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Association Between Physical Activity And Depressive Symptoms In Older Adults: A Cross-Sectional And Replication Study From ELSI-Brazil

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Abstract

Background: *Depression is a prevalent and debilitating mental health condition that disproportionately affects older adults. Physical activity (PA) has been shown to have a protective effect against depression in various populations, including older adults. However, the strength and mechanisms of this association remain unclear.*

Objective: *This study aimed to replicate and extend the findings of Rothon et al. (2010) by investigating the association between physical activity and depressive symptoms in a larger sample of older adults from the Brazilian longitudinal study of aging (ELSI).*

Methods: *We conducted a cross-sectional analysis using data from the second wave (2019-2021) of the ELSI-Brazil, a population-based study of individuals aged 50+. Self-reported physical activity levels and depressive symptoms (assessed through questionnaires (CES-D scores) and physician diagnoses) were evaluated in 6,974 participants. Statistical analyses included descriptive statistics, multivariate logistic regression adjusted for confounders, assessment of model fit, and sensitivity analyses to assess the robustness of our findings.*

Results: *Weekly physical activity was linked to lower diagnosed depression risk (OR=0.61) and appeared robust to confounding. Interestingly, it was not linked to daily depressive symptoms (CES-D scores). Sleep problems, pain, and race (diagnosed depression) were risk factors—social life and having a partner protected against depressive symptoms (CES-D scores).*

Conclusions: *Our findings support prior research suggesting a link between PA and lower depression risk in older adults. The cross-sectional design limits causal inferences and the possibility of residual confounding. Future longitudinal studies are needed to explore causality and mechanisms.*

Introduction

Depression, a prevalent mental health disorder affecting all ages, disproportionately impacts older adults. The Centers for Disease Control and Prevention (CDC, 2022) reports a concerning disparity in depression prevalence across care settings. Rates range from 1-5% for community-dwelling older adults to a significant jump of 13.5% and 11.5% for those requiring home healthcare and hospitalization, respectively (Figure 1) (CDC, 2022). This highlights the vulnerability of older adults and the need for interventions promoting their well-being.

The financial burden of depression in older adults is also substantial. In the United States, the economic cost of major depressive disorder (MDD) rose by a

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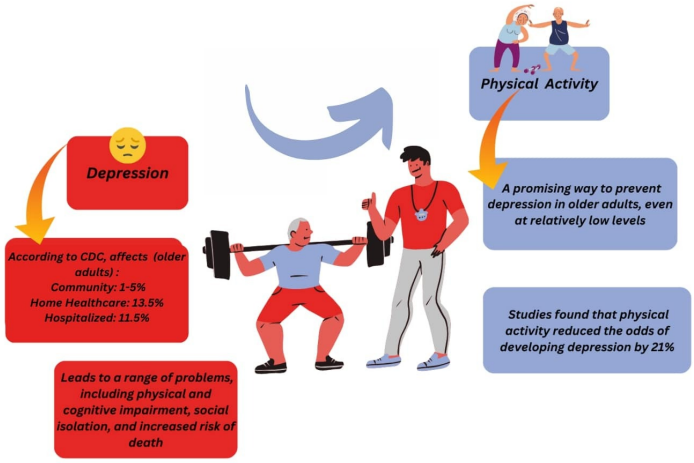

Figure 1: *The impact of depression and physical activity on older adults.*

staggering 37.9% between 2010 and 2018, reaching $326.2 billion (around $1,000 per person) in 2018 (the year 2020 values) (Greenberg et al., 2021). Workplace costs saw the most significant increase, rising by 73.2% during this period (Greenberg et al., 2021). Further analysis by Greenberg et al. (2021) revealed that the incremental direct cost per case for individuals aged 50 and above with MDD varied depending on employment status and treatment. Employed individuals receiving treatment had annual costs of $11,693 and $11,000 in 2010 and 2018, respectively, while those not employed and untreated had costs of $7,859 and $6,599 (Greenberg et al., 2021).

Effective interventions are crucial with the growing older adult population (United Nations, 2022). While research supports the benefits of physical activity for this age group (Garatachea et al., 2009), our understanding of its specific impact on depression in older adults remains limited. This population faces a higher depression risk, often misdiagnosed or inadequately treated due to its distinct presentation (CDC, 2022).

Building on prior studies that explored the physical activity-depression link in various populations, including older adults (e.g., Rothon et al., 2010; Pearce et al., 2021; Laird et al., 2023; Mura et al., 2013), this replicative cross-sectional study examines this association specifically in older Brazilian adults (aged 50+). While cross-sectional studies have established associations, longitudinal data for this population remains scarce.

