









# Possible effects of obesity on motor development, executive functioning, and academic performance of schoolchildren from a neuropsychopedagogical perspective

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## ABSTRACT

**Purpose:** This study aimed to compare the motor competence, executive functioning, and academic performance of students with adequate weight, overweight, and obesity.

**Design/Methodology/Approach:** A total of 1631 children aged between 06 and 08 ( $\pm 7.58$ ) years old, of both genders (903 girls and 728 boys), students of the public school system in the state of Rio de Janeiro, participated in this study. To achieve the objective, participants were introduced to protocols that assessed body mass index, Motor Competence, Executive Functioning, Reading Comprehension, and Academic Performance.

**Findings:** When analyzing the results of the protocols related to motor development, cognitive development, and academic performance, the results show a superiority of children with weights within the expected range in relation to obese children.

**Conclusion:** The findings indicate a potential correlation between body mass index (BMI) and the proficiency of children in motor skills, executive functions, and academic performance. Specifically, the results demonstrate that children who are obese exhibit lower scores in all assessed variables compared to children with a BMI within the normal range.

**Research Limitations and Implications:** This study did not assess the participants level of physical activity or their eating habits.

**Practical Implications:** The research results contribute to the formulation of public policies on obesity as a public health problem, since its impacts go far beyond physical health problems.

**Contribution to the Literature:** This research can add to the literature on the impacts of obesity on the cognitive and motor development of children, showing the importance of developing new studies with regard to prevention.

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**Keywords:** Cognitive performance, Motor competence, Obesity, Schoolchildren.

## 1. INTRODUCTION

The World Health Organization (WHO) defines overweight and obesity as body mass index (BMI)  $\geq 25$  and BMI  $\geq 30$ , respectively. Childhood obesity is one of the biggest public health challenges worldwide. The WHO estimates that approximately 70 million children will be overweight or obese by 2025, as children under 5 years of age have shown a rapid increase in the development of overweight and obesity in recent years ([Abduelkarem et al., 2020](#); [Abdulrahman et al., 2019](#); [Almaqhawi et al., 2022](#); [Di Cesare et al., 2019](#)).

The childhood period is presented as a critical moment for the development of overweight and obesity. Increased consumption of sugars, sodium, and unhealthy fats, as well as ultra-processed foods, including sugar-sweetened beverages and energy-rich, nutrient-poor packaged foods, is associated with weight gain and various nutrition-

related non-communicable diseases (Matos, Adams, & Sabaté, 2021). In addition to these conditions, obesity can affect parameters of child development such as motor performance and cognitive performance (Barros et al., 2022).

Quaye et al. (2023) and Wang, Chan, Ren, and Yan (2016) show in their studies possible influences of obesity on the cognitive performance of individuals, since when compared to individuals with weight within the expected range, obese individuals presented lower levels of global cognition, verbal fluency, delayed recall, logical memory, and Immediate and logical thinking.

An explanation for these possible deficits is explained by studies developed by Caunca et al. (2019) and Fernández-Andújar, Morales-García, and García-Casares (2021), which, when establishing comparisons of encephalic structures of obese individuals with individuals with weight within As expected, they identified cases of atrophy in the frontal lobes, anterior cingulate gyrus, hippocampus, and thalamus. Still, in this context of changes in morphophysiological aspects, studies developed by Brooks et al. (2013), Pannacciulli et al. (2006), Stopyra et al. (2021), and Veit et al. (2020) point out that the increase in BMI is associated with lower metabolic activity in the prefrontal cortex, the cingulate gyrus, the uncinated fasciculus, and a smaller volume of gray matter in the orbitofrontal region.

Obese children perform lower on tasks that require executive functioning skills, math skills, and reading skills (Davis & Cooper, 2011; Deconinck, D'Hondt, Caeyenberghs, Lenoir, & Augustijn, 2019; Wang et al., 2016). Possibly these changes in executive functioning directly influence the academic performance of obese children since the prevalence of obese individuals with learning difficulties is twice as high as in individuals without learning difficulties (Dick & Clough, 2019; Salaun & Berthouze-Aranda, 2012). Jeong and Chun (2021) analyzed that obese individuals have lower academic performance when compared to non-obese individuals; (Hayes, Eichen, Barch, & Wilfley, 2018; Ma & Luo, 2023; Patraca-Camacho et al., 2022).

