The Effects of Physical Activity
on Cognition in Young and Old, and Age-Related Differences

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The Effects of Physical Activity on Cognition in Young and Old Adults, and Age-Related Differences

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“Knowledge has to be improved, challenged, and increased constantly, or it vanishes.”

Peter Drucker

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information, or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

University of Minho, 16 de Outubro de 2023

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Os Efeitos da Atividade Física na Cognição

Resumo

Para trabalhar para um desenvolvimento cognitivo saudável, é importante compreender a cognição, que é referida como o processo consciente ou inconsciente onde o conhecimento é recolhido através de experiências diárias e está em mudança e adaptação porque encontramos novas informações e experiências todos os dias. Os desafios relacionados com a idade e os défices cognitivos podem levar a um declínio gradual da capacidade física e mental, bem como à ansiedade e à depressão, impactando tanto os indivíduos como os seus cuidadores. No grupo mais jovem, níveis mais elevados de atividade física foram associados a um melhor desempenho, alinhando-se com a investigação existente sobre os efeitos positivos de um estilo de vida ativo. Entre os idosos, apesar dos resultados positivos relatados na literatura quanto à relação entre atividade física e desempenho cognitivo, constatou-se que o aumento da atividade física levou a pior desempenho cognitivo em tarefas de função executiva, contrariando o esperado. A comparação de correlações significativas revelou diferenças significativas nos coeficientes de correlação para diversas variáveis CANTAB entre faixas etárias, indicando que as associações entre atividade física e desempenho cognitivo variam nas diferentes faixas etárias. As descobertas refletem a natureza mista e inconsistente da pesquisa sobre a relação entre atividade física e função cognitiva. Combinar os participantes com base em vários fatores e explorar os exercícios, intensidade e frequência mais eficazes pode ajudar a promover o desenvolvimento cognitivo saudável e o envelhecimento.

Palavras-Chaves: *Exercício Físico, Comportamento Sedentário, Estilo de Vida Sedentário, Cognição, Envelhecimento, Estilo de Vida Saudável, Envelhecimento Saudável, Qualidade de Vida.*

The Effects of Physical Activity on Cognition

Abstract

To work for healthy cognitive development, it's important to understand cognition, which is referred to as the conscious or unconscious process where knowledge is collected through daily experiences and is in current change and adaptation because we encounter new information and experiences every day. Age-related challenges and cognitive deficits can lead to a gradual decline in physical and mental capacity as well as anxiety and depression, impacting both individuals and their caregivers. It is important to understand how we can improve or maintain these functions to have a better quality of life. In the younger group, higher levels of physical activity were associated with better performance, aligning with existing research on the positive effects of an active lifestyle. Among the older adults, despite the positive results reported in the literature regarding the relationship between physical activity and cognitive performance, it was found that increased physical activity led to worse cognitive performance in executive function tasks, contrary to expectations. Comparison of significant correlations revealed significant differences in the correlation coefficients for several CANTAB variables between age groups, indicating that the associations between physical activity and cognitive performance vary across different age ranges. The findings reflect the mixed and inconsistent nature of research on the relationship between physical activity and cognitive function. Matching participants based on various factors and exploring the most effective exercises, intensity, and frequency can help promote healthy cognitive development and aging.

Keywords: *Physical Exercise, Sedentary Behavior, Sedentary Lifestyle, Cognition, Aging, Healthy Lifestyle, Healthy Aging, Quality of Life.*

Contents

Introduction

Cognition is referred to as the conscious or unconscious process where knowledge is gathered through experience and the senses (Britannica, 2017). Cognition is in constant change and adaptation because every day we are in contact with new information that changes our behavior across our lifespan, being also influenced by our genetics, our environment, and other factors. Understanding cognition makes working for a healthy cognitive development and consequently healthy aging possible.

The World Health Organization, WHO, (World Health Organization, 2022) explains that aging is a consequence of the influence of the accumulation of a wide variety of molecular and cellular damage that occurs throughout our life, which leads to a gradual decrease in physical and mental capacity, an increase in the danger of developing diseases, and eventually death. As the average life expectancy continues to rise, there is a growth in the concern of individuals for not only to live longer but for those years to be lived with quality, meaning that there is concern from the population to age in a healthy manner and be able to enjoy that period of their lives with the highest quality of life possible.

As individuals age, they often face a myriad of physical challenges, including difficulty walking long distances, climbing stairs, carrying objects, and dealing with the cognitive deficits associated with aging. These cognitive changes, such as a decline in processing speed, working memory, and attention, can lead to difficulties in multitasking and maintaining focus for long periods of time (Adam et al., 2013; Birren & Fisher, 1995; Rieker et al., 2022). Additionally, older adults may experience declines in executive functioning, resulting in problems with planning, organizing, and inhibition (Adam et al., 2013; Gonzalez-Burgos et al., 2019; Rieker et al., 2022). Vocabulary and language comprehension may also be affected, manifesting as difficulties in word retrieval and fluency (Adam et al., 2013; Gonzalez-Burgos et al., 2019; Kemper et al., 2001). These cognitive changes, when coupled with age-related physical limitations, can lead to anxiety and depression, ultimately placing an additional burden on the older adults' caregivers (Silva et al., 2020).

It is possible to observe from contact with others that these changes are not linear or consistent (World Health Organization, 2022). Studies show that education and occupation play a big role in explaining these differences in the impairments that occur with aging (Adam et al., 2013), other studies relate sleep and well-being to these differences (Mellow et al., 2022), and others show that a healthy lifestyle and exercise can explain these variances (Huang et al., 2020).

Likewise, a lot of the research that studies cognitive decline has been consistent on four possible ways to best preserve physical and mental abilities, besides genetics and education (Erickson et al., 2022), being the first regarding diet, meaning a balanced but restricted diet that contains fewer calories than normally needed (Dingle et al., 2022; Miller et al., 2012). Secondly, is cognitive exercises in a way to sustain mental challenges and continuous learning (La Rue., 2010; Miller et al., 2012; Rieker et al., 2022). The third variable that is consistent with the preservation of physical and mental abilities is social interactions (Barnes, 2015; Miller et al., 2012). In addition, the last one is physical exercise (Ballesteros et al., 2022; Barnes, 2015; Gerten et al., 2022; Miller et al., 2012; Rieker et al., 2022), which shows positive results in physical and mental abilities throughout the development of the human being.

