 amplitudes for both obese ($p = 0.03$) and normal weight groups ($p = 0.01$) (Bauer & Houston, 2017; Chen et al., 2018).

Recent works indicated that adolescents with binge eating disorder display poorer inhibition compared to normal-weight samples ($p < 0.05$). However, these differences vanish after controlling for education (Kittel et al., 2017; Lokken et al., 2009). When required to inhibit prepotent responses to appetizing food, body mass index correlated with response inhibition at both the behavioral and neural levels, with more overweight adolescents showing greater behavioral evidence of impulsivity as well as reduced activation of frontal inhibitory regions, including superior frontal gyrus, middle frontal gyrus, ventrolateral prefrontal cortex, medial prefrontal cortex, and orbitofrontal cortex, than leaner individuals. As well, activation in food reward regions (e.g., temporal operculum/insula) in response to food images directly correlated with body mass index (Batterink et al., 2010; Jensen et al., 2019). Overweight and obese adolescents show highly variable, rather slow, and inaccurate reactions, indicating low IC performance due to lapses of attention. Especially in younger samples, it was reported that higher body weight is associated with rapid and inaccurate responses, indicating low IC due to impulsiveness (Pauli-Pott et al., 2010a).

On the other hand, obese participants, compared with those of normal weight, who showed impairments in measures of inhibition ($r = 0.38$, $p = 0.003$) also displayed shifting deficits ($r = 0.30$, $p = 0.02$), and higher subjective stress levels, in response to the Trier Social Stress Task (TSST) ($r = 0.46$, $p < 0.001$). Furthermore, obese individuals show a differential psychophysiological pattern during the TSST. Heart rate increases during negative social evaluation situations $F(1, 29) = 8.45$, $p = 0.007$, $\eta^2 = 0.23$, while no change was observed in normal weight individuals, $F(1, 29) = 1.16$, $p = 0.29$, $p = 0.04$ (Padilla et al., 2019).

Finally, IC capacity might support obese subjects in reducing weight. Therefore, developed weight-reduction programs (Huang et al., 2019; Pauli-Pott et al., 2010b) suggest that children who succeed are younger than those who do not, $t = 2.96$, $p < 0.01$, but also propose that adolescents with obese siblings show a lower success rate in the weight-reduction program, $\chi^2(1, n = 38) = 9.55$, $p < 0.005$.

Findings from computerized attention trainings (Bauer & Houston, 2017; Verbeken et al., 2018) suggest that after training, inhibition subscales (BRIEF) show an interaction between time and condition, F(1, 34) = 12,343, $p = 0.001$, partial $\eta^2 = 0.266$, with inhibition scores decreasing in training groups from pre-training ($M = 15.524$, $SD = 1.125$) to post-training ($M = 14.286$, $SD = 1.165$), while inhibition increases in control groups from pre-training ($M = 18.133$, $SD = 1.331$) to post-training ($M = 19.267$, $SD = 1.379$). There is also between-group difference at posttest, $t(34) = 2.760$, $p = 0.009$, $\eta^2 = 0.2$ while at baseline there is not.

Effects of Physical and Cognitive Activity on Executive Functioning in Adolescent Obesity

This review presents 15 studies about the effects of PA and cognitive training in adolescent obesity. There were 2112 individuals between obesity (1371), normal weight (694), and overweight (47). Overall, 40.6% of the participants were female, the mean age was 14.5 years old, and the mean body mass index was 29.3. Twelve out of the 15 studies focused on the effects of PA in cognitive skills. The remaining studies presented the relationship between cognitive training and body mass index. Exercise involved training plans but also technology, where Nintendo Wii proved to be an effective tool to improve physical performance.

Sample sizes in the reviewed studies were variable due to their main goal, ranging from 20 participants to 4755. Most works have studied adolescents and young adults. It was found that obese adolescents perform worst in executive tasks (Gowey et al., 2018) when compared to highly active peers in the Automated Neuropsychological Assessment Metrics 4 test. Active participants showed better results in visual tracking and attention tasks (96.76% ± 1.85%/90.23% ± 2.01%), response inhibition (97.58% ± 0.94%/92.48% ± 1.05%), processing speed and alternating attention (98.35% ± 1.35%/89.01% ± 4.09%) than obese peers ($p < 0.05$) (Borkertienė et al., 2019). It was also found that regular PA for 3 months improved performance in CF tasks, like the Wisconsin Card Sorting Test in obese samples. Total number of errors in the training group decreased (base line: $M = 27.48$, SD 10.76; posttest: $M = 24.28$, $SD = 10.48$) when compared to the control group (base line: $M = 27.14$, $SD = 15.39$; posttest: $M = 26.22$, $SD = 15.71$) (Chen et al., 2016, 2017).

In a similar vein, another study suggested that moderate anaerobic exercise may improve attention in male adolescents. This has major implications for interventions aimed at improving executive attention, but also school performance (Booth et al., 2013). Therefore, studies keep training gross motor skills through video games which have proven to be effective in EF performance. It was reported that training competitive skills allowed adolescents to get better scores in the Delis-Kaplan Executive Function System ($M = 15.40$ points, $SD = 12.21$) versus cooperative skills training ($M = 6.59$ points, $SD = 9.23$) versus control group ($M = 2.41$ points, $SD = 12.1$) (Staiano et al., 2012). On the other hand, 10-weeks training can improve weight loss and executive performance ($r = 0.479$ $p = 0.38$).

Others replicated the previous study using Nintendo Wii for 5 weeks. A better performance was found after the intervention when compared to pretest, $t(69) = 4.32$, $p < 0.001$, $\eta^2 = 0.5$). It was also reported that participants who showed frustration and boredom feelings scored worst on executive tests, $r^2 = 0.09$, $\beta = -0.30$,

$p < 0.05$ (Flynn et al., 2014). In addition, similar studies indicated that both exercise and plant-based diet improve self-control in adolescent obesity. For instance, obese individuals who were not exposed to any of these two interventions showed low scores in the interference phase of the Stroop test, $t(34) = 2.404$, $p = 0.022$, $d = 0825$ (Xiang et al., 2019). Moreover, a study reported no differences after PA in arithmetic and EF tasks (IC 95%) -0.05 (-0.31-0.21) (Tarp et al., 2016). However, direct associations were reported between PA and IC (Huang et al., 2015). Finally, no effect has been found between physical training and EF measured by the Brief-2 self-report ($r_S = 0.422$; $p = 0.081$) (Watach et al., 2019).

From a different perspective, this review presents the effect of cognitive training on weight loss in adolescent obesity. It was reported that cognitive training moderates the relationship between cognitive skills and weight loss. The higher the performance in executive tests the lesser the overweight percentage (4.39%, 95% CI [2.532%, 6.240%]) when compared to low performance in EF (1.59%, 95% CI [-0.35%, 3.38%]) (Naar-King et al., 2016). Besides, cognitive training impacted WM in obese samples, $F(1.141) = 4.54$, $p \leq 0.05$, $\eta^2 = 0.54$, and effects have proven to last up to 8 weeks post training (Verbeken et al., 2013). Finally, approach–avoidance training as an additional treatment for obese adolescents was effective in weight loss $t(225) = -0.7$, $p = 0.484$ (Warschburger et al., 2018).