Based on what has been mentioned, this study aimed to compare the motor competence, executive functioning, and academic performance of students with adequate weight, overweight, and obesity.

## 2. MATERIALS AND METHODS

### 2.1. Study Ethics

The protocols used were approved by the UFRJ Ethics Committee (Project Opinion Number. 517,483). The children who participated in this research participated in a meeting in the presence of their guardians to become aware of all procedures, taking bioethical principles into account. After the clarifications and freedom to choose to participate or not in the research, each guardian voluntarily signed the Free and Informed Consent Form.

### 2.2. Participants

A total of 1631 children aged between 06 and 08 ( $\pm 7.58$ ) years old, of both sexes (903 girls and 728 boys), participated in this study, students of the municipal public education network in the north and northwest regions of the state of Rio de Janeiro, under the following inclusion criteria: they could not present any physical or intellectual disability; they could not have heart disease, orthopedic disorders, or behavioral disorders (according to medical evaluation during the study).

### 2.3. Assessment Procedures

Initially, the study participants were submitted to verification of the Body Mass Index; this occurred through the verification of the body mass (weight) through a digital electronic scale (Tanita Inner Scan BC 532 Tokyo, Japan), with a capacity of 150 kg and accuracy of 100 g. Participants were instructed to remain motionless on top of the scale, barefoot, and wearing light clothing. To verify height, a portable stadiometer (Holtain) with a length of 2 meters and a scale of 0.1 cm was used. Participants were instructed to remain standing with their heads touching a metal rod and their arms alongside their bodies. Body mass index (BMI) was calculated by dividing body mass (kg) by height (m) squared ( $\text{kg}/\text{m}^2$ ) and classified according to the International Obesity Task Force into three categories: normal weight, overweight, and obesity. (Cole & Lobstein, 2012; Kuczmarski, 2002).

Soon after, the participants were submitted to the Supine-to-Stand (STS) tests which evaluates motor competence and consists of getting up from the ground from the lying position in dorsal decubitus and touching a target fixed on the wall. For the evaluation, in relation to motor competence during the task of getting up from the ground, an analysis of three categories of components of the movements used to move from the supine position to the erect

position was used: Upper Limbs (UL), Region Axial (RA), and lower limbs (LL). The total score can vary from 0 to 14 points (Duncan, Lawson, Walker, Stodden, & Eyre, 2017).

Then, the children were given an evaluation of their executive functioning using the HEAD-FOOT-KNEE-SHOULDER (HFKS) protocol (Ponitz et al., 2008), which measures inhibitory control and cognitive flexibility by giving them tasks that require touching body parts. The familiarization phase of the test consists of direct execution orders, and after understanding the purpose of the test, the participant is instructed to execute the orders in reverse order (e.g., head touch = foot / foot touch = head). After this step, the participant is evaluated with 30 random orders to be executed in reverse, divided into 3 phases. The maximum score is 60 points in this test, with the highest score being the best performance.

After 24 hours, the children were submitted to the Expository Text Reading Comprehension Assessment Test (Saraiva, Moojen, & Munarski, 2006). The compilation of texts provided is specifically tailored for each grade level within the Elementary School curriculum. For the purposes of this study, the text chosen was "The Baby Elephant," taking into consideration the age range and grade level of the participants. The evaluator instructed the children to read the text while adhering to specific guidelines. These guidelines included keeping the text on the table throughout the entire reading process, maintaining appropriate body posture during the evaluation, and reading from start to finish without any interruptions. Failure to comply with these instructions would result in the reading being restarted. This analysis focused on the overall duration of reading, excluding any interruptions caused by coughing, clearing of the throat, nasal congestion, or cold symptoms. The videos were reproduced in the software, which also allowed for the exclusion of excerpts that had pauses. Speed was calculated by the number of words read per minute.

