



Impacts of physical activity on cognitive performance in middle-aged and older adults

Impactos da atividade física no desempenho cognitivo em adultos de meia-idade e pessoas idosas

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ABSTRACT

Introduction: Physical activity (PA) contributes to the prevention of cognitive impairment. Social isolation measures, such as those adopted during the COVID-19 pandemic, may negatively affect PA levels. **Objective:** To assess the longitudinal impacts of PA on cognitive performance in middle-aged and older adults. **Methods:** A longitudinal, quantitative study was conducted in 2018/2019 (T1), 2021 (T2), and 2023 (T3), involving 300 individuals aged 45 years and older, registered at Health Units in Três Lagoas, Mato Grosso do Sul, Brazil. The International Physical Activity Questionnaire, short version, was administered at all three assessments, and the Mini-Mental State Examination (MMSE) was administered at T3. Statistical analyses included logistic regression adjusted for sex, age, and education, as well as ANOVA. **Results:** At T3, most participants were female (65.7%), with a mean age of 65.2 years, 5.7 years of schooling, and 16.7% had cognitive impairment. Participants who were physically inactive at T1 (OR = 2.76; IC 95%: 1.34 – 5.72) and T2 (OR = 3.47; IC 95%: 1.31 – 9.21) had a significantly higher risk of cognitive impairment at T3. The greater the number of times a participant was classified as active across assessments (0–3), the lower the likelihood of cognitive impairment (OR = 0.52; IC 95%: 0.34 – 0.80). Being active in at least one assessment positively influenced MMSE scores compared to being inactive in all assessments. **Conclusion:** Physical inactivity increased the risk of cognitive impairment in middle-aged and older adults. Encouraging and promoting PA in this population is essential to minimize the impacts of aging on cognition.

Keywords: Aged; Middle aged; Exercise; Cognition; Pandemics.

RESUMO

Introdução: A atividade física (AF) contribui para a prevenção do comprometimento cognitivo. Medidas de isolamento social, como as adotadas durante a pandemia da covid-19, podem afetar negativamente a prática de AF. **Objetivo:** Avaliar os impactos longitudinais da prática de AF no desempenho cognitivo de adultos de meia-idade e pessoas idosas. **Métodos:** Estudo longitudinal e quantitativo, desenvolvido em 2018-2019 (T1), 2021 (T2) e 2023 (T3), com 300 indivíduos acima de 45 anos, cadastrados em Unidades de Saúde de Três Lagoas, Mato Grosso do Sul. Foram aplicados o Questionário Internacional de Atividade Física versão curta nas três avaliações e, em T3, o Mini-Exame do Estado Mental (MEEM). As análises incluíram regressão logística ajustada por sexo, idade e escolaridade; e ANOVA. **Resultados:** Em T3, a maioria da amostra era do sexo feminino (65,7%), com média de 65,2 anos de idade, 5,7 anos de escolaridade e 16,7% tinham comprometimento cognitivo. Os participantes que eram fisicamente inativos em T1 (OR = 2,76; IC 95%: 1,34 – 5,72) e em T2 (OR = 3,47; IC 95%: 1,31 – 9,21) tiveram significativamente mais risco de ter comprometimento cognitivo em T3. Quanto maior o número de vezes que o participante foi considerado ativo nas avaliações (0-3), menor a chance de ter comprometimento cognitivo (OR = 0,52; IC 95%: 0,34 – 0,80). Ser ativo em pelo menos uma avaliação teve influência positiva na pontuação do MEEM, em comparação a ser inativo em todas as avaliações. **Conclusão:** A inatividade física aumentou o risco de comprometimento cognitivo em adultos de meia-idade e pessoas idosas. O incentivo e a promoção da prática de AF nessa população são necessários para minimizar os impactos do envelhecimento na cognição.

Palavras-chave: Pessoa idosa; Pessoas de meia-idade; Exercício físico; Cognição; Pandemia de covid-19.

Introduction

Cognitive impairment has negative health consequences, such as functional disabilities and decreased

social relationships¹. Its implications include a high incidence of hospital admission, and a greater propensity for developing delirium, dehydration, and falls, as well

as the emergence of frailty². The association between cognitive impairment and symptoms of depression is also highlighted in middle-aged and older adults, contributing to a variety of physical and emotional challenges that influence quality of life³. Older age, lower educational attainment, not living with a partner, and physical inactivity have been associated with an increased risk of cognitive impairment⁴.