Working Memory Dysfunction in Adolescent Obesity

The final sample consisted of 15 studies. There were 3445 individuals between obesity (64), normal weight (2947), and overweight (434). Overall, 46.7% of the participants were female, the mean age was 13.7 years old, and the mean body mass index was 24.8**.** WM has been rarely studied in obese adolescents. However, it was reported that body mass index correlates inversely with WM performance ($r = -0.098$, $p = 0.027$). It was indicated that both WM training and healthy eating habits directly correlates with WM performance ($r = 0.086$, $p = 0.052$) (Manasse et al., 2014; Tee et al., 2018; Wu et al., 2016). Central obesity strongly correlated with cognitive deficits in adolescents. For instance, awareness and WM deficits were reported in participants who show an increase in central adiposity (Frye et al., 2019). On the other hand, a decrease in body mass index has no effects in WM 0.24, 95% CI [-3.7, 4.1], $p = 0.9$. However, verbal comprehension scores decreased when body mass index increased (adjusted estimated difference -6.1, 95% CI [-11.6, -0.6], $p = 0.03$) (Anderson et al., 2019).

Others reported that fat stored viscerally is associated with low performance in WM ($p = 0.0001 - 0.02$) (Gonzales et al., 2010; Schwartz et al., 2013). In addition, this inverse correlation is also seen between verbal, ($r^2 = -0.21$, $p < 0.05$), spatial ($r^2 = -0.18$, $p < 0.05$) WM and body mass index in obese samples (Alarcón et al., 2016). However, another study found an inverse correlation between WM and weight, but no associations in obese subjects ($p = 0.008$) ($r^2 = -0.15$) (Narimani et al., 2019).

Additionally, recent research reported that obese adolescents show higher response time in the letter-number sequencing test when compared to healthy peers, $F(1, 58) = 16.82$, $p < 0.001$, $\eta^2 = 0.23$ (Padilla et al., 2019). Likewise, similar studies found that both obese and binge eating disorder samples scored low in the digit-span task (Duchesne et al., 2010). However, others found no differences between obese subjects ($M = 19.96$, $SD = 2.71$) and healthy individuals ($M = 20.41$, $SD = 2.4$) in the same tasks (Verdejo-García et al., 2010). Furthermore, obese participants with T2D scored lower in the WM index (WAIS-IV) when compared to a control group ($p < 0.05$). Nevertheless, scores were in the average range of the tasks (Brady et al., 2017). Besides, WM deficits in obese participants predict deficits in learning from negative experiences (Coppin et al., 2014). Finally, poor psychosocial development, bad healthy habits, and high body mass index predict WM deficits in obese adolescents (Li et al., 2008).

Discussion

This is one of the first reviews to gather data to demonstrate the extent to which this relationship exists in adolescence. Sixty studies which met the inclusion criteria were examined, and 45 of these evaluated at least one common executive domain (IC, WM). Obese individuals were found to prefer a smaller and more immediate reward over a larger delayed reward. This is also known as temporal discounting and represents individual's impulsivity or temporal myopia of DM (Green & Myerson, 2013). There is accumulating scientific evidence supporting the relation between temporal discounting and body mass index. People carrying excess body weight, that is, greater body mass index, are more prone to choose smaller, more immediate rewards (Jarmolowicz et al., 2014). Others reported that demographic variables, such as gender, age, education, and income, as well as psychological variables, such as intelligence, depression, and risk-seeking tendency, are also known to affect temporal discounting rates (Jarmolowicz et al., 2014). However, the findings in the literature are mixed, with meta analyses suggesting only a very small correlation between discounting and body mass index. For instance, one of the meta analyses found that 44% of studies reported higher discount rates in obesity, 39% of studies reported no difference in discounting between obese individuals and healthy controls, and two studies found reduced discounting in obesity (McClelland et al., 2016). Another meta study found a more robust relationship for case-controlled designs over correlational designs, but argue for a medium effect size in the association between body mass index and discounting, and that discounting may be a valid therapeutic target (Amlung et al., 2019). Finally, it would be interesting to investigate temporal discounting with weight-loss to understand obesogenic mechanisms of DM.

On the other hand, obese samples have a lower self-efficacy ability to control eating behaviors. Self-efficacy, that is defined as the conviction that one can successfully execute the behavior required to produce the outcomes (Abohamza & Moustafa, 2020), enables a sense of personal agency and plays a unique role in motivational and behavioral processes, including health-related decisions. Both general and domain-specific self-efficacy were associated with healthy behaviors among adolescents (Glasofer et al., 2013). For example, studies conducted over brief time-spans suggest that self-efficacy is a good predictor of eating and weight-related behaviors in adolescents (Cortés-Ramírez et al., 2019). Others found that among girls self-related agency beliefs regarding eating predicted stronger intentions to eat healthy and intentions were predictors of behavior (Wolkoff et al., 2011).

It is mandatory to promote self-efficacy in adolescents, because it predicts engagement and performance in weight control behavior (Ames et al., 2012). Some works showed strong correlations between self-efficacy and increasing PA among adolescent girls (Verloigne et al., 2016) and, with proper planning of interventions, it impacts an individual's intake of fruit and vegetables and reduces energy-dense food intake (Luszczynska et al., 2016). Establishing healthy habits during adolescence is important, given that eating behavior that is likely to cause fatness is actively adopted during this age (Scaglioni et al., 2018), while consumption of fruits and vegetables, which has immediate and long-term health-protective benefits, is likely to decline (Pearson et al., 2011). Instilling self-efficacy is important in ensuring healthier food choices and dietary intake among adolescents, since, as others mentioned, eating behaviors and habits established during adolescence are likely to persist into adulthood (Muturi et al., 2016).

In summary, results indicate that IC dysfunction in adolescent obesity predicts weight increase over time. Most likely, this impairment plays a role in resisting the impulse to obtain appetizing but unhealthy food, and in downregulating the motivation to consume desirable food: these two functions recruit the prefrontal cortex (Hollmann et al., 2012). However, the mechanisms underlying the relationship between IC and obesity remain poorly understood. Some studies have evaluated obese individuals with positron emission tomography and suggest a lower dopamine D2 receptor density in the striatum in comparison with normal weight controls. This reduction was associated with higher metabolic activity in prefrontal regions, suggesting a mechanism that might contribute to overeating. In addition, this mechanism would be subtended by prefrontal pathways involved in IC (Reyes et al., 2015).

The study of decreased microstructural integrity of WHM in adolescent obesity is also a new approach to the study of executive dysfunction. WHM is frequently used to refer to fractional anisotropy, however, it is one of several indicators; others examined diffusivity parameters to provide a detailed picture of the underlying microstructural WHM differences (Nouwen et al., 2017). The data suggest that the reduction in fractional anisotropy in participants with T2D stemmed from an increased diffusivity in the radial axis, which is associated with demyelination in animal studies (Samara et al., 2020). Obesity-related WHM volumetric alterations that reflect macrostructural changes show complex patterns, revealing direct associations with body mass index in frontal, temporal, and parietal lobes (Vangberg et al., 2019) and an inverse relationship with the basal ganglia and corona radiata (Yokum et al., 2012). Intriguingly, 6-week diet programs reversed this effect (Haltia et al., 2007).

One of the main findings from this perspective is related to the effects of obesity on WHM integrity of the corpus callosum. Several works used a voxel-wise whole-brain analysis and identified an inverse correlation between body mass index and microstructural architecture of the WHM, primarily in the corpus callosum in subjects with different body mass index. An increased body mass index reduced fractional anisotropy values in the entire corpus callosum with greater changes in the genu, even after correcting for vascular and inflammatory markers (Verstynen et al., 2013). Axial diffusivity was found to decrease in the splenium, genu, and body (Mueller et al., 2011; Ryan & Walther, 2014; Xu et al., 2013), while radial diffusivity showed high values in the genu and splenium (Mueller et al., 2011; Xu et al., 2013). These findings show that obesity is largely associated with axonal damage accompanied with demyelination of the corpus callosum (Kullmann et al., 2015).