Finally, the children were submitted to a verification of academic performance through an evaluation composed of 20 questions, chosen randomly through the electronic platform in a personalized way for the public under investigation, equally divided between the curricular components of Portuguese Language (PL) and Mathematics (MT). The assessment was performed with the child sitting comfortably in a well-ventilated and illuminated room. Before starting, the team of the evaluators was informed that the maximum time for carrying out the referred evaluation was one hundred and twenty minutes. It should be noted that all evaluation protocols were carried out in the participants' school environment.

#### 2.4. Statistical Analysis

The data analysis of this study was performed based on the comparison of statistical results using the Prism 9.5.1 statistics program. The results initially obtained were calculated using descriptive statistics (mean and standard deviation). Subsequently, the results obtained for each evaluated variable were tested for verification of their normality by the Shapiro-Wilk test, which was classified as non-parametric. Therefore, for intergroup comparison, the Mann-Whitney test was used for two independent samples.

### 3. RESULTS

The results indicated that the values related to the BMI of the boys participating in this study varied between 14.02 and 29.06 points, with an average performance equal to 17.73 (4.26); among the girls, the values varied between 15.21 and 28.36 points, with an average performance equal to 17.88 (3.63) points. When comparing the results obtained with the proposed reference values for the children's age group, it was identified that 25.54% (186) of the boys were classified as obese, 28.70% (209) as overweight, and 45.74% (333) with weight within the expected range. Within the female population, it is evident from Figure 1 that 23.69% (214) were classified as obese, 38.98% (352) were categorized as overweight, and 37.32% (337) fell within the expected weight range.

When evaluated regarding motor competence, the results for the group of girls with obesity showed a lower score of 18% ( $p < 0.01$ ) in relation to those with overweight and a lower score of 24% ( $p < 0.01$ ) in relation to girls with weight within the expected range in the STS. The analysis of the group of boys generated the following results: boys with obesity obtained a lower score of 20% ( $p < 0.01$ ) compared to overweight peers and a lower result of 26% ( $p < 0.01$ ) compared to boys with the expected weight. Indicating a possible negative influence of obesity on the motor competence of children, Table 1.

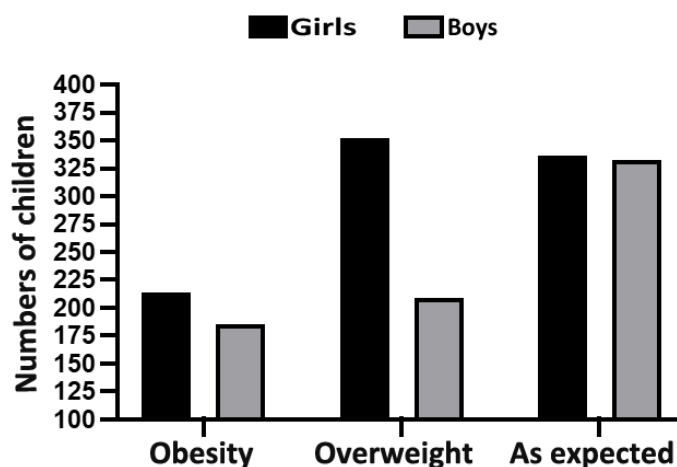


Figure 1. Results obtained through BMI classifications.

Table 1. Results of students with adequate weight, overweight and obesity in skills related to Motor competence

Variables	Obesity		Overweigh		As expected	
	Girls	Boys	Girls	Boys	Girls	Boys
Minimum	7	6	8	7	7	8
Maximum	13	13	14	14	14	121% em relaça4
Average	9.5	10.25	11.30	12.40	11.87	13.01
Standard deviation	1.43	2.56	3.82	2.95	4.42	3.11

In Table 2, it is noted that obese boys had lower results of 18% ( $p < 0.01$ ) compared to the overweight group and 21% ( $p < 0.01$ ) compared to those with the expected weight when assessed on their executive functioning capabilities. Among the group of girls with obesity, the data showed a lower performance of 21% when compared to the overweight group and 22% when compared to girls with the expected weight for the performance of tasks related to executive functioning. Therefore, it is clear that obesity should be considered an unfavorable factor in skills related to the executive functioning of children.

Table 2. Results of students with adequate weight, overweight and obesity in skills related to executive functioning.