According to the WHO, it is recommended for the average adult to exercise for at least 150 to 300 minutes, at moderate intensity, per week, or a vigorous equivalent physical activity, for example, hiking.

Many studies reveal that exercise during the middle age period is associated with the possibility of healthy aging (Kachouri et al., 2022; Lennox et al., 2019), not only at a physical level but also in an improvement in the cognitive level and a reduction in chronic diseases, and better mental health. It is observed that the practice of physical exercise can help increase blood circulation in the brain (Barnes, 2015), as well as neuronal activity, cortical plasticity, brain volume, and neurogenesis (Eskes et al., 2010; Gordon et al., 2008). In terms of cognitive function, an improvement in episodic memory, processing speed, verbal fluency, and semantic memory is also observed (Barnes, 2015; Gordon et al., 2008; Kachouri et al., 2022).

Multiple studies explain the positive effects of PA on cognition across multiple age groups. For example, a study by Salas-Gómez et al. (2020) explored the association between PA with executive function and memory in college students, using an IPAQ-SF Questionnaire, it was found that the practice of PA improved the ability to inhibit automatic responses and enhance mental flexibility. Another study by Chou et al. (2021) explored the sustained effects of acute resistance training on inhibition in a sample of middle-aged adults (being this sample assigned to two groups: the control group and the group that exercised), a Stroop Test was administered pre- and post-training (40 minutes post-training) and the training consisted in two sets of 7 exercises. It was found that moderate-intensity resistance training improves executive functions.

Therefore, Physical activity (PA) plays a pivotal role in enhancing the overall quality of life in older adults while significantly impacting their physical and psychological health. This influence is multifaceted, and various factors such as gender, marital status, education level, and age can come into play (Sun et al., 2013).

In consequence, this work seeks to explore the connection between physical activity and cognition, with a particular focus on the potential age-related differences in this relationship. The hypothesis theorizes that reduced physical activity levels are associated with lower cognitive task performance, in opposition individuals with higher levels of physical activity are associated with higher cognitive task performance, also that there are significant differences in the correlation coefficients between IPAQ scores and CANTAB variables across different age groups.

Method

Participants

A sample of 188 participants, ages between 17 and 89, were collected by members of the Psychological Neuroscience Laboratory, from Minho University. 92 participants were excluded because they did not complete all the evaluation steps or because they did not fit the criteria for inclusion in the study. A sample of 96 participants was used for this analysis.

The inclusion criteria were: (i) participants with ages between 18 and 30 and between 55 and 90 (10 participants were excluded) and (ii) absence of psychiatric or neurological diseases (18 participants were excluded). The exclusion criterion was (i) participants who did not complete all assessment steps from the study (64 participants were excluded due to incomplete participation derived from the confinement and health protecting measures offered amidst the COVID-19 pandemic).

Instruments

The CANTAB, Cambridge Neuropsychological Test Automated Battery, is culturally neutral and linguistically neutral, is non-invasive, and requires no technical or previous knowledge, making it appropriate for large, multi-location, and diverse participant study groups. CANTAB is susceptible to detect changes in neuropsychological performance including tests of working memory, learning, executive function; visual, verbal, and episodic memory, attention, information processing, reaction time; social and emotional recognition, decision making, and response control. CANTAB has 4 test domains (Cambridge Cognition, 2019; Robbins et al., 1994):

1. Executive Function, which comprises high-level thinking and decision-making.
2. Attention and Psychomotor Speed, which report our ability to selectively attend to specific information whilst ignoring irrelevant information, and the relationship between cognitive functions and physical movements.
3. Memory, which refers to our ability to store information, long- or short-term.
4. And, Emotion and Social Cognition, which assesses the ability to respond to emotion-laden stimuli.

Within CANTAB, we conducted several tests, in order to measure different cognitive domains, including the **Multitasking Test (MTT)**, which assesses the ability to manage conflicting information. In each trial, an arrow is displayed either on the right or left side of the screen, and the participant is tasked with making a corresponding right or left response. Prior to each trial, the subject receives instructions specifying whether to respond based on the arrow's 'direction' or 'side.' In certain sections of the test, the directions and sides of the arrows are switched trial after trial, falling under the Executive Function Domain.

The following indices were derived from the MTT (Multi-Tasking Test) and include:

1. *CANTAB_Congruent_Error_MTT:* This index measures the number of incorrect responses during assessed congruent trials, indicating when the subject pressed the wrong button.

2. *CANTAB_Direction_Block_Errors_MTT:* It quantifies the number of errors during the assessed block(s) where the rule is to respond to the direction of an arrow.

3. *CANTAB_Direction_Errors_MTT:* This index counts the number of incorrect responses during assessed trials that require reacting to the direction of an arrow.

4. *CANTAB_Incongruent_Errors_MTT:* Measures the number of incorrect responses during assessed incongruent trials.

5. *CANTAB_Multitasking_Block_Errors_MTT:* This index indicates the number of errors made during trials in assessed block(s) that involve using both rules.

6. *CANTAB_Side_Block_Errors_MTT:* It measures the number of errors during trials in assessed block(s) where the rule is to respond to a specific side of the screen.

7. *CANTAB_Side_Errors_MTT:* This index quantifies the number of incorrect responses during assessed trials where subjects should respond to a side of the screen.

8. *CANTAB_Single_Task_Block_Errors_MTT:* Counts the number of errors during trials in assessed block(s) where only a single rule is in use.

9. *CANTAB_TotalCorrect_MTT:* Measures the number of trials with correct responses within the response window, calculated across all assessed trials.

10. *CANTAB_Commission_Errors_MTT:* This index tracks the number of trials with commission errors, where a response occurred when no stimulus was present.

11. CANTAB_Total_Incorrect_MTT: Quantifies the number of trials with incorrect responses within the response window, calculated across all assessed trials.

12. *CANTAB_Omission_Errors_MTT:* Measures the number of trials with no response at all.

The **Reaction Time Index (RTI)** evaluates both motor and mental response speed, including factors like movement time, reaction time, response accuracy, and impulsivity. In this task, participants are required to press and hold a button at the bottom of the screen. They should release the button when a yellow dot appears on the screen, and press where the yellow dot appears, before returning to the initial position. This test falls under the Attention and Psychomotor Speed Domain.

The following indices were obtained from RTI (Response Time Index) and include:

1. *CANTAB_Five_Choice_Error_Score_Inaccurate_RIT:* This index measures the total number of trials in which the subject made inaccurate responses across all assessment trials where the stimulus could appear in any of five locations.