Furthermore, adolescent obesity showed effects on the WHM integrity of the fornix and cingulum through ROI-based analysis (region of interest). These are prominent tracts within the limbic system. In the last decade, studies worked over the obesity-related effects on the fornix, revealing reduced WHM integrity. They found both decreased fractional anisotropy values (Bettcher et al., 2013), radial diffusivity, and mean diffusivity values (Metzler-Baddeley et al., 2013) to point to demyelination in the fornix with increasing body mass index. On the other hand, it was found that with increased body mass index, inverse correlations are observed between fractional anisotropy values of the bilateral cingulum in a large sample of young lean adolescents (He et al., 2015). In line with these results, the cingulum and other prominent structures within the temporal and frontal lobes are vulnerable to body weight.

Finally, the present study is also in line with others who found that reduced WHM integrity with increased body mass index was observed in further regions of the brain, especially in studies with large sample sizes (Kullmann et al., 2015). Thereby, studies including severely and morbidly obese participants show more extensive compromise in WHM integrity. Overall, connections within the limbic system and those connecting the temporal and frontal lobe are susceptible to obesity, which can already be seen in adolescence (Yau, Kang et al., 2014). Other works reported that in young to middle aged adults, body mass index as well as waist circumference were inversely associated with fractional anisotropy values in the inferior and superior peduncle (Verstynen et al., 2013) and the corona radiata (Shott et al., 2015; Verstynen et al., 2013), which showed increased axial diffusivity values (Xu et al., 2013). The corona radiata is fundamental to carry information from and to the cerebral cortex.

This review identified that both the function and the anatomy of the orbitofrontal cortex are altered in obese adolescents as evidenced by functional magnetic resonance imaging and magnetic resonance imaging data before meal compared to healthy weight controls. Similarly, they showed elevated orbitofrontal cortex activity after meal, functioning inversely to the patterns seen in lean controls (Maayan et al., 2011). This could suggest the development of resistance to signaling in obese adolescents (Davids et al., 2010). This is essential to the study of executive dysfunction in adolescent obesity, due to studies correlating higher body mass index with a great number of errors in IC behavioral tasks (Batterink et al., 2010). Others contributed to this finding by revealing the inverse correlation between body mass index, overall performance on IC behavioral task, and orbitofrontal cortex gray matter volume (Maayan et al., 2011). The latter shows that there is a difference in neuroanatomy of obese individuals that is detectable behaviorally by the age of 15 years (Delgado-Rico et al., 2013).

This review also indicated that obese samples show verbal WM deficits when compared to healthy individuals (Padilla et al., 2019). However, others pointed out no deficits in spatial WM in obese adolescents (Narimani et al., 2019; Verdejo-García et al., 2010). Therefore, the evidence is inconclusive about WM deficits in adolescent obesity, thus, controlling for multiple variables is strongly suggested, so that variables no longer act as cofounders. Others are encouraged to study the relationship between obesity and WM, since much research has focused on several EF setting aside WM.

Regarding the effects of PA on cognitive functioning, it was reported that normal weight individuals get better scores on executive tasks than their obese counterpart. Moreover, research proved that a 3-month training plan may impact CF in obese individuals. However, individual variables, such as motivation, must be controlled; otherwise, results will lack reliability. Although most studies found the effects of PA on EF, two works proved no effects on arithmetic tasks and the Brief-2, most likely due to the type of the task (Tarp et al., 2016; Watach et al., 2019). EF have been associated with test-based but not self-reported tasks. This relationship may be explained by the similarities between the task demands. PA tasks require active storage and manipulation of information, as well as the integration of information to solve the task, processes that are central to EF, especially to WM (Guye et al., 2019).

The effects of PA mediated by technology has also proven benefits on cognitive functioning and a decrease of body mass index in obese population. For instance, it was proposed that EF training through computerized software reduced the overweight percentage (Naar-King et al., 2016). Similar research has suggested that 8-week training plans can impact body mass index reduction (Verbeken et al., 2018). This impact showed a great transfer to life quality in obese adolescents. Future studies should also work on clinical trials developing both PA and cognitive training protocols to assess the effect on EF. Finally, the authors also recommend additional longitudinal studies to assess whether executive dysfunction is a cause or a consequence of adolescent obesity.

References

Abohamza, E., & Moustafa, A. A. (2020). Motivational interviewing for the treatment of addiction. In A. A. Moustafa (Ed.), *Cognitive, clinical, and neural aspects of drug dddiction* (pp. 289-313). Elsevier. https://doi.org/10.1016/B978-0-12-816979-7.00014-5

Alarcón, G., Ray, S., & Nagel, B. J. (2016). Lower working memory performance in overweight and obese adolescents is mediated by white matter microstructure. *Journal of the International Neuropsychological Society*, *22*(3), 281-292. https://doi.org/10.1017/S1355617715001265

Ames, G. E., Heckman, M. G., Grothe, K. B., & Clark, M. M. (2012). Eating self-efficacy: Development of a short-form WEL. *Eating Behaviors*, *13*(4), 375-378. https://doi.org/10.1016/j.eatbeh.2012.03.013

Amlung, M., Marsden, E., Holshausen, K., Morris, V., Patel, H., Vedelago, L., & McCabe, R. E. (2019). Delay discounting as a transdiagnostic process in psychiatric disorders: A meta-analysis. *JAMA Psychiatry*, *76*(11), 1176-1186. https://doi.org/10.1001/jamapsychiatry.2019.2102

Anderson, Y. C., Kirkpatrick, K., Dolan, G. M. S., Wouldes, T. A., Grant, C. C., Cave, T. L., Hofman, P. L. (2019). Do changes in weight status affect cognitive function in children and adolescents with obesity? A secondary analysis of a clinical trial. *BMJ Open*, *9*(2), Article e021586. https://doi.org/10.1136/bmjopen-2018-021586

Antón, E., Carreiras, M., & Duñabeitia, J. A. (2019). The impact of bilingualism on executive functions and working memory in young adults. *PLoS ONE*, *14*(2), Article e0206770. https://doi.org/10.1371/journal.pone.0206770

Ardila, A. (2018). Is intelligence equivalent to executive functions? *Psicothema*, *30*(2), 159-164. https://doi.org/10.7334/psicothema2017.329

Baddeley, A. (2018). *Working memories: Postmen, divers and the cognitive revolution*. Routledge. https://doi.org/10.4324/9781315627601

Baddeley, A. D., & Hitch, G. J. (2019). The phonological loop as a buffer store: An update. *Cortex*, *112*, 91-106. https://doi.org/10.1016/j.cortex.2018.05.015

Bartholdy, S., Allen, K., Hodsoll, J., O'Daly, O. G., Campbell, I. C., Banaschewski, T., Bokde, A., Bromberg, U., Büchel, C., Burke, E., Conrod, P., Desrivières, S., Flor, H., Frouin, V., Gallinat, J., Garavan, H., Heinz, A., Berndt, I., Martinot, J., … Schmidt, U. (2017). Identifying disordered eating behaviours in adolescents: How do parent and adolescent reports differ by sex and age? *European Child & Adolescent Psychiatry*, *26*(6), 691-701. https://doi.org/10.1007/s00787-016-0935-1

Bastian, M., Heymann, S., & Jacomy, M. (2009). Gephi: An open source software for exploring and manipulating networks. *Proceedings of the International AAAI Conference on Web and Social Media*, *3*(1), 361-362. https://doi.org/10.13140/2.1.1341.1520

Batterink, L., Yokum, S., & Stice, E. (2010). Body mass correlates inversely with inhibitory control in response to food among adolescent girls: An fMRI study. *NeuroImage*, *52*(4), 1696-1703. https://doi.org/10.1016/j.neuroimage.2010.05.059