Variables	Obesity		Overweigh		As expected	
	Girls	Boys	Girls	Boys	Girls	Boys
Minimum	27	29	25	26	23	24
Maximum	44	50	53	51	54	52
Average	38.80	38.05	47.33	45.27	47.72	46.05
Standard deviation	4.02	5.08	6.29	7.68	5.21	7.93

Assessments of reading comprehension ability showed the following results: Boys with obesity had an average lower performance of 16% ( $p < 0.01$ ) compared to their overweight peers and 18% ( $p < 0.01$ ) compared to their peers. To the group with a weight within the expected range.

Table 3. Results of students with adequate weight, overweight and obesity in a reading comprehension task.

Variables	Obesity		Overweigh		As expected	
	Girls	Boys	Girls	Boys	Girls	Boys
Minimum	48	46	46	45	45	44
Maximum	71	74	72	70	73	72
Average	59.04	57.31	67.30	66.49	69.07	68.19
Standard deviation	6.14	7.44	7.02	6.10	8.41	7.58

The results obtained by girls with obesity indicated a lower performance of 13% ( $p < 0.01$ ) in relation to those with overweight and 16% ( $p < 0.01$ ) when compared to the group with the expected weight. It can be seen, then, that obese children have a lower reading fluency than overweight children, and the weight is within the expected range, indicating possible unfavorable interferences of obesity in the ability to decode and mentally manipulate information [Table 3](#).

[Table 4](#) shows us that obese boys, in the evaluation of academic performance, presented lower results of 16% ( $p < 0.01$ ) in relation to overweight and 19% ( $p < 0.01$ ) when compared to the weight group, as expected. Regarding the performance of girls, the group with obesity obtained a lower result of 11% ( $p < 0.05$ ) compared to overweight girls and 14% ( $p < 0.05$ ) compared to those with weight within the expected range. These results indicate that the variables evaluated in this study probably influence, to a moderate extent, the academic performance of children.

**Table 4.** Results of students with adequate weight, overweight and obesity in an academic performance assessment.

Variables	Obesity		Overweigh		As expected	
	Girls	Boys	Girls	Boy	Girls	Boys
Minimum	10	09	11	10	12	11
Maximum	18	17	17	18	18	18
Average	14.44	13.62	16.17	15.81	16.60	16.21
Standard deviation	1.74	1.43	2.12	1.63	1.58	1.95

#### 4. DISCUSSION

The results of this study indicate that having a high BMI and being obese in the investigated age group (6-8 years) predicts cognitive and motor declines, given that obese individuals present in all the variables analyzed performed lower than those of children with weight within expectations.

Our motor competence test results are comparable to those of [Martins et al. \(2021\)](#), [Hilpert et al. \(2017\)](#), and [Lopes, Santos, Moreira, Pereira, and Lopes \(2015\)](#). All of these studies show that non-obese people perform better than obese people by more than 20%.

When analyzing the results in relation to executive functioning, it can be said that, in fact, presenting an extremely high standard of body mass may be associated with a decrease in tasks that assess abilities related to executive functioning when compared to individuals with weights inside the normal range. The data from the studies by [Dassen, Houben, Allom, and Jansen \(2018\)](#); [Kittel, Schmidt, and Hilbert \(2017\)](#); and [Cserjési, Molnár, Luminet, and Lénárd \(2007\)](#) support this relationship of interurrences.

As described in the studies by [Goldschmidt et al. \(2018\)](#), [Pearce, Mackey, Nadler, and Vaidya \(2018\)](#), and [Van Der Oord, Braet, Cortese, and Claes \(2018\)](#), maturational changes in the associative regions of our cortex could be a reason for how obesity affects children's executive functioning. These studies also show that children with obesity can do worse than expected in other cognitive tasks besides executive functions.

Considering then that the low level of motor development ([Hawani et al., 2023](#)) and [Mutola, Gómez-Olivé, and Ng \(2023\)](#) as well as the low executive functioning ([Lowe, Reichelt, & Hall, 2019](#)) have been reported in the literature as the main factors that cause alterations in the cognitive capacity and academic standards of children, it can be considered that it is not de facto a surprise that children with obesity have presented inferior results when evaluated in relation to academic performance in relation to children with weight within the expected.