2. *CANTAB_Five_Choice_Error_Score_Premature_RIT:* This index quantifies the total number of trials in which the subject responded before the presentation of the target stimulus. It is calculated across all assessment trials where the stimulus could appear in any of five locations.

3. *CANTAB_Five_Choice_Correct_Movement_Time_MEAN_RIT:* This index measures the average time taken for a subject to release the response button and select the target stimulus after it flashes yellow on the screen. It's calculated across correct, assessed trials in which the stimulus could appear in any of five locations, measured in milliseconds.

4. *CANTAB_Five_Choice_Correct_Reaction_Time_MEAN_RIT:* This index calculates the average time it took for a subject to release the response button after the presentation of a target stimulus. It's measured across correct, assessed trials in which the stimulus could appear in any of five locations, in milliseconds.

5. *CANTAB_Five_Choice_Total_Error_Score_RIT:* This index counts the total number of trials in which the subject made various types of response errors, including inaccurate responses, premature responses, no responses, incorrect location responses, and the use of multiple fingers or finger-dragging. It's calculated across all assessment trials where the stimulus could appear in any of five locations.

Within the Memory Domain, three distinct cognitive assessments are conducted:

a. **Spatial Span (SSP):** This evaluation focuses on visuospatial working memory capacity. Participants are presented with a series of boxes that change color and are tasked with selecting these boxes in the same order they were initially presented, either in a forward or reversed sequence.

The following indices were derived from SSP (Spatial Span), which includes:

1. *CANTAB_Forward_Number_Attempts_Pass_MEAN_SSP:* This index calculates the average number of attempts it took for a subject to successfully pass the span length. It applies only to Forward variants.

2. *CANTAB_Forward_Span_Length_SSP:* This index measures the longest sequence of boxes that the subject successfully recalled. It is specific to Forward variants.

3. *CANTAB_Forward_Span_Reached_SSP:* This index measures the longest sequence that the subject successfully reached (but did not pass). It is specific to Forward variants.

4. *CANTAB_Forward_Total_Errors_SSP:* This index quantifies the total number of times a subject incorrectly touched a box that was not the next one in the sequence. It is applicable only to Forward variants.

5. *CANTAB_Forward_Total_Usage_Errors_SSP:* This index counts the total number of times a subject incorrectly selected a box that was not part of the target sequence. It is relevant exclusively to Forward variants.

b. **Verbal Recognition Memory (VRM):** Designed to assess verbal memory and new learning, this test begins with the presentation of a list of words. Participants were presented with a series of words displayed one at a time on the screen. They were then required to complete three phases of this task, which involved (1) immediate recall of the words, (2) recognizing the words from a provided list, and (3) recalling the words after a delay.

The following indices were derived from VRM (Verbal Recognition Memory) and include:

1. *CANTAB_Delayed_Recognition_Correct_Distractor_VRM:* This index tallies the total number of times the subject accurately responds 'no' to a distractor word in the delayed recognition phase.

2. *CANTAB_Delayed_Recognition_Correct_Old_Stim_VRM:* It measures the total number of words correctly recognized by the subject in the delayed recognition phase.

3. *CANTAB_Delayed_Recognition_Incorrect_Distractor_VRM*: This index quantifies the total number of times the subject incorrectly responds 'yes' to a distractor word during the delayed recognition phase.

4. *CANTAB_Delayed_Recognition_Total_Correct_VRM:* This index combines the total number of target words correctly recognized by the subject in the delayed recognition phase with the total number of correctly rejected distractor words.

5. *CANTAB_Free_Recall_Correct_VRM:* Measures the total number of distinct words correctly recalled by the subject from the presentation phase during immediate free recall.

6. *CANTAB_Free_Recall_Novel_Words_VRM:* Calculates the total number of novel words provided by the subject during immediate free recall that were not presented during the presentation phase.

7. *CANTAB_Free_Recall_Preservations_VRM:* This index counts the number of times the subject repeats a word shown during the presentation phase in the immediate free recall stage.

8. *CANTAB_Immediate_Recognition_Correct_Distractors_VRM:* This index keeps track of the total number of times the subject correctly responds 'no' to a distractor word in the immediate recognition phase.

9. *CANTAB_Immediate_Recognition_Correct_Old_Stim_VRM:* Measures the total number of words correctly recognized by the subject in the immediate recognition phase.

10. *CANTAB_Immediate_Recognition_Incorrect_Distractors_VRM:* Quantifies the total number of times the subject incorrectly responds 'yes' to a distractor word in the immediate recognition phase.

11. *CANTAB_Immediate_Recognition_Total_Correct_VRM:* This index sums the total number of target words correctly recognized by the subject in the immediate recognition phase with the total number of correctly rejected distractor words.

c. **Delayed Matching to Sample (DMS):** This assessment simultaneously gauges visual matching skills and short-term visual recognition for non-verbalizable patterns.

Participants are shown a pattern followed by a brief delay (0, 4, 8, or 12 seconds). Their task is to choose one of four options corresponding to the previously displayed pattern."

The following indices were extracted from DMS (Delayed Matching to Sample), including:

1. *CANTAB_Total_Correct_DMS:* Measures the total number of times a subject selected the correct answer on their first box choice across all assessed trials, including both simultaneous presentation and all delays.
2. *CANTAB_Total_Correct_0SDELAY_DMS:* Tracks the total number of times a subject selected the correct answer on their first box choice for trials where the response stimuli appeared on screen immediately (0-second delay) after the target stimulus was shown.
3. *CANTAB_Total_Correct_12SDELAY_DMS:* Records the total number of times a subject chose the correct answer on their first box choice for trials with a 12-second delay between the presentation of the target stimulus and response stimuli.
4. *CANTAB_Total_Correct_4SDELAY_DMS:* Measures the total number of times a subject chose the correct answer on their first box choice for trials with a 4-second delay between the target stimulus and response stimuli.
5. *CANTAB_Total_Correct_ALLDELAY_DMS:* Quantifies the total number of times a subject selected the correct answer on their first box choice for all trials with any delay between the target and response stimuli.
6. *CANTAB_Total_Correct_SIMULTANEOUS_DMS:* Measures the total number of times a subject chose the correct answer on their first box choice for trials where the target and response stimuli appeared simultaneously (no delay).
7. *CANTAB_Total_Errors_DMS:* Tracks the total number of times a subject failed to choose the correct box on their first selection, making an error, across all assessed trials, regardless of which incorrect box was chosen.
8. *CANTAB_Total_Errors_ALLDELAYS_DMS:* Records the total number of times a subject made an error by failing to choose the correct box on their first selection for any trial containing a delay between the presentation of the target stimulus and response stimuli.