Bauer, L. O., & Houston, R. J. (2017). The value of instability: An investigation of intrasubject variability in brain activity among obese adolescent girls. *International Journal of Obesity*, *41*(10), 1489-1495. https://doi.org/10.1038/ijo.2017.144

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development*, *81*(6), 1641-1660. https://doi.org/10.1111/j.1467-8624.2010.01499.x

Bettcher, B. M., Walsh, C. M., Watson, C., Miller, J. W., Green, R., Patel, N., & Kramer, J. H. (2013). Body mass and white matter integrity: The influence of vascular and inflammatory markers. *PLoS ONE*, *8*(10), Article e77741. https://doi.org/10.1371/journal.pone.0077741

Blondel, V. D., Guillaume, J. -L., Lambiotte, R., & Lefebvre, E. (2008). Fast unfolding of communities in large networks. *Journal of Statistical Mechanics: Theory and Experiment*, *28*(8), Article 10008 https://doi.org/10.1088/1742-5468/2008/10/P10008

Booth, J. N., Tomporowski, P. D., Boyle, J. M., Ness, A. R., Joinson, C., Leary, S. D., & Reilly, J. J. (2013). Associations between executive attention and objectively measured physical activity in adolescence: Findings from ALSPAC, a UK cohort. *Mental Health and Physical Activity*, *6*(3), 212-219. https://doi.org/10.1016/j.mhpa.2013.09.002

Borkertienė, V., Stasiulis, A., Zacharienė, B., Kyguolienė, L., & Bacevičienė, R. (2019). Association among executive function, physical activity, and weight status in youth. *Medicina*, *55*(10), Article 677. https://doi.org/10.3390/medicina55100677

Brady, C. C., Vannest, J. J., Dolan, L. M., Kadis, D. S., Lee, G. R., Holland, S. K., & Shah, A. S. (2017). Obese adolescents with type 2 diabetes perform worse than controls on cognitive and behavioral assessments. *Pediatric Diabetes*, *18*(4), 297-303. https://doi.org/10.1111/pedi.12383

Campos Rodríguez, A. Y., Romero García, J. A., Hall-López, J. A., & Ochoa Martínez, P. Y. (2021). Overview of overweight and obesity in Latin American schools. *Retos, 39*, 863-869. https://doi.org/10.47197/retos.v0i39.78426

Carroll, J. (2007). Young children's cognitive development: Interrelationships among executive functioning, working memory, verbal ability, and theory of mind. *Child and Adolescent Mental Health*, *12*(2), 100. https://doi.org/10.1111/j.1475-3588.2007.00450_2.x

Chen, F. -T., Chen, S. -R., Chu, I. -H., Liu, J. -H., & Chang, Y. -K. (2017). Multicomponent exercise intervention and metacognition in obese preadolescents: A randomized controlled study. *Journal of Sport and Exercise Psychology*, *39*(4), 302-312. https://doi.org/10.1123/jsep.2017-0013

Chen, S., Jia, Y., & Woltering, S. (2018). Neural differences of inhibitory control between adolescents with obesity and their peers. *International Journal of Obesity*, *42*(10), 1753-1761. https://doi.org/10.1038/s41366-018-0142-x

Chen, S. -R., Tseng, C. -L., Kuo, S. -Y., & Chang, Y. -K. (2016). Effects of a physical activity intervention on autonomic and executive functions in obese young adolescents: A randomized controlled trial. *Health Psychology*, *35*(10), 1120-1125. https://doi.org/10.1037/hea0000390

Cohen, J. I., Yates, K. F., Duong, M., & Convit, A. (2011). Obesity, orbitofrontal structure and function are associated with food choice: A cross-sectional study. *BMJ Open*, *1*(2), Article e000175. https://doi.org/10.1136/bmjopen-2011-000175

Coppin, G., Nolan-Poupart, S., Jones-Gotman, M., & Small, D. M. (2014). Working memory and reward association learning impairments in obesity. *Neuropsychologia*, *65*, 146-155. https://doi.org/10.1016/j.neuropsychologia.2014.10.004

Cortés-Ramírez, J. C., Gómez-Peresmitré, G., Platas Acevedo, R. S., Villalobos-Gallegos, L., & Marín-Navarrete, R. (2019). Psychometric properties of the self-efficacy scale for a healthy diet in individuals with obesity. *Salud Mental*, *42*(6), 289-296. https://doi.org/10.17711/SM.0185-3325.2019.038

Dassen, F. C. M., Houben, K., Allom, V., & Jansen, A. (2018). Self-regulation and obesity: The role of executive function and delay discounting in the prediction of weight loss. *Journal of Behavioral Medicine*, 41(6), 806-818. https://doi.org/10.1007/s10865-018-9940-9

Daucourt, M. C., Schatschneider, C., Connor, C. M., Al Otaiba, S., & Hart, S. A. (2018). Inhibition, updating working memory, and shifting predict reading disability symptoms in a hybrid model: Project KIDS. *Frontiers in Psychology*, *9*, Article 238. https://doi.org/10.3389/fpsyg.2018.00238

Davids, S., Lauffer, H., Thoms, K., Jagdhuhn, M., Hirschfeld, H., Domin, M., & Lotze, M. (2010). Increased dorsolateral prefrontal cortex activation in obese children during observation of food stimuli. *International Journal of Obesity*, *34*(1), 94-104. https://doi.org/10.1038/ijo.2009.193

de Groot, C. J., van den Akker, E. L. T., Rings, E. H. H. M., Delemarre-van de Waal, H. A., & van der Grond, J. (2017). Brain structure, executive function and appetitive traits in adolescent obesity. *Pediatric Obesity*, *12*(4), e33-e36. https://doi.org/10.1111/ijpo.12149

Delgado-Rico, E., Soriano-Mas, C., Verdejo-Román, J., Río-Valle, J. S., & Verdejo-García, A. (2013). Decreased insular and increased midbrain activations during decision-making under risk in adolescents with excess weight. *Obesity*, *21*(8), 1662-1668. https://doi.org/10.1002/oby.20375

Di Cesare, M., Sorić, M., Bovet, P., Miranda, J. J., Bhutta, Z., Stevens, G. A., & Bentham, J. (2019). The epidemiological burden of obesity in childhood: A worldwide epidemic requiring urgent action. *BMC Medicine*, 17(21), 2-20. https://doi.org/10.1186/s12916-019-1449-8

Donofry, S. D., Stillman, C. M., & Erickson, K. I. (2020). A review of the relationship between eating behavior, obesity and functional brain network organization. *Social Cognitive and Affective Neuroscience*, *15*(10), 1157-1181. https://doi.org/10.1093/scan/nsz085

Duchesne, M., Mattos, P., Appolinário, J. C., de Freitas, S. R., Coutinho, G., Santos, C., & Coutinho, W. (2010). Assessment of executive functions in obese individuals with binge eating disorder. *Brazilian Journal of Psychiatry*, *32*(4), 381-388. https://doi.org/10.1590/S1516-44462010000400011

Faul, L., Fogleman, N. D., Mattingly, K. M., & Depue, B. E. (2019). Inhibitory control mediates a negative relationship between body mass index and intelligence: A neurocognitive investigation. *Cognitive, Affective, & Behavioral Neuroscience*, *19*(2), 392-408. https://doi.org/10.3758/s13415-019-00695-2

Favieri, F., Forte, G., & Casagrande, M. (2019). The executive functions in overweight and obesity: A systematic review of neuropsychological cross-sectional and longitudinal studies. *Frontiers in Psychology*, *10*(2126), 1-27. https://doi.org/10.3389/fpsyg.2019.02126