Therefore, it should be noted that the results found in this study are important for the formulation of public policies on obesity as a public health problem because, in addition to its impacts, there are also two physical health problems. Finally, it is important to point out that the present study presents limitations due to the fact that the level of physical activity and eating habits of the participants were not evaluated.

#### 5. CONCLUSIONS

The findings of this study indicate a potential correlation between body mass index (BMI) and motor skills and executive functioning in the examined children. Specifically, the participants with a BMI within the expected range demonstrated superior performance in tasks such as STS, HFKS, reading comprehension, and Academic Performance compared to their overweight or obese counterparts.

Hence, the findings of this study underscore the significance of a comprehensive theoretical framework that encompasses all key variables of interest in order to develop integrated strategies for addressing overweight and obesity issues among children. Consequently, further research on this topic is recommended to enhance comprehension of the association between childhood obesity and cognitive functioning.

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#### INSTITUTIONAL REVIEW BOARD STATEMENT

The Ethical Committee of the Universidade Federal do Rio de Janeiro, Brazil has granted approval for this study on 29 January 2014 (Ref. No. 517,483).

#### CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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#### AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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#### REFERENCES

- Abduelkarem, A. R., Sharif, S. I., Bankessli, F. G., Kamal, S. A., Kulhasan, N. M., & Hamrouni, A. M. (2020). Obesity and its associated risk factors among school-aged children in Sharjah, UAE. *PLoS One*, *15*(6), e0234244. <https://doi.org/10.1371/journal.pone.0234244>
- Abdulrahman, A.-H., Bashir, M., Musa, K., Muath, A., Wahid, A., Mona, A., & Thana, H. (2019). Overweight and obesity among Saudi children and adolescents: where do we stand today? *Saudi Journal of Gastroenterology*, *25*(4), 229-235. [https://doi.org/10.4103/sjg.sjg\\_617\\_18](https://doi.org/10.4103/sjg.sjg_617_18)
- Almaqhawi, A., Alkhateeb, A., AlHussain, A. K., Alqahtani, K. S., Aldrweesh, A. K., & Aljarri, S. A. (2022). Prevalence and associated risk factors of childhood obesity in the Eastern Province of Saudi Arabia. *Cureus*, *14*(10), e30015. <https://doi.org/10.7759/cureus.30015>
- Barros, W. M. A., Silva, K. G. D., Silva, R. K. P., Souza, A. P. D. S., Silva, A. B. J. D., Silva, M. R. M., . . . Souza, V. D. O. N. (2022). Effects of overweight/obesity on motor performance in children: A systematic review. *Frontiers in Endocrinology*, *12*, 759165. <https://doi.org/10.3389/fendo.2021.759165>
- Brooks, S. J., Benedict, C., Burgos, J., Kempton, M., Kullberg, J., Nordenskjöld, R., . . . Johansson, L. (2013). Late-life obesity is associated with smaller global and regional gray matter volumes: A voxel-based morphometric study. *International Journal of Obesity*, *37*(2), 230-236. <https://doi.org/10.1038/ijo.2012.13>
- Cauca, M. R., Gardener, H., Simonetto, M., Cheung, Y. K., Alperin, N., Yoshita, M., . . . Wright, C. B. (2019). Measures of obesity are associated with MRI markers of brain aging: The Northern Manhattan study. *Neurology*, *93*(8), e791-e803. <https://doi.org/10.1212/wnl.0000000000007966>
- Cole, T. J., & Lobstein, T. (2012). Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatric Obesity*, *7*(4), 284-294. <https://doi.org/10.1111/j.2047-6310.2012.00064.x>
- Cserjési, R., Molnár, D., Luminet, O., & Lénárd, L. (2007). Is there any relationship between obesity and mental flexibility in children? *Appetite*, *49*(3), 675-678. <https://doi.org/10.1016/j.appet.2007.04.001>
- Dassen, F. C., 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>
- Davis, C. L., & Cooper, S. (2011). Fitness, fatness, cognition, behavior, and academic achievement among overweight children: Do cross-sectional associations correspond to exercise trial outcomes? *Preventive Medicine*, *52*, S65-S69. <https://doi.org/10.1016/j.ypmed.2011.01.020>