9. *CANTAB_Color_Error_DMS:* Measures the number of times a subject failed to select the correct box on their first choice, opting for a distractor stimulus with the same color elements but different physical attributes, across all assessed trials.

10. *CANTAB_Color_Error_ALLDELAYS_DMS:* Records the number of times a subject selected the wrong box on their first choice, choosing a distractor stimulus with the same color elements but different physical attributes, in trials containing a delay component.

11. *CANTAB_Distractor_Error_DMS:* Quantifies the number of times a subject failed to select the correct box on their first choice, opting for a distractor stimulus with no common elements to the original target stimulus, across all assessed trials.

12. *CANTAB_Distractor_Error_ALLDELAYS_DMS:* Records the number of times a subject failed to choose the correct box on their first selection, selecting a distractor stimulus with no common elements to the original target stimulus, in trials containing a delay component.

13. *CANTAB_Pattern_Error_DMS:* Measures the number of times a subject failed to choose the correct box on their first selection, selecting a distractor stimulus with the same pattern/physical attributes but different colors, across all assessed trials.

14. *CANTAB_Pattern_Error_ALLDELAYS_DMS*: Records the number of times a subject selected the wrong box on their first choice, choosing a distractor stimulus with the same pattern/physical attributes but different color elements, in trials containing a delay component.

To understand the level of physical activity of the participants it was applied the International Physical Activity Questionnaire, IPAQ, which is used to measure health-related information regarding physical activity (PA) in populations. It is a well-developed and widely used instrument that can be used to obtain comparable estimates of physical activity between populations and countries. (Salas-Gomez et al., 2020; Craig et al., 2003)

Procedures

Prior to participating in the experiment, all participants provided informed consent, which had received approval from the Ethics Committee of Life and Health Science of the University of Minho (CE.CVS 095/2018). Subsequently, participants completed a social demographic survey and answered questions related to their general health, in addition to the International Physical Activity Questionnaire (IPAQ).

On the following day, the participants underwent cognitive testing using the Cambridge Neuropsychological Test Automated Battery (CANTAB), which included assessments such as the Multitasking Test (MTT), Reaction Time (RIT), Spatial Span (SSP), Verbal Recognition Memory (VRM), and Delayed Matching to Sample (DMS).

Statistical Analysis

The objective of this analysis is to focus on the influence of physical activity on cognition, more specifically assessing potential age-related differences in such relationship, so the statistical analysis of this paper was centered on specific data such as the Demographic Data (Age, Gender, and Education), IPAQ Scale (categorized in 5 categories: Low Activity, Moderate to Low Activity, Moderate Activity, Moderate to High Activity) and 5 CANTAB Tests, the MTT (Multitasking Test), the RTI (Reaction Time), the SSP (Spatial Span), the VRM (Verbal Recognition Memory), and Delayed Matching to Sample (DMS).

Statistical analysis involved descriptive statistics measures (absolute and relative frequencies, means, and respective standard deviations), Pearson correlations, and a comparison of coefficients of correlation, based on the transformation of r to z values of Fisher, which was performed in variables that showed a statistically significant relationship with IPAQ scores.

Statistical analysis was performed using SPSS (Statistical Package for the Social Sciences) version 20 for Windows. A comparison of the correlation coefficients of Fisher was performed using the Vassarstats website (http://vassarstats.net/).

Results

In Tables 1,2,3 and 4, the sociodemographic characterization of the sample is presented. Thus, the sample consists of 96 subjects, with the majority being male (Young Adults (YA) N = 41, Older Adults (OA) N = 21), aged between 18 and 30 years (M ± SD =21,87 ± 3,252) and 50 to 90 (M ± SD =70,28 ± 6,777). Regarding years of education, it ranges from 3 to 23 years (YA M ± SD = 15,22 ± 2,563, OA M ± SD=7,24 ± 4,172).

Table 1.

Sociodemographic Characterization of the sample (N = 96)

Age		
	18-30 Years Old	50-90 Years Old
N	67	29
Mean	21,87	70,28
Std. Deviation	3,252	6,777

Table 2.

Gender Characterization of the participants (N = 96)

Gender				
	18-30 Years Old		50-90 Years Old	
	Frequency	Percent	Frequency	Percent
Male	41	61,2	21	72,4

Female	26	38,8	8	27,6

Table 3.

Education Characterization of the participants (N = 96)

Education		
	18-30 Years Old	50-90 Years Old
N	67	29
Mean	15,22	7,24
Std. Deviation	2,563	4,172

Physical activity pattern of study participants

The analysis focused on 96 valid data points for the IPAQ Total Category. This variable encompasses a spectrum of physical activity levels, ranging from "Low Activity" to "High Activity." As shown in Table 5, most participants in YA reported having a level of physical activity classified as "Low Activity " (N = 32). In OA it is possible to observe that most participants reported having a level of physical activity classified as “Moderate to Low Activity” (N = 10).

Table 5.

Physical activity pattern of study participants (N = 96)

IPAQ Category Total				
	18-30 Years Old		50-90 Years Old	
	Frequency	Percent	Frequency	Percent
Low Activity	32	47,8	6	20,7
Moderate to Low Activity	14	20,9	10	34,5

Moderate Activity	4	6,0	6	20,7
Moderate to High Activity	6	9,0	4	13,8
High Activity	11	16,4	3	10,3

Relationships between the level of physical activity and the CANTAB Multitasking Test

To initiate the statistical analyses, we assessed the existence of a relationship between the level of physical activity and the CANTAB Multitasking Test in the 18-30 age group using the Pearson test.

In this context, a statistically significant and negative correlation was observed between IPAQ and the "CANTAB_Direction_Errors_MTT" dimension *r* = - .252, *p* = .039, "CANTAB_Incongruent_Errors_MTT" *r* = - .299, *p* = .014, and "CANTAB_Total_Incorrect_MTT" *r* = - .293, p = .016. Additionally, a statistically significant, positive correlation was found between IPAQ and "CANTAB_TotalCorrect_MTT" *r* = .251, *p* = .040.