In view of the above, it is important that modifiable risk factors be addressed to minimize the consequences of cognitive impairment. The practice of physical activity (PA) is relevant because it contributes to the promotion of healthy aging and is associated with the maintenance and improvement in cognitive function and the prevention of chronic conditions⁵. Greater practice of PA and regular sleep (6-8 hours per night) lead to higher scores on cognitive assessments⁶. Furthermore, increasing low- to moderate-intensity PA by 35% or more results in significant improvements in aerobic capacity, gait speed, verbal memory, executive functioning, and overall cognition⁷.

However, some factors can directly influence the practice of PA, such as the COVID-19 pandemic, as during this period, many individuals reduced or even stopped practicing PA⁸⁻¹¹. Recommendations for social distancing and isolation were maintained for a long period and activities only began to return to pre-pandemic routines at the end of 2021 and the beginning of 2022. This was mainly due to vaccination against the disease, which led to a decrease in the number of deaths and hospitalizations¹².

Studies that analyze cognitive performance trajectories before, during, and after the COVID-19 pandemic, relating them to physical activity, in older individuals (≥ 45 years) are scarce. One study analyzed the effects of the pandemic on the cognition of 3142 participants aged 50 or older from the United Kingdom¹³. A decline in cognition was identified during and after the pandemic, which was associated with a reduction in PA during that period¹³. However, the study used data from the years 2019, 2021, and 2022, when activities were still returning to normal, so was unable to show longer-term impacts.

Cognitive impairment can have a negative impact on people's lives and although PA practice can reduce the risk of this impairment, the pandemic may have affected PA participation. Thus, the objective of the current study was to evaluate the longitudinal impacts of PA on the cognitive performance of middle-aged and older adults.

Methods

The database of the research group "Assistance, research, teaching and management in Public Health", research line Health and aging, was used. The work obtained approval from the ethics committee for research with human beings of the Federal University of Mato Grosso do Sul, Brazil (opinions nº 2,596,194 and 4,467,405). Before the three interviews, all participants read and signed the Informed Consent Form.

This is a quantitative, longitudinal study conducted at three points in time, herein referred to as before the pandemic (T1), during the pandemic (T2), and after the pandemic (T3). The study sites were the Family Health Units (FHUs) in the municipality of Três Lagoas, Mato Grosso do Sul. In 2010 (the last census available at the start of the project), the city had 101,791 inhabitants, of which 16.1% were aged between 45-59 years and 9.9% were older adults (≥ 60 years). In 2018, which marked the beginning of data collection, the city had nine FHUs.

The study included 300 individuals aged 45 years or older, registered at the nine FHUs in the municipality. These individuals were randomly selected from a list of all individuals over 45 years of age attended by the health teams. The total number of eligible individuals was 26,331.

The sample size for the pre-pandemic data collection was estimated based on a calculation using the proportion estimation formula for a finite population, adopting a significance level of 5% ($\alpha = 0.05$), sampling error of 6% ($e = 0.06$), and conservative estimate of 50% ($p = 0.50$), which provides the largest sample size. The finite population of $N = 26,331$ (total number of individuals over 45 years of age in the municipality) was considered, and the minimum sample size was 265 individuals, to which 10% was added to mitigate possible losses, resulting in 292 participants. At the end of the data collection, 300 individuals were interviewed (final sampling error of 5.6%).

Data collection at T1 took place between November 2018 and June 2019, at T2 between February and December 2021, and at T3 between March and July 2023. Assessments were conducted by trained evaluators, either at the participants' homes or at the FHU facilities, and each assessment lasted approximately 40 minutes.

PA practice was assessed at three data collection points using the short version of the International Physical Activity Questionnaire, which considers walking, and moderate and vigorous-intensity PA per-

formed for at least 10 minutes. This tool has been validated in Brazil for use in adults¹⁴ and older adults¹⁵. Participants were classified as: active (at least 150 minutes of moderate activity or 75 minutes of vigorous activity per week) or inactive (when they did not reach the aforementioned time, encompassing the groups that fall into the physically inactive and sedentary behavior categories)¹⁶.

A sociodemographic characterization was carried out, including sex, age (years), and education level (years). Cognitive performance was assessed in the post-pandemic period using the Mini-Mental State Examination (MMSE), which is a screening instrument for cognitive function and covers the domains of temporal orientation, spatial orientation, immediate memory, attention and calculation, recall memory, and language. The instrument is validated for application in the Brazilian population and has a maximum score of 30 points. Cut-off scores were used according to the participants' education level to classify them as having, or not, cognitive impairment¹⁷.