- Deconinck, F. J. A., D'Hondt, E., Caeyenberghs, K., Lenoir, M., & Augustijn, M. J. C. M. (2019). The association between mental rotation capacity and motor impairment in children with obesity—an exploratory study. *Peer Journal*, 7, e8150. <https://doi.org/10.7717/peerj.8150>
- 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(1), 1-20. <https://doi.org/10.1186/s12916-019-1449-8>
- Dick, J., & Clough, S. (2019). Learning disability and obesity: A case report of challenges and reasonable adjustments. *British Dental Journal*, 227(1), 19-24. <https://doi.org/10.1038/s41415-019-0468-3>
- Duncan, M. J., Lawson, C., Walker, L. J., Stodden, D., & Eyre, E. L. (2017). The utility of the supine-to-stand test as a measure of functional motor competence in children aged 5–9 years. *Sports*, 5(3), 67. <https://doi.org/10.3390/sports5030067>
- Fernández-Andújar, M., Morales-García, E., & García-Casares, N. (2021). Obesity and gray matter volume assessed by neuroimaging: A systematic review. *Brain Sciences*, 11(8), 999. <https://doi.org/10.3390/brainsci11080999>
- Goldschmidt, A. B., O'Brien, S., Lavender, J. M., Pearson, C. M., Le Grange, D., & Hunter, S. J. (2018). Executive functioning in a racially diverse sample of children who are overweight and at risk for eating disorders. *Appetite*, 124, 43-49. <https://doi.org/10.1016/j.appet.2017.03.010>
- Hawani, A., Chikha, A., Zoghiami, W., Souissi, M., Trabelsi, O., Mrayeh, M., & Muscella, A. (2023). Working memory in overweight boys during physical education classes. *Children*, 10, 805. <https://doi.org/10.3390/children10050805>
- Hayes, J. F., Eichen, D. M., Barch, D. M., & Wilfley, D. E. (2018). Executive function in childhood obesity: Promising intervention strategies to optimize treatment outcomes. *Appetite*, 124, 10-23. <https://doi.org/10.1016/j.appet.2017.05.040>
- Hilpert, M., Brockmeier, K., Dordel, S., Koch, B., Weiß, V., Ferrari, N., . . . Graf, C. (2017). Sociocultural influence on obesity and lifestyle in children: A study of daily activities, leisure time behavior, motor skills, and weight status. *Obesity Facts*, 10(3), 168-178. <https://doi.org/10.1159/000464105>
- Jeong, G., & Chun, B. (2021). Analysis of the relationship between obesity factors and health-related physical fitness factors among people with intellectual disabilities in South Korea. *International Journal of Environmental Research and Public Health*, 18(12), 6533. <https://doi.org/10.3390/ijerph18126533>
- 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>
- Kuczmarski, R. J. (2002). *2000 CDC growth charts for the United States: methods and development*. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics. No. 246.
- Lopes, L., Santos, R., Moreira, C., Pereira, B., & Lopes, V. P. (2015). Sensitivity and specificity of different measures of adiposity to distinguish between low/high motor coordination. *Jornal De Pediatria*, 91(1), 44-51. <https://doi.org/10.1016/j.jped.2014.05.005>
- Lowe, C. J., Reichelt, A. C., & Hall, P. A. (2019). The prefrontal cortex and obesity: A health neuroscience perspective. *Trends in Cognitive Sciences*, 23(4), 349-361. <https://doi.org/10.1016/j.tics.2019.01.005>
- Ma, F.-F., & Luo, D.-M. (2023). Relationships between physical activity, fundamental motor skills, and body mass index in preschool children. *Frontiers in Public Health*, 11, 1094168. <https://doi.org/10.3389/fpubh.2023.1094168>
- Martins, M. I. S., Vitoriano, N. A. M., Martins, C. A., Carvalho, E. M., Jucá, R. V. B. d. M., Alves, J. S. M., . . . Mont'Alverne, D. G. B. (2021). Aspects of motor development and quality of life in the context of child obesity. *Journal of Human Growth and Development*, 31(1), 58-65. <https://doi.org/10.36311/jhgd.v31.11071>
- Matos, R. A., Adams, M., & Sabaté, J. (2021). The consumption of ultra-processed foods and non-communicable diseases in Latin America. *Frontiers in Nutrition*, 8, 622714. <https://doi.org/10.3389/fnut.2021.622714>
- Mutola, S., Gómez-Olivé, F. X., & Ng, N. (2023). The path between socioeconomic inequality and cognitive function: A mediation analysis based on the HAALSI cohort in rural South Africa. *Frontiers in Public Health*, 11, 1011439. <https://doi.org/10.3389/fpubh.2023.1011439>
- Pannacciulli, N., Del Parigi, A., Chen, K., Le, D. S. N., Reiman, E. M., & Tataranni, P. A. (2006). Brain abnormalities in human obesity: A voxel-based morphometric study. *Neuroimage*, 31(4), 1419-1425. <https://doi.org/10.1016/j.neuroimage.2006.01.047>
- Patraca-Camacho, L., Cibrián-Llenderal, T., Acosta-Mesa, H. G., Rodríguez-Landa, J. F., Romo-González, T., Rosas-Nexticapa, M., & Herrera-Meza, S. (2022). Assessment of executive functions and physical activity in girls and boys with normal weight, overweight and obesity. *Pediatric Obesity*, 17(10), e12930. <https://doi.org/10.1111/ijpo.12930>
- Pearce, A. L., Mackey, E., Nadler, E. P., & Vaidya, C. J. (2018). Sleep health and psychopathology mediate executive deficits in pediatric obesity. *Childhood Obesity*, 14(3), 189-196. <https://doi.org/10.1089/chi.2017.0281>
- Ponitz, C. E. C., McClelland, M. M., Jewkes, A. M., Connor, C. M., Farris, C. L., & Morrison, F. J. (2008). Touch your toes! Developing a direct measure of behavioral regulation in early childhood. *Early Childhood Research Quarterly*, 23(2), 141-158. <https://doi.org/10.1016/j.ecresq.2007.01.004>
- Quaye, E., Galecki, A. T., Tilton, N., Whitney, R., Briceño, E. M., Elkind, M. S. V., . . . Levine, D. A. (2023). Association of obesity with cognitive decline in black and white Americans. *Neurology*, 100(2), e220–e231. <https://doi.org/10.1212/WNL.0000000000201367>