IPAQ is negatively correlated with several MTT error-related variables, indicating that as physical activity levels increase, errors in the MTT tend to decrease. Notably, the correlation with CANTAB_TotalCorrect_MTT is positive and statistically significant, suggesting that as physical activity levels increase, the total number of correct responses on the MTT also tends to increase.

Table 6.

Level of physical activity and CANTAB Multitasking Test (18-30 age group)

		CANTAB_Congruent Error MTT	CANTAB_Direction_Block Errors MTT	CANTAB_Direction Errors MTT	CANTAB_Incongruent_Errors_MTT	CANTAB_Multitasking_Block_Errors_M	CANTAB_Side_Block_Errors_MTT	CANTAB_Side_Errors_MTT	CANTAB_Single_Task_Block_Errors_M	CANTAB_TotalCorrect_MTT	CANTAB_Comission_Errors_MTT	CANTAB_Total_Incorrect_MTT	CANTAB_Omission_Errors_MTT
IPAQ	*r*	-.085	-.192	-.252	-.299	-.220	-.172	-.239	-.229	.251	.154	-.293	-.089
	p	.496	.120	.039	.014	.074	.163	.052	.062	.040	.214	.016	.475

N	67	67	67	67	67	67	67	67	67	67	67	67

In the same manner, the Pearson test was employed, this time for the age group ranging from 50 to 90 years old. Our analysis revealed a statistically significant, positive correlation between IPAQ scores and "CANTAB_Single_Task_Block_Errors_MTT" *r* = 0.450, *p* = 0.14. This indicates that as IPAQ Total Category scores rise, the number of errors made in single-task trials also tends to increase. A comparable relationship was observed between IPAQ scores and "CANTAB_Direction_Block_Errors_MTT" *r* = 0.368, *p* = 0.050, suggesting that higher levels of physical activity, as indicated by IPAQ scores, correlate with an increased likelihood of making errors related to interference during the CANTAB test.

Table 7.

Level of physical activity and CANTAB Multitasking Test (50-90 age group)

		CANTAB_Congruent Error MTT	CANTAB_Direction Block Errors	CANTAB_Direction Errors MTT	CANTAB_Incongruent Errors MTT	CANTAB_Multitasking_Block_Error	CANTAB_Side_Block_Errors_MTT	CANTAB_Side_Errors_MTT	CANTAB_Single_Task_Block_Erro	CANTAB_TotalCorrect_MTT	CANTAB_Comission_Errors_MTT	CANTAB_Total_Incorrect_MTT	CANTAB_Omission_Errors_MTT
IPAQ	*r*	.077	.368	.284	.302	-.121	.218	.061	.450	-.200	.214	.274	-.019
	p	.690	.050	.135	.112	.533	.256	.755	.014	.297	.265	.151	.921
	N	29	29	29	29	29	29	29	29	29	29	29	29

To understand the differences between the relationship of IPAQ scores and CANTAB variables, between the age groups a comparison of the Two Independent Values of r was made. It was found that in" CANTAB_Direction_Errors_MTT" the correlation coefficient for this variable in the 18-30-year-old group is - 0.252, while in the 50-90-year-old group, it is 0.284. The calculated z-value is - 2.36, and the two-tailed p-value is 0.018, indicating that the difference in the correlation coefficients between the two age groups is statistically significant, in other words, there is evidence to suggest that the correlation between CANTAB Direction Errors and IPAQ score differs between the two age groups.

The correlation coefficient for the “CANTAB_Incongruent_Errors_MTT” variable is -0.299 for the 18-30 years old group and 0.302 for the 50-90 years old group. The z-value is - 0.394, and the two-tailed p-value < 0.001, which suggests a highly significant difference in correlation coefficients between the two age groups.

In the 18-30-year-old group, the correlation coefficient for the “CANTAB_Total_Incorrect_MTT” variable is - 0.293, while in the 50-90-year-old group, it is 0.274. The z-value is - 0.251, and the two-tailed p-value is 0.012. This indicates a statistically significant difference in the correlation coefficients between the two age groups.

For the “CANTAB_TotalCorrect_MTT” variable, the correlation coefficient is 0.251 in the 18-30-year-old group and - 0.200 in the 50-90-year-old group. The z-value is 0.191, and the two-tailed p-value is 0.049, suggesting a statistically significant difference in correlation coefficients between the two age groups.

In the 18-30-year-old group, the correlation coefficient for the “CANTAB_Single_Task_Block_Errors_MTT” variable is - 0.229, and in the 50-90-year-old group, it is 0.450. The z-value is - 3.12, and the two-tailed p-value is 0.002, which indicates a highly significant difference in the correlation coefficients between the two age groups.

The correlation coefficient in the “CANTAB_Direction_Block_Errors_MTT” variable is - 0.129 in the 18-30-year-old group and 0.368 in the 50-90-year-old group. The z-value is - 2.22, and the two-tailed p-value is 0.026, this indicates a statistically significant difference in the correlation coefficients between the two age groups.

Table 8.

Comparison of Correlations

Variables	18-30 Years Old	50-90 Years Old	Z	Two-tailed p-value
CANTAB_Direction_Errors_MTT	-.252	.284	-2.36	0.018
CANTAB_Incongruent_Errors_MTT	-.299	.302	-.394	0.000
CANTAB_Total_Incorrect_MTT	-.293	.274	-.251	0.012
CANTAB_TotalCorrect_MTT	.251	-.200	.191	0.049
CANTAB_Single_Task_Block_Errors_MTT	-.229	.450	-3.12	0.002
CANTAB_Direction_Block_Errors_MTT	-.129	.368	-2.22	0.026

Relationships between the level of physical activity and CANTAB Reaction Time Test

The Pearson test was used to assess the relationship between the level of physical activity and the CANTAB Reaction Time Test in the 18-30 age group. In this context, a statistically significant negative correlation emerged between IPAQ scores and "CANTAB_Five_Coice_Correct_Movement_Time_MEAN_RIT" $r = -0.241$, $p = 0.050$, indicating that the mean movement time tends to decrease as IPAQ scores, reflecting physical activity levels, increase.

Due to the nature of the task, a simple reaction time task, young adults did not make any mistakes. Therefore, the correlation between IPAQ and the variable "CANTAB_Five_Choice_Error_Score_No_Response_RIT" was not calculated in this age group.

Table 9.