The analyses were performed using IBM SPSS Statistics (version 25.0; IBM Corp., Armonk, NY, USA). It was found that 30% of the data were identified as missing, following a monotone pattern¹⁸, since most of the missing values were due to discontinuation of participation – change of city, change of address, or refusal to participate in data collection. No significant differences were identified for sex and age between participants who responded to all assessments and those who discontinued participation. The missing data were then considered Missing Completely at Random (Little's MCAR test: $X^2(21) = 17.39$, $p = 0.687$)¹⁹ and were treated by imputation using the expectation maximization (EM) method.

Initially, a descriptive analysis of sociodemographic data was conducted (absolute and relative frequency or mean and standard deviation) of the total sample and according to cognitive performance after the pandemic (Table 1). Participants were categorized as active and inactive in each assessment. The prevalence of physical inactivity was compared using Cochran's Q test. Changes in PA category were identified when comparing T1 and T2, and T2 and T3, and the proportions were plotted in a figure (Figure 1).

To identify the associations between PA and cognitive performance, three analyses were conducted. The first considered the percentage of participants with and without cognitive impairment at T3, calculated

according to PA at the three time points. A cumulative PA score was also created according to the number of times participants were classified as active (0, 1, 2, or 3) (see: Gomes et al.²⁰). For these variables, crude and adjusted binary logistic regression models were estimated for PA practice and PA score. The analyzed outcome was the presence of cognitive impairment at T3. The adjusted model was controlled for sex, age, and education level (Table 2). Finally, to identify differences in cognitive performance according to the PA trajectories, five groups were created (see: Gomes et al.²⁰): 1) always active (in all three time periods); 2) always inactive (in all three time periods); 3) started inactive (T1) and ended active (T3); 4) started active (T1) and ended inactive (T3); and 5) fluctuated (classified in the same category in T1 and T3, but in the opposite category in T2). Since the MMSE scores after the pandemic showed a distribution within the normal range, according to the assessment of skewness and kurtosis²¹, the scores in each group were compared using one-way ANOVA with post-hoc Difference between means (DMS). A significance level of 5% was considered in all analyses.

Results

Table 1 presents the sample characterization data. The majority of the sample were female, with a mean age of 65.2 years and 5.7 years of schooling, with 16.7% classified as having cognitive impairment at T3.

Table 1 – Sociodemographic characteristics and cognitive performance of the sample at T3 (2023).

Variables	n (%) or mean (standard deviation)	Cognitive performance after the pandemic	
		Without cognitive impairment (n = 250)	With cognitive impairment (n = 50)
Sex			
Male	103 (34.3)	92 (36.8)	11 (22.0)
Female	197 (65.7)	158 (63.2)	39 (78.0)
Age (years)	65.2 (10.9)	65.3 (10.5)	64.5 (12.6)
Schooling (years)	5.7 (4.6)	6.9 (4.0)	5.5 (4.7)

Figure 1 illustrates the transitions in PA category across the three data collection periods. More than half of the sample was inactive at T1 (60.3%), and this value increased to 75% at T2 and to 83.7% at T3, with a significant difference in prevalence ($p < 0.001$). Almost half of the sample remained inactive (48.7%), and only 5% remained active across the three periods.

Table 2 presents the data on the association between PA in the three assessments and cognitive performance after the pandemic. Participants who were inactive before (OR = 2.76; 95% CI: 1.34 - 5.72) and during the pandemic (OR = 3.47; 95% CI: 1.31 - 9.21) were more likely to present cognitive impairment after the pandemic. Furthermore, the greater the number of times a participant was considered active in the assessments,

the lower the chance of having cognitive impairment (OR = 0.52; 95% CI: 0.34 - 0.80).

Table 3 demonstrates the variations in the MMSE mean in relation to the PA trajectories. There was a significant difference in scores between the “always inactive” and “started inactive and ended active” groups, and between the “always inactive” and “started active and ended inactive” groups.