- Salaun, L., & Berthouze-Aranda, S. E. (2012). Physical fitness and fatness in adolescents with intellectual disabilities. *Journal of Applied Research in Intellectual Disabilities*, 25(3), 231-239. <https://doi.org/10.1111/j.1468-3148.2012.00659.x>
- Saraiva, R. A., Moojen, S. M. P., & Munarski, R. (2006). *Assessment of reading comprehension of expository texts*. São Paulo: Casa do Psicólogo.
- Stopyra, M., Friederich, H.-C., Lavandier, N., Mönning, E., Bendszus, M., Herzog, W., & Simon, J. (2021). Homeostasis and food craving in obesity: A functional MRI study. *International Journal of Obesity*, 45(11), 2464-2470. <https://doi.org/10.1038/s41366-021-00920-4>
- Van Der Oord, S., Braet, C., Cortese, S., & Claes, L. (2018). Testing the dual pathway model of ADHD in obesity: A pilot study. *Eating and Weight Disorders-Studies on Anorexia, Bulimia and Obesity*, 23(4), 507-512. <https://doi.org/10.1007/s40519-017-0375-z>
- Veit, R., Horstman, L. I., Hege, M. A., Heni, M., Rogers, P. J., Brunstrom, J. M., . . . Kullmann, S. (2020). Health, pleasure, and fullness: Changing mindset affects brain responses and portion size selection in adults with overweight and obesity. *International Journal of Obesity*, 44(2), 428-437. <https://doi.org/10.1038/s41366-019-0400-6>
- Wang, C., Chan, J. S., Ren, L., & Yan, J. H. (2016). Obesity reduces cognitive and motor functions across the lifespan. *Neural Plasticity*, 2016, 2473081. <https://doi.org/10.1155/2016/2473081>