Level of physical activity and CANTAB Reaction Time Test (18-30 age group)

		CANTAB_Five_Choice_Error_Score_Inacurate_RIT	CANTAB_Five_Choice_Error_Score_Premature_RIT	CANTAB_Five_Choice_Correct_Movement_Time_MEAN_RIT	CANTAB_Five_Choice_Correct_Reaction_Time_MEAN_RIT	CANTAB_Five_Choice_Total_Error_Score_RIT
IPA	*r*	-.149	-.102	-.241	.017	-.182

p	.227	.413	.050	.891	.140
N	67	67	67	67	67

For the 50-90 age group, the Pearson test was employed. In this context, no statistically significant correlation was observed between the IPAQ and CANTAB task.

Table 10.

Level of physical activity and CANTAB Reaction Time Test (50-90 age group)

		CANTAB_Five_Choice_Error_Score_Inacurate_RIT	CANTAB_Five_Choice_Error_Score_No_Response_RIT	CANTAB_Five_Choice_Error_Score_Premature_RIT	CANTAB_Five_Choice_Correct_Movement_Time_MEAN_RIT	CANTAB_Five_Choice_Correct_Reaction_Time_MEAN_RIT	CANTAB_Five_Choice_Total_Error_Score_RIT
IPAQ	*r*	.195	.299	.106	.225	.002	.183
	p	.312	.115	.583	.242	.992	.342
	N	29	29	29	29	29	29

In the same manner, to understand the differences of the relationship between IPAQ scores and CANTAB variables, between the age groups a comparison of the Two Independent Values of r was performed. It was found that in" CANTAB_Five_Coice_Correct_Movement_Time_MEAN_RIT" the correlation coefficient for this variable in the 18-30 years old group is 0.241, while in the 50-90 years old group, it is 0.225. The calculated z-value is 0.07, and the two-tailed p-value is 0.944 which is notably higher than the conventional significance level of α = 0.05. This suggests that there is no statistically significant difference in the correlation coefficients between the two age groups for the variable "CANTAB_Five_Choice_Correct_Movement_Time_MEAN_RIT.". In other words, the correlation between this variable and the IPAQ score appears to be consistent between the two age groups.

Table 11.

Comparison of Correlations.

Variables	18-30 Years Old	50-90 Years Old	Z	Two-tailed p-value
CANTAB_Five_Coice_Correct_Movement_Time_MEAN_RIT	.241	.225	0.07	0.944

Relationships between the level of physical activity and CANTAB Spatial Span Test

The Pearson test was used to assess the relationship between the level of physical activity and the CANTAB Spatial Span Test in the 18-30 age group. In this context, no statistically significant correlation was observed between the IPAQ and CANTAB task.

Table 12.

Level of physical activity and CANTAB Spatial Span Test (18-30 age group)

		CANTAB_Forward_Number_Attemps_Pass_MEAN_SSP	CANTAB_Forward_Span_Length_SSP	CANTAB_Forward_Span_Reached_SSP	CANTAB_Forward_Total_Errors_SSP	CANTAB_Forward_Total_Usage_Errors_SSP
IPAQ	*r*	-.062	-.003	-.035	.031	.040
	p	.620	.980	.780	.802	.748
	N	67	67	67	67	67

The Pearson test was used to assess the relationship between the level of physical activity and the CANTAB Spatial Span Test in the 50-90 age group. In this context, no statistically significant correlation was observed between the IPAQ and CANTAB task.

Table 13.

Level of physical activity and CANTAB Spatial Span Test (50-90 age group)

		CANTAB_Forward_Number_Attempts_Pass_MEAN_SSP	CANTAB_Forward_Span_Length_SSP	CANTAB_Forward_Span_Reached_SSP	CANTAB_Forward_Total_Errors_SSP	CANTAB_Forward_Total_Usage_Errors_SSP
IPAQ	*r*	-.035	-.354*	-.354*	-.220	-.323*
	p	.856	.060	.060	.251	.088
	N	29	29	29	29	29

Relationships between the level of physical activity and CANTAB Verbal Recognition Memory

The Pearson test was used to assess the relationship between the level of physical activity and CANTAB Verbal Recognition Memory in the 18-30 age group. In this context, a statistical, positive relationship was found between IPAQ and "CANTAB_Immediate_Recognition_Correct_Old_Stim_VRM" *r* = .264, *p* = .031, indicating that as the level of physical activity increases, the number of words that the participant correctly recognizes immediately increases.

Table 14.

Level of physical activity and CANTAB Verbal Recognition Memory (18-30 age group)

		CANTAB_Delayed_Recognition_Correct_Di	CANTAB_Delayed_Recognition_Correct_Ol	CANTAB_Delayed_Recognition_Incorrect	CANTAB_Delayed_Recognition_Total_Corr	CANTAB_Free_Recall_Correct_VRM	CANTAB_Free_Recall_Novel_Words_VRM	CANTAB_Free_Recall_Preservations_VRM	CANTAB_Immediate_Recognition_Correct_	CANTAB_Immediate_Recognition_correct_	CANTAB_Immediate_Recognition_Incorrect	CANTAB_Immediate_Recognition_Total_Co
IPAQ	*r*	-.006	.061	.006	.044	.072	-.053	.090	-.097	.264	.097	.171
	p	.960	.626	.960	.722	.560	.669	.470	.434	.031	.434	.166

N	67	67	67	67	67	67	67	67	67	67	67

For the 50-90 age group, no statistically significant relationship was found between the variables for this group too.

Table 15.

Level of physical activity and CANTAB Verbal Recognition Memory (50-90 age group)

		CANTAB_Delayed_Recognition_Correct_	CANTAB_Delayed_Recognition_Correct_	CANTAB_Delayed_Recognition_Incorr	CANTAB_Delayed_Recognition_Total_Co	CANTAB_Free_Recall_Correct_VRM	CANTAB_Free_Recall_Novel_Words_VR	CANTAB_Free_Recall_Preservations_VR	CANTAB_Immediate_Recognition_Corre	CANTAB_Immediate_Recognition_correc	CANTAB_Immediate_Recognition_Incorr	CANTAB_Immediate_Recognition_Total_
IPAQ	*r*	-.017	.066	.017	.067	-.236	-.265	.187	-.039	-.123	.039	-.137
	p	.934	.743	.934	.740	.219	.165	.331	.839	.525	.839	.479
	N	29	29	29	29	29	29	29	29	29	29	29

In the same manner, to understand the differences of the relationship between IPAQ scores and CANTAB variables, between the age groups a comparison of the Two Independent Values of r was performed. It was found that in" CANTAB_Immediate_Recognition_Correct_Old_Stim_VRM" the correlation coefficient for this variable in the 18-30 years old group is 0.264, while in the 50-90 years old group, it is - 0.123. The calculated z-value is 1.69, and the two-tailed p-value is 0.091, suggesting that the difference was not significant.