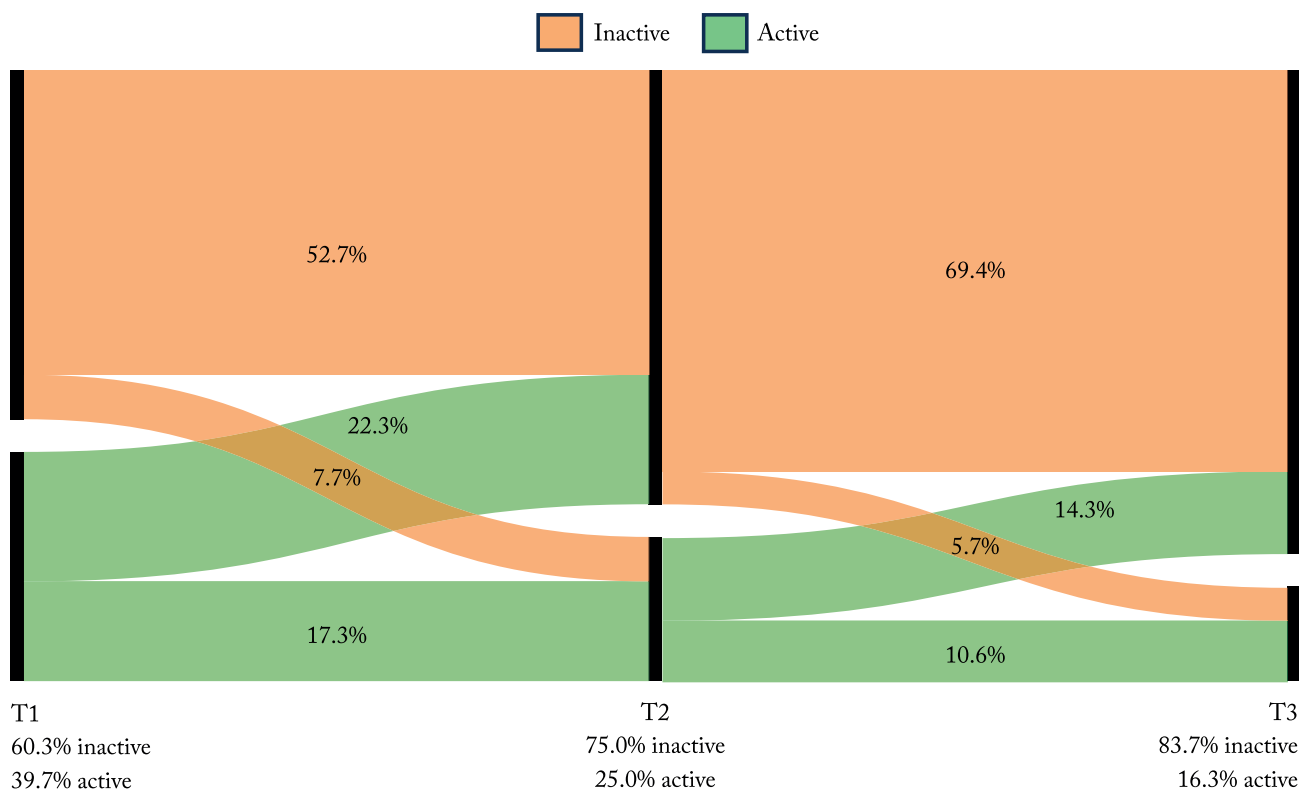


Figure 1 – Changes in physical activity (active and inactive) in the periods before (T1), during (T2), and after the pandemic (T3) in middle-aged and older adults.

Table 2 – Cognitive performance and logistic regression models according to physical activity indicators before, during, and after the pandemic.

Physical activity	Post-pandemic cognitive performance - Frequency (%)		Crude OR (95% CI)	Adjusted OR [†] (95% CI)
	Without cognitive impairment	With cognitive impairment *		
Before the pandemic				
Active	108 (43.2)	11 (22.0)	Ref	Ref
Inactive	142 (56.8)	39 (78.0)	2.70 (1.32 - 5.51)*	2.76 (1.34 - 5.72)*
During the pandemic				
Active	70 (28.0)	5 (10.0)	Ref	Ref
Inactive	180 (72.0)	45 (90.0)	3.50 (1.33 - 9.18)*	3.47 (1.31 - 9.21)*
After the pandemic				
Active	43 (17.2)	6 (12.0)	Ref	Ref
Inactive	207 (82.8)	44 (88.0)	1.52 (0.61 - 3.80)	1.47 (0.58 - 3.70)
Number of assessments as active (continuous, 0-3) –mean (standard deviation)	0.88 (0.94)	0.44 (0.71)	0.53 (0.35 - 0.80)*	0.52 (0.34 - 0.80)*

♦ Outcome event. † Adjusted for sex, age, and education. * $p \leq 0.05$. Ref: Reference category for the independent variables. OR: Odds ratio. CI: Confidence interval.

