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Risks of Obesity in Adolescence: The Role of Physical Activity in Executive Functions

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Abstract: The aim of this study was to analyze the efficiency of a physical activity program on executive performance in obese adolescents. Fifteen adolescents (5 males and 10 females), with a mean age of 14.73 years and an IMC mean of 36.74 participated in the study. None of the participants presented a compulsive eating disorder when screened by the Binge Eating Scale. A pretest and posttest assessment, twelve months later, was conducted by using a neuropsychological battery that evaluated the cognitive flexibility (Comprehensive Trail Making Test), inhibition control (Stroop Neuropsychological Screening Test and by the Frontal Assessment Battery), and planning (Tower of London). ANOVA of repeated measures was performed. The within-subjects tests demonstrated significant statistical differences between the two moments of evaluation at the level of inhibitory control and cognitive flexibility tasks, with higher performances in the second evaluation. These results suggest that the inclusion of obese adolescents in such programs may promote their executive capacities.

Keywords: obesity; executive functions; physical activity; adolescence

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1. Introduction

The global prevalence of obesity has almost tripled since 1975 [1]. According to the Childhood Obesity Surveillance Initiative (COSI) Portugal 2019, 29.6% of boys are overweight and 13.4% are obese, and 29.5% of girls are overweight and 10.6% are obese [2].

Obesity is a disease that kills and can be avoided, which justifies the need for intervention in this area. One of the main causes of obesity is physical inactivity, and most of the population does not practice physical exercise [1].

In order to understand appetite and bodyweight, a study found alterations in several brain regions related to reward, homeostatic regulation of intake, sensory and motor processing, and cognitive control and attention by using neuroimaging techniques [3]. In neuropsychology, the results regard the association between low executive income and failure to maintain an adequate diet [4–6].

Executive functions (EFs) refer to a subset of cognitive operations that underlie goal-directed actions including inhibition (the ability to suppress impulses and natural, habitual, or dominant behavioral responses), working memory (the ability to hold and process new and already stored information), and cognitive flexibility (the ability to switch perspectives or one's focus of attention) [7,8]. Previous studies have shown that obese adolescents present alterations in different components of EF, such as inhibitory control [9], working memory [9,10], and cognitive flexibility [9,11]. The impact of physical activity (PA) practice on cognitive performance, and specifically in EF, may be related to physiological changes produced in the brain and/or cognitive strategies necessary to perform exercise [12].

There is growing evidence that regular PA is an effective and low-cost health behavior that supports cognitive and brain development in children and adolescents [13]. Indeed, previous randomized controlled trials have shown that PA intervention increases brain-derived neurotrophic factor, vascular endothelial growth factor, and insulin-like growth

factor-1 levels in the serum [14], as well as improves brain structural and functional integrity, and that these changes might result in improvements in executive functions (EFs) in preadolescent and adolescent [15,16].

It has been well documented that EFs are closely associated with academic performance indicating that any relationship between PA and EFs might be especially important to the effective functioning of school-aged children [17]. The results from a study suggest the beneficial effects of regular PA intervention on cognitive performance are greater in lower baseline performers [18].

Cognitive flexibility seems to be more robustly associated with all fitness components, whereas planning ability and inhibition might depend on the component analyzed [19].

In this perspective, some studies were performed with the purpose of analyzing the effects of physical exercise programs on EF; in one of them, it was recorded that after a 13-week program of aerobic exercise, benefits to planning capacity [20] and in a second, after a 4-month PA program, benefits in working memory, verbal memory, attention, and processing speed were demonstrated [21]. The short duration of PA programs was reported by these authors as a possible explanation for the changes in the different components of EF, suggesting that the intervention period should be reviewed in future studies. It was proposed that body mass index (BMI) decreases are associated with an increase in cognitive skills [22].

Thus, based on the literature and taking into account the lack of studies in this field in Portugal, we defined the objective of analyzing the importance of a PA program on executive performance (cognitive flexibility, inhibitory control, and planning) in obese adolescents. An improvement in their executive tasks following participation in a 12-month PA program was expected.