Flynn, R. M., Richert, R. A., Staiano, A. E., Wartella, E., & Calvert, S. L. (2014). Effects of exergame play on EF in children and adolescents at a summer camp for low income youth. *Journal of Educational and Developmental Psychology*, *4*(1), 209-225. https://doi.org/10.5539/jedp.v4n1p209

Friedman, N. P., & Miyake, A. (2017). Unity and diversity of executive functions: Individual differences as a window on cognitive structure. *Cortex*, *86*, 186-204. https://doi.org/10.1016/j.cortex.2016.04.023

Frye, S. S., Fernandez-Mendoza, J., Calhoun, S. L., Gaines, J., Vgontzas, A. N., Liao, D., & Bixler, E. O. (2019). Childhood obesity, weight loss and developmental trajectories predict the persistence and remission of childhood sleep-disordered breathing. *Pediatric Obesity*, *14*(1), Article e12461. https://doi.org/10.1111/ijpo.12461

Glasofer, D. R., Haaga, D. A. F., Hannallah, L., Field, S. E., Kozlosky, M., Reynolds, J., & Tanofsky-Kraff, M. (2013). Self-efficacy beliefs and eating behavior in adolescent girls at-risk for excess weight gain and binge eating disorder. *International Journal of Eating Disorders*, *46*(7), 663-668. https://doi.org/10.1002/eat.22160

Goldschmidt, A. B., Hipwell, A. E., Stepp, S. D., McTigue, K. M., & Keenan, K. (2015). Weight gain, executive functioning, and eating behaviors among girls. *PEDIATRICS*, *136*(4), e856-e863. https://doi.org/10.1542/peds.2015-0622

Gómez-Tabares, A. S. (2020). Perspectivas de estudio sobre el comportamiento suicida en niños y adolescentes: una revisión sistemática de la literatura utilizando la teoría de grafos. *Psicología desde El Caribe*. Advanced online publication. https://rcientificas.uninorte.edu.co/index.php/psicologia/article/view/13628/214421445704.

Gonzales, M. M., Tarumi, T., Miles, S. C., Tanaka, H., Shah, F., & Haley, A. P. (2010). Insulin sensitivity as a mediator of the relationship between BMI and working memory-related brain activation. *Obesity*, *18*(11), 2131-2137. https://doi.org/10.1038/oby.2010.183

Goossens, G. H. (2017). The metabolic phenotype in obesity: Fat mass, body fat distribution, and adipose tissue function. *Obesity Facts*, *10*(3), 207-215. https://doi.org/10.1159/000471488

Gowey, M. A., Lim, C. S., Dutton, G. R., Silverstein, J. H., Dumont-Driscoll, M. C., & Janicke, D. M. (2018). Executive function and dysregulated eating behaviors in pediatric obesity. *Journal of Pediatric Psychology*, *43*(8), 834-845. https://doi.org/10.1093/jpepsy/jsx091

Green, L., & Myerson, J. (2013). How many impulsivities? A discounting perspective. *Journal of the Experimental Analysis of Behavior*, *99*(1), 3-13. https://doi.org/10.1002/jeab.1

Gustavson, D. E., Panizzon, M. S., Franz, C. E., Reynolds, C. A., Corley, R. P., Hewitt, J. K., & Friedman, N. P. (2019). Integrating verbal fluency with executive functions: Evidence from twin studies in adolescence and middle age. *Journal of Experimental Psychology: General*, *148*(12), 2104-2119. https://doi.org/10.1037/xge0000589

Guye, S., Röcke, C., Martin, M., & von Bastian, C. C. (2019). Functional ability in everyday life: Are associations with an engaged lifestyle mediated by working memory? *The Journals of Gerontology: Series B*, *75*(9), 1873-1883. https://doi.org/10.1093/geronb/gbz056

Halberstadt, J., De vet, E., Nederkoorn, C., Jansen, A., Van Weelden, O., Eekhout, I., Heymans, M., & Seidell, J. (2017). The association of selg-regulation with weight loss maintenance after an intensive combined lifestyle intervention for children and adolescents with severe obesity. *BMC obesity, 4*(13), 1-10. https://doi.org/10.1186/s40608-016-0140-2.

Haltia, L. T., Viljanen, A., Parkkola, R., Kemppainen, N., Rinne, J. O., Nuutila, P., & Kaasinen, V. (2007). Brain white matter expansion in human obesity and the recovering effect of dieting. *The Journal of Clinical Endocrinology & Metabolism*, *92*(8), 3278-3284. https://doi.org/10.1210/jc.2006-2495

He, Q., Chen, C., Dong, Q., Xue, G., Chen, C., Lu, Z. -L., & Bechara, A. (2015). Gray and white matter structures in the midcingulate cortex region contribute to body mass index in Chinese young adults. *Brain Structure & Function*, *220*(1), 319-329. https://doi.org/10.1007/s00429-013-0657-9

Hollmann, M., Hellrung, L., Pleger, B., Schlögl, H., Kabisch, S., Stumvoll, M., & Horstmann, A. (2012). Neural correlates of the volitional regulation of the desire for food. *International Journal of Obesity*, *36*(5), 648-655. https://doi.org/10.1038/ijo.2011.125

Huang, J., Xiong, M., Xiao, X., Xu, X., & Hong, X. (2019). fNIRS correlates of the development of inhibitory control in young obese subjects. *Journal of Integrative Neuroscience*, *18*(3), 253-259. https://doi.org/10.31083/j.jin.2019.03.183

Huang, T., Tarp, J., Domazet, S. L., Thorsen, A. K., Froberg, K., Andersen, L. B., & Bugge, A. (2015). Associations of adiposity and aerobic fitness with executive function and math performance in Danish adolescents. *The Journal of Pediatrics*, *167*(4), 810-815. https://doi.org/10.1016/j.jpeds.2015.07.009

Jarmolowicz, D. P., Cherry, J. B. C., Reed, D. D., Bruce, J. M., Crespi, J. M., Lusk, J. L., & Bruce, A. S. (2014). Robust relation between temporal discounting rates and body mass. *Appetite*, *78*, 63-67. https://doi.org/10.1016/j.appet.2014.02.013

Jastreboff, A. M., Sinha, R., Arora, J., Giannini, C., Kubat, J., Malik, S., & Caprio, S. (2016). Altered brain response to drinking glucose and fructose in obese adolescents. *Diabetes*, *65*(7), 1929-1939. https://doi.org/10.2337/db15-1216

Jensen, C. D., Duraccio, K. M., Barnett, K. A., Carbine, K. A., Stevens, K. S., Muncy, N. M., & Kirwan, C. B. (2019). Sleep duration differentially affects brain activation in response to food images in adolescents with overweight/obesity compared to adolescents with normal weight. *Sleep*, *42*(4), 1-11. https://doi.org/10.1093/sleep/zsz001

Kamijo, K., Pontifex, M. B., Khan, N. A., Raine, L. B., Scudder, M. R., Drollette, E. S., & Hillman, C. H. (2014). The negative association of childhood obesity to cognitive control of action monitoring. *Cerebral Cortex*, *24*(3), 654-662. https://doi.org/10.1093/cercor/bhs349

Kittel, R., Schmidt, R., & Hilbert, A. (2017). Executive functions in adolescents with binge-eating disorder and obesity. *International Journal of Eating Disorders*, *50*(8), 933-941. https://doi.org/10.1002/eat.22714

Kulendran, M., Vlaev, I., Sugden, C., King, D., Ashrafian, H., Gately, P., & Darzi, A. (2014). Neuropsychological assessment as a predictor of weight loss in obese adolescents. *International Journal of Obesity*, *38*(4), 507-512. https://doi.org/10.1038/ijo.2013.198