Table 3 – Mean score in the assessment of cognitive performance after the pandemic according to physical activity trajectories.

Physical activity trajectories	Cognitive performance after the pandemic Mean (standard deviation)	p-value [†]
(a) Always Active (n = 15)	24.16 (3.14)	0.017*
(b) Always Inactive (n = 146)	22.65 (4.64) ^{‡§}	
(c) Started Inactive and ended Active (n = 29)	24.68 (3.35) [‡]	
(d) Started Active and ended Inactive (n = 99)	24.34 (4.09) [§]	
(e) Fluctuated (n = 11)	23.45 (3.27)	
Total	23.51 (4.31)	

Note: Cognitive performance assessed by the Mini-Mental State Examination. ANOVA: $p = 0.017$. The DMS post hoc test identified statistically significant differences between groups (b) Always inactive and (c) Started inactive and ended active ($p = 0.019$), and between groups (b) Always inactive and (d) Started active and ended inactive ($p = 0.002$).

Discussion

Physical inactivity (before and during the pandemic) was associated with cognitive impairment after the pandemic. The frequency with which participants were considered active was inversely related to the presence of cognitive impairment. Furthermore, being active in at least one assessment had a positive influence on cognitive performance, compared to being inactive in all assessments, regardless of sex, age, and education level. As a secondary result, an increase in the prevalence of physical inactivity was identified when comparing the three assessments.

Previous studies corroborate our results by showing that physical inactivity is associated with cognitive decline^{22,23}. It is important to mention that, compared to the pre-pandemic period, cognitive decline accelerated²⁴ in the first two years of the pandemic. When investigating associated risk factors, reduced practice of PA was among the main factors identified¹³, which was also associated with a reduction in subjective memory²⁵. A systematic review identified that PA is a possible protective factor against cognitive decline in individuals with the Apolipoprotein E4 gene (APOE e4)²⁶. This association was observed regardless of the methods used to assess physical activity and cognitive decline²⁶.

When considering the inverse association identified between the number of times PA occurs and cognitive impairment, the role of exerkines should be

emphasized. These molecules are produced and secreted by different tissues in response to acute or chronic physical exercise²⁷. They provide growth factors, neurotransmitters, and anti-inflammatory cytokines, and increase metabolites such as lactate and ketone bodies, promoting improvements in cognition²⁸. Furthermore, exerkines reduce inflammation and oxidative stress and increase stem cell mobilization, generating anti-inflammatory and immunomodulatory effects, and thus promoting cognitive function²⁸.

Myokines (exerkines released by muscle tissue), such as irisin and lactate, cross the blood-brain barrier and play a role in regulating mitochondrial content, dynamics, and transcription factors. In this way, they modulate brain mitochondrial bioenergetics and biogenesis. Furthermore, irisin is able to increase the expression of the BDNF gene, which encodes brain-derived neurotrophic factor, in the hippocampus and cortical cells. This results in increased neurogenesis, neuroplasticity, and cognitive function²⁹, supporting the idea that PA can contribute positively to cognitive performance, as observed in the current study.

In this study, the higher frequency of assessments in which the participant was classified as active was associated with a lower chance of cognitive impairment and better performance. The World Health Organization guidelines, while recommending a minimum of weekly PA, emphasize that doing any PA is better than doing none, even if it does not reach the minimum recommended times and frequencies¹⁶. Although the benefits vary depending on intensity, frequency, and duration, the central evidence is that regular physical activity, even at light levels, is associated with a lower risk of cognitive impairment³⁰. Studies summarized in a review indicate that PA initiated in old age brings benefits to cognition and life expectancy, reinforcing the importance of PA for older people, even those who have been inactive throughout their lives³¹. Light activities may be more relevant in older age, when moderate or vigorous exercise becomes less accessible³².

It is noteworthy that, despite intuitive expectations, the mean score on the cognitive assessment of participants who were “always active” was not the highest among all the groups analyzed. Although no significant differences were identified between this group and those with the highest means (i.e., “Started inactive and ended active” and “Started active and ended inactive”), some factors such as the very small size of the “always active” group ($n = 15$), possibility of low statistical power

er, heterogeneity of the group, and absence of a cognitive assessment at T1 may have influenced the result.