2. Materials and Methods

2.1. Participants

A total of 27 obese adolescents (12 boys and 15 girls), with a mean BMI of 35.24 (SD = 4.68) and mean age of 14.56 years (SD = 1.58) participated in this study. All of them were being followed by a central hospital in Lisbon and were selected from the casuist of this hospital to be included in the Pediatric Obesity Treatment Program (TOP) promoted by Lusófona University and the Hospital of Lisbon. No compensations were offered. Participants with compulsive intake disorder, severe psychopathology, and/or without the involvement of a parent or caregiver were excluded.

During the 12 months of the PA program, there were 12 dropouts (not attendance in TOP sessions). The program was completed by 15 participants (5 boys and 10 girls), with a mean age of 14.73 years (SD = 1.62). There were no statistically significant differences for BMI between those who abandoned the study and those who continued $t(25) = 1.968$; $p = 0.060$ (Table 1).

Table 1. Difference between participants who performed two and one assessment for BMI.

	Number of Assessments					
	2 Moments (n = 15)		**1 Moment (n = 12)**			
	M	**DP**	**M**	**DP**	***t*(25)**	***p***
ÍMC	36.74	5.20	33.35	3.21	1.968	0.060

2.2. Design

This was a multifactorial within-subjects design. The outcomes of inhibiting control (interference in the Stroop task and scores in the contradictory and Go-no-Go instructions of the FAB), cognitive flexibility (total performance time in seconds of the Comprehensive Trail Making Test), and planning (total number of exercises and movements and total of

execution time) were defined as independent variables, and the evaluation/time (pretest and posttest) were defined as dependent variables.

2.3. Instruments

The Binge Eating Scale (BES) [23], was used to screen compulsive ingestion disorder. The three dimensions of EF were evaluated as follows: cognitive flexibility was evaluated by the Comprehensive Trail Making Test (CTMT) [24], the inhibition capacity by the Stroop Neuropsychological Screening Test (Stroop) [25] and the Frontal Assessment Battery (FAB) [26], and the planning by the Tower of London (ToL) [27].

2.4. Procedures

The study was approved by the institutional Ethics Committee. Participants and their parents gave informed consent and were informed about the study prior to participation. The clinical history and BMI were collected, and the neuropsychological assessment was applied individually in a quiet room. All participants were evaluated at the beginning and end of the physical exercise program. The program lasted 12 months and aimed to promote PA and interactive sessions in the management of weight skills according to the recommendations of Interventions for treating obesity in children [28]. TOP is a multidisciplinary program focused on the treatment of obesity in adolescence, based on medical, nutritional, and PA counseling. The PA sessions (the intervention was developed in the faculty with exercise sessions) were held weekly at the university and within them each participant could choose a peer. Medical and nutritional sessions were held at the Hospital of Lisbon.

3. Results

Due to the number of dropouts and in order to analyze the homogeneity of these cases with those that remained until the end of the study, initially, we analyzed the differences between these groups in relation to BMI and all dependent variables, through the independent *t*-test. The results revealed that the participants who performed the two evaluations did not differ from those who performed only one, regarding the income of the tasks of prevention control, cognitive flexibility, and planning (Table 2).

Table 2. Differences between participants who performed two and one evaluation for income in executive functions.

	Number of Assessments					
	2 Moments (*n* = 15)		**1 Moment (*n* = 12)**			
	M	**DP**	**M**	**DP**	***t*(25)**	***p***
Inhibition Control Interference (Stroop)	26.66	17.36	34.00	17.19	−1.095	0.284
Contradictory Instructions (FAB)	1.00	1.46	0.75	1.35	0.455	0.653
Go-no-Go (FAB)	1.80	1.52	2.75	0.86	−2.040	0.053
Cognitive Flexibility Total Time (CTMT)	269.93	113.61	278.08	123.92	−0.178	0.860
Planning Total Number of Exercises (ToL)	4.00	1.81	5.16	1.69	−1.709	0.100
Total Number of Movements (ToL)	33.33	13.03	26.08	11.24	1.525	0.140
Time of Realization (ToL)	218.86	58.02	204.58	60.46	0.624	0.538