Kullmann, S., Schweizer, F., Veit, R., Fritsche, A., & Preissl, H. (2015). Compromised white matter integrity in obesity. *Obesity Reviews*, *16*(4), 273-281. https://doi.org/10.1111/obr.12248

Landínez Martínez, D. A., Robledo Giraldo, S., & Montoya Londoño, D. M. (2019). Executive function performance in patients with obesity: A systematic review. *Psychologia*, *13*(2), 121-134. https://doi.org/10.21500/19002386.4230

Lawyer, S. R., Boomhower, S. R., & Rasmussen, E. B. (2015). Differential associations between obesity and behavioral measures of impulsivity. *Appetite*, *95*, 375-382. https://doi.org/10.1016/j.appet.2015.07.031

Li, Y., Dai, Q., Jackson, J. C., & Zhang, J. (2008). Overweight is associated with decreased cognitive functioning among school-age children and adolescents. *Obesity*, *16*(8), 1809-1815. https://doi.org/10.1038/oby.2008.296

Lokken, K. L., Boeka, A. G., Austin, H. M., Gunstad, J., & Harmon, C. M. (2009). Evidence of executive dysfunction in extremely obese adolescents: A pilot study. *Surgery for Obesity and Related Diseases*, *5*(5), 547-552. https://doi.org/10.1016/j.soard.2009.05.008

Luszczynska, A., Hagger, M. S., Banik, A., Horodyska, K., Knoll, N., & Scholz, U. (2016). Self-efficacy, planning, or a combination of both? A longitudinal experimental study comparing effects of three interventions on adolescents' body fat. *PLoS ONE*, *11*(7), Article e0159125. https://doi.org/10.1371/journal.pone.0159125

Maayan, L., Hoogendoorn, C., Sweat, V., & Convit, A. (2011). Disinhibited eating in obese adolescents is associated with orbitofrontal volume reductions and executive dysfunction. *Obesity*, *19*(7), 1382-1387. https://doi.org/10.1038/oby.2011.15

MacPherson, S. E., Healy, C., Allerhand, M., Spanò, B., Tudor-Sfetea, C., White, M., & Cipolotti, L. (2017). Cognitive reserve and cognitive performance of patients with focal frontal lesions. *Neuropsychologia*, *96*, 19-28. https://doi.org/10.1016/j.neuropsychologia.2016.12.028

Mamrot, P., & Hanć, T. (2019). The association of the executive functions with overweight and obesity indicators in children and adolescents: A literature review. *Neuroscience & Biobehavioral Reviews*, *107*, 59-68. https://doi.org/10.1016/j.neubiorev.2019.08.021

Manasse, S. M., Juarascio, A. S., Forman, E. M., Berner, L. A., Butryn, M. L., & Ruocco, A. C. (2014). Executive functioning in overweight individuals with and without loss-of-control eating. *European Eating Disorders Review*, *22*(5), 373-377. https://doi.org/10.1002/erv.2304

Mangone, A., Yates, K. F., Sweat, V., Joseph, A., & Convit, A. (2018). Cognitive functions among predominantly minority urban adolescents with metabolic syndrome. *Applied Neuropsychology: Child*, *7*(2), 157-163. https://doi.org/10.1080/21622965.2017.1284662

Mansur, R. B., Subramaniapillai, M., Zuckerman, H., Park, C., Iacobucci, M., Lee, Y., & McIntyre, R. S. (2019). Effort-based decision-making is affected by overweight/obesity in major depressive disorder. *Journal of Affective Disorders*, *256*, 221-227. https://doi.org/10.1016/j.jad.2019.06.002

McClelland, J., Dalton, B., Kekic, M., Bartholdy, S., Campbell, I. C., & Schmidt, U. (2016). A systematic review of temporal discounting in eating disorders and obesity: Behavioural and neuroimaging findings. *Neuroscience & Biobehavioral Reviews*, *71*, 506-528. https://doi.org/10.1016/j.neubiorev.2016.09.024

Metzler-Baddeley, C., Baddeley, R. J., Jones, D. K., Aggleton, J. P., & O'Sullivan, M. J. (2013). Individual differences in fornix microstructure and body mass index. *PLoS ONE*, *8*(3), Article e59849. https://doi.org/10.1371/journal.pone.0059849

Miller, J. L., Couch, J., Schwenk, K., Long, M., Towler, S., Theriaque, D. W., & Leonard, C. M. (2009). Early childhood obesity is associated with compromised cerebellar development. *Developmental Neuropsychology*, *34*(3), 272-283. https://doi.org/10.1080/87565640802530961

Moreno-López, L., Soriano-Mas, C., Delgado-Rico, E., Rio-Valle, J. S., & Verdejo-García, A. (2012). Brain structural correlates of reward sensitivity and impulsivity in adolescents with normal and excess weight. *PLoS ONE*, *7*(11), Article e49185. https://doi.org/10.1371/journal.pone.0049185.

Moreno-López, L., Contreras, Oren., Soriano, Carles., Stamatakis, E., Verdelo, A. (2016). Disrupted functional connectivity in adolescent obesity. *NeuroImage, 12*(1), 262-268. https://doi.org/10.1016/j.nicl.2016.07.005

Mueller, K., Anwander, A., Möller, H. E., Horstmann, A., Lepsien, J., Busse, F., Pleger, B. (2011). Sex-dependent influences of obesity on cerebral white matter investigated by diffusion-tensor imaging. *PLoS ONE*, *6*(4), Article e18544. https://doi.org/10.1371/journal.pone.0018544

Muturi, N. W., Kidd, T., Khan, T., Kattelmann, K., Zies, S., Lindshield, E., & Adhikari, K. (2016). An examination of factors associated with self-efficacy for food choice and healthy eating among low-income adolescents in three U.S. states. *Frontiers in Communication*, *1*, Article 6. https://doi.org/10.3389/fcomm.2016.00006

Naar-King, S., Ellis, D. A., Carcone, A. I., Templin, T., Jacques-Tiura, A. J., Hartlieb, K. B., & Jen, K. -L. C. (2016). Sequential multiple assignment randomized trial (SMART) to construct weight loss interventions for african american adolescents. *Journal of Clinical Child & Adolescent Psychology*, *45*(4), 428-441. https://doi.org/10.1080/15374416.2014.971459

Naets, T., Vervoort, L., Ysebaert, M., Van Eyck, A., Verhulst, S., Bruyndonckx, L., & Braet, C. (2018). WELCOME: improving WEight controL and CO-Morbidities in children with obesity via Executive function training: Study protocol for a randomized controlled trial. *BMC Public Health*, *18*, Article 1075. https://doi.org/10.1186/s12889-018-5950-3

Narimani, M., Esmaeilzadeh, S., Azevedo, L. B., Moradi, A., Heidari, B., & Kashfi-Moghadam, M. (2019). Association between weight status and executive function in young adults. *Medicina (Kaunas)*, *55*(7), Article 363. https://doi.org/10.3390/medicina55070363

NCD Risk Factor Collaboration (NCD-RisC). (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: A pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. *The Lancet*, *390*(10113), 2627-2642. https://doi.org/10.1016/S0140-6736(17)32129-3

Nouwen, A., Chambers, A., Chechlacz, M., Higgs, S., Blissett, J., Barrett, T. G., & Allen, H. A. (2017). Microstructural abnormalities in white and gray matter in obese adolescents with and without type 2 diabetes. *NeuroImage: Clinical*, *16*, 43-51. https://doi.org/10.1016/j.nicl.2017.07.004

Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2014). Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA*, *311*(8), 806-814. https://doi.org/10.1001/jama.2014.732

Organización Panamericana de la Salud. (2014). *Plan de acción para la prevención de la obesidad en la niñez y la adolescencia*. Organización Mundial de la Salud, Oficina Regional para las Américas. https://iris.paho.org/handle/10665.2/49139

Padilla, M. M., Fernández-Serrano, M. J., Verdejo García, A., & Reyes del Paso, G. A. (2019). Negative social evaluation impairs executive functions in adolescents with excess weight: Associations with autonomic responses. *Annals of Behavioral Medicine*, *53*(4), 383-391. https://doi.org/10.1093/abm/kay051

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Systematic Reviews*, *10*, Article 89. https://doi.org/10.1186/s13643-021-01626-4

Pauli-Pott, U., Albayrak, Ö., Hebebrand, J., & Pott, W. (2010a). Association between inhibitory control capacity and body weight in overweight and obese children and adolescents: Dependence on age and inhibitory control component. *Child Neuropsychology*, *16*(6), 592-603. https://doi.org/10.1080/09297049.2010.485980

Pauli-Pott, U., Albayrak, Ö., Hebebrand, J., & Pott, W. (2010b). Does inhibitory control capacity in overweight and obese children and adolescents predict success in a weight-reduction program? *European Child & Adolescent Psychiatry*, *19*(2), 135-141. https://doi.org/10.1007/s00787-009-0049-0

Pearce, A. L., Mackey, E., Cherry, J. B. C., Olson, A., You, X., Magge, S. N., & Vaidya, C. J. (2017). Effect of adolescent bariatric surgery on the brain and cognition: A pilot study. *Obesity*, *25*(11), 1852-1860. https://doi.org/10.1002/oby.22013

Pearson, N., Ball, K., & Crawford, D. (2011). Predictors of changes in adolescents' consumption of fruits, vegetables and energy-dense snacks. *British Journal of Nutrition*, *105*(5), 795-803. https://doi.org/10.1017/S0007114510004290

Pehlivanova, M., Wolf, D. H., Sotiras, A., Kaczkurkin, A. N., Moore, T. M., Ciric, R., & Satterthwaite, T. D. (2018). Diminished cortical thickness is associated with impulsive choice in adolescence. *The Journal of Neuroscience*, *38*(10), 2471-2481. https://doi.org/10.1523/JNEUROSCI.2200-17.2018

Piché, M. -E., Tchernof, A., & Després, J. -P. (2020). Obesity phenotypes, diabetes, and cardiovascular diseases. *Circulation Research*, *126*(11), 1477-1500. https://doi.org/10.1161/CIRCRESAHA.120.316101

Prasetya, D. D., Prasetya Wibawa, A., & Hirashima, T. (2018). The performance of text similarity algorithms. *International Journal of Advances in Intelligent Informatics*, *4*(1), 63-69. https://doi.org/10.26555/ijain.v4i1.152

Qavam, S. E., Anisan, A., Fathi, M., & Pourabbasi, A. (2015). Study of relationship between obesity and executive functions among high school students in Bushehr, Iran. *Journal of Diabetes & Metabolic Disorders*, *14*, Article 79. https://doi.org/10.1186/s40200-015-0211-9

Rankin, J., Matthews, L., Cobley, S., Han, A., Sanders, R., Wiltshire, H. D., & Baker, J. S. (2016). Psychological consequences of childhood obesity: Psychiatric comorbidity and prevention. *Adolescent Health, Medicine and Therapeutics*, *7*, 125-146. https://doi.org/10.2147/AHMT.S101631

Reinert, K. R. S., Po'e, E. K., & Barkin, S. L. (2013). The relationship between executive function and obesity in children and adolescents: A systematic literature review. *Journal of Obesity*, *20(13)*, 1-10. https://doi.org/10.1155/2013/820956

Reyes, S., Peirano, P., Peigneux, P., Lozoff, B., & Algarin, C. (2015). Inhibitory control in otherwise healthy overweight 10-year-old children. *International Journal of Obesity*, *39*(8), 1230-1235. https://doi.org/10.1038/ijo.2015.49

Rofey, D. L., Arslanian, S. A., El Nokali, N. E., Verstynen, T., Watt, J. C., Black, J. J., & Erickson, K. I. (2015). Brain volume and white matter in youth with type 2 diabetes compared to obese and normal weight, non-diabetic peers: A pilot study. *International Journal of Developmental Neuroscience*, *46*, 88-91. https://doi.org/10.1016/j.ijdevneu.2015.07.003

Ross, N., Yau, P. L., & Convit, A. (2015). Obesity, fitness, and brain integrity in adolescence. *Appetite*, *93*, 44-50. https://doi.org/10.1016/j.appet.2015.03.033

Ruiz, L. D., Zuelch, M. L., Dimitratos, S. M., & Scherr, R. E. (2019). Adolescent obesity: Diet quality, psychosocial health, and cardiometabolic risk factors. *Nutrients*, *12*(1), Article 43. https://doi.org/10.3390/nu12010043

Ryan, L., & Walther, K. (2014). White matter integrity in older females is altered by increased body fat. *Obesity*, *22*(9), 2039-2046. https://doi.org/10.1002/oby.20815

Samara, A., Murphy, T., Strain, J., Rutlin, J., Sun, P., Neyman, O., & Eisenstein, S. A. (2020). Neuroinflammation and white matter alterations in obesity assessed by diffusion basis spectrum imaging. *Frontiers in Human Neuroscience*, *13*, Article 464. https://doi.org/10.3389/fnhum.2019.00464

Scaglioni, S., De Cosmi, V., Ciappolino, V., Parazzini, F., Brambilla, P., & Agostoni, C. (2018). Factors influencing children's eating behaviours. *Nutrients*, *10*(6), Article 706. https://doi.org/10.3390/nu10060706

Schwartz, D. H., Leonard, G., Perron, M., Richer, L., Syme, C., Veillette, S., & Paus, T. (2013). Visceral fat is associated with lower executive functioning in adolescents. *International Journal of Obesity*, *37*(10), 1336-1343. https://doi.org/10.1038/ijo.2013.104

Shott, M. E., Cornier, M. -A., Mittal, V. A., Pryor, T. L., Orr, J. M., Brown, M. S., & Frank, G. K. W. (2015). Orbitofrontal cortex volume and brain reward response in obesity. *International Journal of Obesity*, *39*(2), 214-221. https://doi.org/10.1038/ijo.2014.121

Staiano, A. E., Abraham, A. A., & Calvert, S. L. (2012). Competitive versus cooperative exergame play for African American adolescents' executive function skills: Short-term effects in a long-term training intervention. *Developmental Psychology*, *48*(2), 337-342. https://doi.org/10.1037/a0026938

Sweat, V., Yates, K. F., Migliaccio, R., & Convit, A. (2017). Obese adolescents show reduced cognitive processing speed compared with healthy weight peers. *Childhood Obesity*, *13*(3), 190-196. https://doi.org/10.1089/chi.2016.0255

Tarp, J., Domazet, S. L., Froberg, K., Hillman, C. H., Andersen, L. B., & Bugge, A. (2016). Effectiveness of a school-based physical activity intervention on cognitive performance in Danish adolescents: LCoMotion—learning, cognition and motion—A cluster randomized controlled trial. *PLoS ONE*, *11*(6), Article e0158087. https://doi.org/10.1371/journal.pone.0158087

Tee, J. Y. H., Gan, W. Y., Tan, K. -A., & Chin, Y. S. (2018). Obesity and unhealthy lifestyle associated with poor executive function among Malaysian adolescents. *PLoS ONE*, *13*(4), Article e0195934. https://doi.org/10.1371/journal.pone.0195934