This means that the correlation between this variable and the IPAQ score appears to differ somewhat between the two age groups, but this difference is not strong enough to be considered statistically significant at the typical significance level of 0.05.

Table 11.

Comparison of Correlations.

Variables	18-30 Years Old	50-90 Years Old	Z	Two-tailed p-value
CANTAB_Immediate_Recognition_Correct_Old_Stim_VRM	.264	-.123	1.69	0.091

Relationships between the level of physical activity and CANTAB Delayed Matching to Sample

The Pearson test was used to assess the relationship between the level of physical activity and CANTAB Delayed Matching to Sample in the 18-30 age group using the Pearson test. It was observed a statistically negative correlation between IPAQ scores and "CANTAB_Pattern_Error_ALLDELAYS_DMS" *r* = - .280, *p* = .022, suggesting that as the level of physical activity increases the subject has a higher tendency to commit fewer errors selecting the incorrect box that has the same pattern or physical attributes but not the same color, on their first selection, in trials that contained a delay component. It also found a statistically, negative correlation between IPAQ scores and "CANTAB_Total_Errors_ALLDELAYS_DMS" *r* = - 0.268, *p* = .028. This suggests that as physical activity levels increase, there is a tendency for the number of errors in the task to decrease on trials that contain a delay component.

Furthermore, a statistically significant positive correlation was identified between IPAQ scores and "CANTAB_Total_Correct_ALLDELAY_DMS" *r* = 0.268, *p* = .028. This indicates that higher levels of physical activity are associated with improved cognitive performance in tasks where the participant selects the correct answer on their first box choice for all trials with any delay between the target and response stimuli.

Table 16.

Level of physical activity and CANTAB Delayed Matching to Sample (18-30 age group)

		CANTAB_Total_Correct_DMS	CANTAB_Total_Correct_0SDELAY_DMS	CANTAB_Total_Correct_12SDELAY_DMS	CANTAB_Total_Correct_4SDELAY_DMS	CANTAB_Total_Correct_ALLDELAY_DMS	CANTAB_Total_Correct_SIMULTANEOUS_DMS	CANTAB_Total_Errors_DMS	CANTAB_Total_Errors_ALLDELAYS_DMS	CANTAB_Color_Error_DMS	CANTAB_Color_Error_ALLDELAYS_DMS	CANTAB_Distractor_Error_DMS	CANTAB_Distractor_Error_ALLDELAYS_DMS	CANTAB_Pattern_Error_DMS	CANTAB_Pattern_Error_ALLDELAYS_DMS
IPAQ	*r*	.233	.089	.178	.182	.268	.177	-.233	-.268	-.052	-.024	-.036	-.036	-.229	-.280
	p	.058	.473	.150	.139	.028	.152	.058	.028	.674	.845	.771	.771	.063	.022
	N	67	67	67	67	67	67	67	67	67	67	67	67	767	67

In turn, we once again assessed the relationship between the level of physical activity and the CANTAB Delayed Matching to Sample in the 50-90 age group using the Pearson test. However, it was not possible to discern the presence of statistically significant relationships between the variables ($p > .05$).

Table 17.

Level of physical activity and CANTAB Delayed Matching to Sample (50-90 age group)

		CANTAB_Total_Correct_DMS	CANTAB_Total_Correct_0SDELAY_DMS	CANTAB_Total_Correct_12SDELAY_DMS	CANTAB_Total_Correct_4SDELAY_DMS	CANTAB_Total_Correct_ALLDELAY_DMS	CANTAB_Total_Correct_SIMULTANEOUS_DMS	CANTAB_Total_Errors_DMS	CANTAB_Total_Errors_ALLDELAYS_DMS	CANTAB_Color_Error_DMS	CANTAB_Color_Error_ALLDELAYS_DMS	CANTAB_Distractor_Error_DMS	CANTAB_Distractor_Error_ALLDELAYS_DMS	CANTAB_Pattern_Error_DMS	CANTAB_Pattern_Error_ALLDELAYS_DMS
IPAQ	*r*	-.071	.054	.031	-.082	.010	-.215	.071	-.010	.094	.111	.239	.239	-.049	-.140
	p	.714	.780	.872	.673	.958	.263	.714	.958	.627	.568	.212	.212	.799	.470

N	29	29	29	29	29	29	29	29	29	29	29	29	29	29

In the same manner, to understand the differences of the relationship between IPAQ scores and CANTAB variables, between the age groups a comparison of the Two Independent Values of r. It was found that in" CANTAB_Pattern_Error_ALLDELAYS_DMS" the correlation coefficient for this variable in the 18-30 years old group is - 0.280, while in the 50-90 years old group, it is - 0.140. The calculated z-value is - 0.63, and the two-tailed p-value is 0.529, which is substantially higher than the significance level of α = 0.05. This suggests that there is no statistically significant difference in the correlation coefficients for this variable between the two age groups.

The correlation coefficient for the "CANTAB_Total_Errors_ALLDELAYS_DMS" variable is - 0.268 for the 18-30-year-old group and - 0.010 for the 50-90-year-old group. The z-value is - 1.14, and the two-tailed p-value is 0.254. The higher two-tailed p-value suggests that there is no statistically significant difference in the correlation coefficients between the two age groups for this variable, indicating a consistent relationship between "CANTAB_Total_Errors_ALLDELAYS_DMS" and IPAQ score across age groups.

In the 18-30-year-old group, the correlation coefficient for the "CANTAB_Total_Correct_ALLDELAY_DMS" variable is 0.268, while in the 50-90-year-old group, it is 0.010. The z-value is 1.14, and the two-tailed p-value is 0.254, which suggests that there is no statistically significant difference in the correlation coefficients between the two age groups for this variable, suggesting a consistent relationship between "CANTAB_Total_Correct_ALLDELAY_DMS" and IPAQ score across age groups.

Table 11.

Comparison of Correlations.