In order to assess the effectiveness of the program in executive functioning, data from the 15 participants who performed both evaluations were analyzed through an ANOVA

of repeated measures, which demonstrated statistically significant differences between the two moments of evaluation F (1.14) = 20.216; p = 0.001 (Table 3). The analysis of the differences was performed with the Student's t-test for paired samples. Results showed significant statistical differences in the inhibition control and cognitive flexibility ($p < 0.05$), with higher performances in posttest.

Table 3. Descriptive values of the results obtained in the two evaluation moments.

	Evaluations					
	Pretest		**Posttest**			
	M	**DP**	**M**	**DP**	***F***	***p***
Inhibition Control Interference (Stroop)	26.66	17.36	20.20	19.47	4.879	0.044
Contradictory Instructions (FAB)	1.00	1.46	1.80	1.52	5.091	0.041
Go-no-Go (FAB)	1.80	1.52	2.73	0.79	5.555	0.034
Cognitive Flexibility Total Time (CTMT)	269.93	113.61	199.53	65.61	16.846	0.001
Planning Total Number of Exercises (ToL)	4.00	1.81	4.53	1.72	0.624	0.443
Total Number of Movements (ToL)	33.33	13.03	27.73	15.92	1.628	0.223
Time of Realization (ToL)	218.86	58.02	207.60	88.95	0.525	0.481

4. Discussion

The aim of this study was to analyze the effectiveness of a PA program on the executive performance (cognitive flexibility, inhibition capacity, and planning) of obese adolescents. An improvement in their executive tasks following participation in a 12-month PA program was expected.

Our findings showed changes in the inhibition capacity and cognitive flexibility but not in the planning, so it is not possible to confirm the hypothesis. Data from this study show an increase in inhibition control and cognitive flexibility after 12 months of PA, however, contrary to the results found by another study [20], the planning did not suffer any effects, which suggests that the program applied was not efficient in stimulating/training this domain. It is possible that the exercise plan promoted did not include tasks that stimulated this competence. This kind of PA may not promote the ability to think about future events and mentally anticipate the correct way to accomplish a task or achieve a specific goal. In addition, it is important to underline that PA exercises were planned without any implications for the adolescents, so this dimension may not have been stimulated efficiently.

Another explanation may be related to the multimodal model of executive functions that proposed that cognitive processes between the beginning and end of adolescence undergo a longitudinal, rectilinear, and continuous maturation [29]. However, the triadic model of motivated behavior presupposes that the maturity of cognitive functions does not develop linearly and, still, the regulated executive functions depend on a triadic balance between the emotional areas such as the nucleus accumbens, the emotional regulation area of the amygdala, and the prefrontal circuit. The results of the present study can also be interpreted according to this model.

Taken together, data from this study seems to be encouraging, as it is indicated that regular PA promotes the stimulation of EF. As EF plays a crucial role in all decisions of daily living, is it possible that an improvement of inhibitory control and cognitive flexibility could promote adherence to a healthy and adequate diet. Although promising, some limitations in this study should be mentioned. The reduced number of participants must

be mentioned, however, several reasons may explain this issue; it was a longitudinal study lasting 12 months that required weekly attendance at the university gymnasium and some did not live in Lisbon. On the other hand, exercising regularly may not be easy, and this may also reflect the ease of this population to give up, which makes us hypothesize that these adolescents had low inhibitory control. The absence of results from a comparison group and the lack of emotional data from participants also must be mentioned.

The study of Gil-Madrona et al., 2018 [30] concluded that 63.5% of the 1.140 adolescents do not practice sports regularity, so future studies are needed to provide further information on the role of PA and executive functions in prevention and control of obesity in preadolescence and adolescence.

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Data Availability Statement: Data may be made available upon request.

Conflicts of Interest: The authors declare no conflict of interest.

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