Theodoraki, T. E., McGeown, S. P., Rhodes, S. M., & MacPherson, S. E. (2020). Developmental changes in executive functions during adolescence: A study of inhibition, shifting, and working memory. *British Journal of Developmental Psychology*, *38*(1), 74-89. https://doi.org/10.1111/bjdp.12307

Valencia-Hernández, D. -S., Robledo, S., Pinilla, R., Duque-Méndez, N. D., & Olivar-Tost, G. (2020). SAP algorithm for citation analysis: An improvement to tree of science. *Ingeniería e Investigación*, *40*(1), 45-49. https://doi.org/10.15446/ing.investig.v40n1.77718

Vallaster, C., Kraus, S., Merigó Lindahl, J. M., & Nielsen, A. (2019). Ethics and entrepreneurship: A bibliometric study and literature review. *Journal of Business Research*, *99*, 226-237. https://doi.org/10.1016/j.jbusres.2019.02.050

van Meer, F., Charbonnier, L., & Smeets, P. A. M. (2016). Food decision-making: Effects of weight status and age. *Current Diabetes Reports*, *16*(9), Article 84. https://doi.org/10.1007/s11892-016-0773-z

Vangberg, T. R., Eikenes, L., & Håberg, A. K. (2019). The effect of white matter hyperintensities on regional brain volumes and white matter microstructure, a population-based study in HUNT. *NeuroImage*, *203*, Article 116158. https://doi.org/10.1016/j.neuroimage.2019.116158

Verbeken, S., Braet, C., Goossens, L., & van der Oord, S. (2013). Executive function training with game elements for obese children: A novel treatment to enhance self-regulatory abilities for weight-control. *Behaviour Research and Therapy*, *51*(6), 290-299. https://doi.org/10.1016/j.brat.2013.02.006

Verbeken, S., Braet, C., Naets, T., Houben, K., Boendermaker, W., & Zeepreventorium. (2018). Computer training of attention and inhibition for youngsters with obesity: A pilot study. *Appetite*, *123*, 439-447. https://doi.org/10.1016/j.appet.2017.12.029

Verdejo-García, A., Pérez-Expósito, M., Schmidt-Río-Valle, J., Fernández-Serrano, M. J., Cruz, F., Pérez-García, M., & Campoy, C. (2010). Selective alterations within executive functions in adolescents with excess weight. *Obesity*, *18*(8), 1572-1578. https://doi.org/10.1038/oby.2009.475

Verloigne, M., Cardon, G., De Craemer, M., D'Haese, S., & De Bourdeaudhuij, I. (2016). Mediating effects of self-efficacy, benefits and barriers on the association between peer and parental factors and physical activity among adolescent girls with a lower educational level. *PLoS ONE*, *11*(6), Article e0157216. https://doi.org/10.1371/journal.pone.0157216

Verstynen, T. D., Weinstein, A., Erickson, K. I., Sheu, L. K., Marsland, A. L., & Gianaros, P. J. (2013). Competing physiological pathways link individual differences in weight and abdominal adiposity to white matter microstructure. *NeuroImage*, *79*, 129-137. https://doi.org/10.1016/j.neuroimage.2013.04.075

Walø-Syversen, G., Kvalem, I. L., Kristinsson, J., Eribe, I. L., Rø, Ø., & Dahlgren, C. L. (2019). Executive function, eating behavior, and preoperative weight loss in bariatric surgery candidates: An observational study. *Obesity Facts*, *12*(5), 489-501. https://doi.org/10.1159/000502118

Warschburger, P., Gmeiner, M., Morawietz, M., & Rinck, M. (2018). Evaluation of an approach-avoidance training intervention for children and adolescents with obesity: A randomized placebo-controlled prospective trial. *European Eating Disorders Review*, *26*(5), 472-482. https://doi.org/10.1002/erv.2607

Watach, A. J., Radcliffe, J., Xanthopoulos, M. S., Novick, M. B., & Sawyer, A. M. (2019). Executive function impairments in adolescents with obesity and obstructive sleep apnea syndrome. *Biological Research For Nursing*, *21*(4), 377-383. https://doi.org/10.1177/1099800419846411

Wolkoff, L. E., Tanofsky-Kraff, M., Shomaker, L. B., Kozlosky, M., Columbo, K. M., Elliott, C. A., & Yanovski, J. A. (2011). Self-reported vs. actual energy intake in youth with and without loss of control eating. *Eating Behaviors*, *12*(1), 15–20. https://doi.org/10.1016/j.eatbeh.2010.09.001

Wu, X., Nussbaum, M. A., & Madigan, M. L. (2016). Executive function and measures of fall risk among people with obesity. *Perceptual and Motor Skills*, *122*(3), 825-839. https://doi.org/10.1177/0031512516646158

Xiang, M. -Q., Liao, J. -W., Huang, J. -H., Deng, H. -L., Wang, D., Xu, Z., & Hu, M. (2019). Effect of a combined exercise and dietary intervention on self-control in obese adolescents. *Frontiers in Psychology*, *28*(10), 1-11. https://doi.org/10.3389/fpsyg.2019.01385

Xu, J., Li, Y., Lin, H., Sinha, R., & Potenza, M. N. (2013). Body mass index correlates negatively with white matter integrity in the fornix and corpus callosum: A diffusion tensor imaging study. *Human Brain Mapping*, *34*(5), 1044-1052. https://doi.org/10.1002/hbm.21491

Yang, Y., Shields, G. S., Guo, C., & Liu, Y. (2018). Executive function performance in obesity and overweight individuals: A meta-analysis and review. *Neuroscience & Biobehavioral Reviews*, *84*, 225-244. https://doi.org/10.1016/j.neubiorev.2017.11.020

Yau, P. L., Castro, M. G., Tagani, A., Tsui, W. H., & Convit, A. (2012). Obesity and metabolic syndrome and functional and structural brain impairments in adolescence. *PEDIATRICS*, *130*(4), e856-e864. https://doi.org/10.1542/peds.2012-0324

Yau, P. L., Javier, D. C., Ryan, C. M., Tsui, W. H., Ardekani, B. A., Ten, S., & Convit, A. (2010). Preliminary evidence for brain complications in obese adolescents with type 2 diabetes mellitus. *Diabetologia*, *53*(11), 2298-2306. https://doi.org/10.1007/s00125-010-1857-y

Yau, P. L., Kang, E. H., Javier, D. C., & Convit, A. (2014). Preliminary evidence of cognitive and brain abnormalities in uncomplicated adolescent obesity. *Obesity*, *22*(8), 1865-1871. https://doi.org/10.1002/oby.20801

Yau, P. L., Kim, M., Tirsi, A., & Convit, A. (2014). Retinal vessel alterations and cerebral white matter microstructural damage in obese adolescents with metabolic syndrome. *JAMA Pediatrics*, *168*(12), Article e142815. https://doi.org/10.1001/jamapediatrics.2014.2815

Yokum, S., Ng, J., & Stice, E. (2012). Relation of regional gray and white matter volumes to current BMI and future increases in BMI: A prospective MRI study. *International Journal of Obesity*, *36*(5), 656-664. https://doi.org/10.1038/ijo.2011.175

Zelazo, P. D., & Müller, U. (2010). Executive function in typical and atypical development. In U. Goswami (Ed.), *The Wiley-Blackwell handbook of childhood cognitive development* (pp. 574-603). Wiley-Blackwell. https://doi.org/10.1002/9781444325485.ch22

Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational Research Methods*, *18*(3), 429-472. https://doi.org/10.1177/1094428114562629

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