Variables	18-30 Years Old	50-90 Years Old	Z	Two-tailed p-value
CANTAB_Pattern_Error_ALLDELAYS_DMS	.281	-.140	-0.63	0.529

CANTAB_Total_Errors_ALLDELAYS_DMS	-.268	-0.10	-1.14	0.254
CANTAB_Total_Correct_ALLDELAY_DMS	.268	.010	1.14	0.254

Discussion

The present analysis aimed to understand the connection between physical activity and cognition, with a particular focus on the potential age-related differences in this relationship. The results show that there is an impact of the intensity of physical activity on cognitive performance in both age groups, it is possible to understand that it varies according to the age and specific cognitive task.

Significative results were found between physical activity level and executive function in both age groups (Young Adults ages 18 to 30, and Older Adults ages 50 to 90). It was observed that in the younger group, individuals with higher levels of physical activity tended to make fewer errors in the direction blocks and incongruent trials which resulted in making fewer errors in general, consequently, individuals with a higher level of physical activity also had a higher number of correct answers. According to overall literature concerning the relationship between physical activity and cognitive function, these results were expected since there is a positive impact of an active lifestyle on executive function, as reported by Hillman et al. (2006) who hypothesized that physical activity would positively influence task switching performance in young adults, responding more quickly in comparison to the young adults of the sedentary group. Smith et al. (2010) also report in a meta-analysis, that there are modest improvements in executive functions as well as in attention and processing speed after moderate physical training in adults over 18 years old.

In adults over the age of 50 and below 90, it was observed that with the increase in the physical activity level, there was a higher tendency to commit errors related to interference in direction blocks, as well as the number of errors in single block trials overall. The outcomes deviate from what was anticipated in the existing literature. However, some studies also demonstrate the adverse effects of high physical activity intensity, being sedentary behavior positively correlated with cognitive performance (Ekblom et al., 2019; Gerten et al., 2022; Rosenberg et al., 2015). There is also evidence that an appropriate amount of sleep (Vance et al., 2005) or the incorrect type of physical activity (Northey et al., 2018) can have an impact on cognitive performance.

Regarding motor and processing speed, in younger adults, it was noted that higher levels of physical activity were associated with shorter durations between releasing the starting button and reaching the yellow circle. A comprehensive meta-analysis conducted by Smith et al. in 2010 examined twenty-four studies that investigated the effects of physical activity, particularly aerobic activity, on processing speed and attention. Across these studies, modest improvements were consistently observed. Notably, combined interventions, which included strength training alongside aerobic activities, yielded better results compared to interventions focused solely on aerobic exercise.

These results are consistent with the literature (Gajewski et al., 2023; Northey et al., 2018) and support the hypothesis of the impact of physical activity on cognitive performance. Nevertheless, a study by Smith et al., (2010) showed that certain types of exercises do not benefit working memory as the sole physical activity but combined with other types of physical exercise improve not only working memory but also attention and processing speed.

In verbal learning and memory, it was possible to observe that in the younger adult group, the increased levels of physical activity were associated with an increase in the number of words that the participants recognized immediately. A study performed by Xu et al. (2011) revealed that participants who had a greater level of physical activity had greater scores in delayed word recall tests.

Relatively to tasks that explore memory, it was observed that the younger adult group exhibited an improved performance and made fewer errors, across all task delays (4 to 12 seconds) as the level of physical activity increased. These findings align with existing literature on the subject. A meta-analysis conducted by Roig et al. in 2013 revealed an overall positive effect on memory. The meta-analysis also examined acute interventions, such as running or cycling, which were associated with more substantial improvements in long-term memory but showed only moderate effects on short-term memory. Conversely, cardiovascular exercises like aerobics, stretching, dancing, or yoga were linked to slight enhancements in short-term memory but had no discernible impact on long-term memory. In contrast, Older Adults did not yield significant results, supporting previous literature regarding weak, or no overall impact of physical activity on cognition (Loprinzi et al., 2019).

Understanding the impact of physical activity on cognitive function reveals notable disparities between younger and older adults. While some studies, such as Spirduso et al. (1975), suggest that cognitive performance in active older adults is similar to younger adults, Etnier et al.'s (2006) meta-analysis proposes a more nuanced perspective. They argue that the relationship between physical activity and cognitive functioning is age-dependent, showing that the effect differs across age groups.

In a recent study by Gajewski et al. (2023), an exploration of the connection between physical activity and cognitive functions in younger, middle-aged, and older adults unveiled a moderate association influenced by age. This investigation identified a noteworthy link between physical activity and general intelligence, as well as specific cognitive functions such as sustained attention, psychomotor speed, logical reasoning, and interference processing, although not verbal memory. Interestingly, the study also revealed that older adults experience more substantial cognitive gains from physical activity when compared to younger adults. These insights suggest that certain cognitive variables exhibit significant variations in physical activity across age groups. It is evident that increased physical activity is linked to improved executive function, faster motor and processing speed, and enhanced word recognition in younger adults, aligning with prior research (Hillman et al., 2006; Northey et al., 2018).

However, among older adults, the observed results present a mixed picture, contrary to expectations, as there seems to be a weak to negligible impact of physical activity on cognitive performance (Etnier et al., 2006; Gajewski et al., 2023).

These disparities were anticipated, given the expected decline in cognitive function with age. Nevertheless, age is not the sole factor contributing to variations in cognitive outcomes associated with physical activity. This relationship between physical activity and cognition is intricate, as it must consider multiple influencing factors, including age, educational background, social environment, sleep, and leisure activities (Adam et al., 2013; Huang et al., 2020; Mellow et al., 2022).

Conclusion and Future Possible Studies

In summary, the findings indicate that varying levels of physical activity can exert a substantial impact on cognitive test outcomes across a range of measures. Although Physical Activity has been associated with positive effects on general health, is still challenging to explain why these effects result. Existing research suggests that various factors contribute to these effects, including genetics, healthy eating, a stimulating environment, engaging activities, work responsibilities, education, exercise, and sleep.

In order to understand the relationship between physical exercise and cognitive performance this analysis would benefit for additional factors to gain a deeper understanding, as well as a larger sample size and additional cognitive measures to provide more comprehensive results. Also, to understand these effects, for future studies it would be beneficial to do a pre- and post-assessment of the cognitive measures as well as physical measures, to understand the influence of these measures in a interventional study.

To achieve more cohesive results, it is suggested that future studies should aim to match participants based on factors such as education levels, clinical history, habits, occupation, and other relevant variables. By doing so, researchers can better understand the most effective exercises or activities, their intensity, and frequency for optimal results in promoting healthy cognitive development and ultimately healthy aging.

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