The findings showed an increase in the prevalence of physical inactivity across the three assessments. The increase during the pandemic period, as previously identified³³, could be associated with various factors, such as advanced age, the presence of chronic diseases, and prior physical inactivity⁸. Conversely, some studies indicate that younger people were the most affected during this period, with higher rates of physical inactivity^{9,10}. In addition, one study observed a certain balance between the percentage of people who, a year after the end of COVID-19 restrictions, became more active, more inactive, or maintained their previous behavior³⁴. This divergence may reflect variations in individual experiences and adaptations to the new post-pandemic context.

One of the main consequences of being physically inactive is a higher incidence of premature mortality³⁵. Furthermore, it is responsible for a significant proportion of global deaths, including more than 70% of deaths from all causes and cardiovascular diseases³⁶. Physical inactivity can also be identified as a contributing factor to higher mortality rates from breast and prostate cancer, fractures, recurrent falls, impaired activities of daily living, functional limitations, cognitive decline, dementia, Alzheimer's disease, and depression³⁷.

Interventions that promote PA are fundamental because, in addition to mitigating the risks associated with physical inactivity, they protect cognitive health. Programs that encourage regular exercise are essential for preserving cognitive function, especially among vulnerable populations, thus contributing to the prevention of cognitive deficits and improvements in quality of life. Likewise, it is necessary to reverse the current scarcity of studies that specifically assess the impact of the pandemic on the increase in sedentary behavior and physical inactivity and, consequently, the prevalence of cognitive decline in the population.

Limitations include the absence of baseline cognitive assessment (T1 and T2), which prevents the assertion of longitudinal cognitive decline and limits causal inferences, as well as the possibility of reverse causality. Further limitations include the predominantly female sample limits the generalizability of the results to men; the use of self-report questionnaires to assess PA may introduce memory bias and other bias towards socially desirable reporting; and the fact that variables such as anxiety and depression, especially relevant during the

pandemic, were not evaluated. However, we highlight as strengths the longitudinal assessment of PA before, during, and after the pandemic, the application of a widely used instrument for cognitive assessment, and the analysis adjusted for confounding variables (sex, age, and education), which strengthens its robustness. Also noteworthy is the analysis of information from the Central-West region of Brazil, for which there is still little research on this topic.

In conclusion, physical inactivity before and during the COVID-19 pandemic increased the risk of cognitive impairment in middle-aged and older adults after the pandemic. The more times a participant was considered active in the assessments, the lower the chance of having cognitive impairment. Scores on the cognitive assessment instrument were better in participants who "started inactive and ended active" and "started active and ended inactive" compared to those who were "always inactive", indicating that being active at some point is better for cognitive performance than always being inactive.

The study highlights the relevance of PA as a protective factor against cognitive decline, providing valuable evidence for public health policies aimed at promoting an active lifestyle among aging individuals and older adults. Future studies should focus on identifying the impacts of PA on cognition over longer periods after the pandemic (i.e., five years and 10 years), conducting cognitive assessments at all data collection points, evaluating cognitive performance using other more comprehensive instruments and batteries, and assessing other relevant variables, such as depression and anxiety.

Conflict of interest

The authors declare no conflict of interest.

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Author contributions

Barbosa AM: Conceptualization; Methodology; Research; Data curation; Funding acquisition; Original manuscript drafting; Approval of the final manuscript version. Serpa RT: Conceptualization; Drafting - revision and editing; Approval of the final manuscript version. Gomes GAO: Data analysis; Writing - revision and editing; Approval of the final manuscript version. Luchesi BM:

Conceptualization; Methodology; Data analysis; Data curation; Project management; Original manuscript writing; Approval of the final manuscript version. Martins TCR: Conceptualization; Methodology; Data analysis; Data curation; Supervision; Data presentation design; Original manuscript writing; Approval of the final manuscript version. Kwiatkoski M: Conceptualization; Methodology; Data analysis; Supervision; Funding acquisition; Original manuscript writing; Approval of the final manuscript version.

Statement regarding the use of artificial intelligence tools in the article writing process

The authors did not use artificial intelligence tools for preparation of the manuscript.

Availability of research data and other materials

Data are available upon request from reviewers.

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Reviewers' assessment

The authors and/or reviewers did not authorize the publication of either of the two reviews.