Studies suggest that regular physical activity, even at low levels, could be a promising approach to preventing depression in older adults. A recent meta-analysis by Dishman et al. (2021) supports this notion. Additionally, Laird et al. (2023) found that engaging in 400 minutes of moderate-to-vigorous activity weekly can lower depression risk by 16% in older adults. Those with chronic conditions may see an even more significant reduction (44%) with 600-1200 minutes of activity. These findings highlight the importance of exploring minimal activity requirements for older adults, particularly those with chronic illnesses, to mitigate depression risk. The potential benefits are significant, suggesting that regular physical activity, a low-cost and accessible intervention, could be a valuable strategy.

However, a knowledge gap exists regarding the specific impact of physical activity on depression in older adults compared to other populations. While cross-sectional studies have established a link between these factors (e.g., Rothon et al., 2010), longitudinal data for older adults remains scarce. This study aims to address this gap by investigating the impact of engaging in physical activity at least once a week on depression or depressive symptoms in a sample of older adults residing in Brazil, a middle-income country. We acknowledge the substantial age difference between our population and the adolescent population studied by Rothon et al. (2010), and our research design has been adapted accordingly to be more relevant to older adults in Brazil.

Materials and Methods

This study investigated the association between physical activity and depression in older adults (aged 50 years and above) from the ELSI Brazil cohort study (Lima-Costa et al., 2023). The ELSI-Brazil study was approved by the Fundação Oswaldo Cruz (FIOCRUZ) ethics committee, Minas Gerais, Brazil (protocol num-

ber 34649814.3.0000.5091), ensuring adherence to ethical guidelines for human subject research.

We utilized a cross-sectional design, analyzing data from the second wave of the baseline survey conducted between 2015 and 2016. The baseline survey design involves periodic sample refreshments in each wave. Wave 2, employed in this analysis, was conducted in 2019-2021 and included 9,949 participants with an average age of 65.5 years.

Building on the findings of Rothon et al. (2010), who studied adolescents in a prospective cohort design, we focused on a sample of older adults and employed a cross-sectional approach. Similar to their study, physical activity levels were assessed through questionnaires. However, for depression assessment, we utilized the Center for Epidemiologic Studies Depression Scale-8 (CES-D 8), a validated self-report measure commonly used with adults in conjunction with physician diagnosis. This differs from the Short Moods and Feelings Questionnaire (SMFQ) employed by Rothon et al. (2010).

Physical activity levels were measured using the short version of the International Physical Activity Questionnaire (IPAQ), a validated tool. The IPAQ gathers information on the frequency, duration, and intensity of various physical activities participants engaged in during the preceding week. It categorizes activities into three domains: vigorous-intensity (causing significant increases in heart rate and breathing), moderate-intensity (causing moderate increases), and low-intensity (such as walking). Based on the IPAQ data, participants were categorized as either meeting recommended physical activity levels (at least 150 minutes of moderate-intensity activity or 75 minutes of vigorous-intensity activity per week or an equivalent combination, as recommended by the World Health Organization for individuals aged 50 and above, or not meeting these levels (Peixoto et al., 2018).

Additionally, due to potential overlap across self-reported physical activity variables (low, moderate, and vigorous intensity), we created a new binary variable, "weeklyPA." This variable captured any self-reported physical activity (including walks of at least 10 minutes) performed at least once a week.

Our analysis focused on several key variables. Sociodemographic characteristics such as age, sex, ethnicity, region of residence, and marital status were collected. Health status was assessed through self-reported chronic diseases (including heart disease, diabetes, and chronic kidney disease), sleep problems, and pain. Depression was assessed using two methods: physician diagnosis and CES-D 8 questionnaire scores categorized to indicate different levels of depressive symptomatology. To understand the relationship between physical activity and depression, we employed logistic regression analyses. In these analyses, physical activity served as the independent variable, and depression (determined by physician diagnosis or CES-D 8 scores above 3) was the dependent variable.

To guide the selection of covariates in our logistic regression models, we considered established risk factors for geriatric depression as identified in the literature (National Institute on Aging, 2021; Wu, Feng, & Pan, 2022; Maier et al. (2021). This process prioritized variables with minimal interaction with the outcome variables (depression or depressive symptoms) and ensured reliable data collection through self-reported measures. This approach allowed us to examine the association between physical activity and depression while accounting for the potential influence of other factors.

Finally, we conducted sensitivity analyses using E-values to assess the robustness of our findings. E-values help us understand how much unmeasured confounding variables might affect the observed relationships between physical activity and depression.

Results

Our study investigated the association between various factors and depression in older adults (n=6,974, average age: 65.5 years). The sample was predominantly female (60.6%) and retired (57.1%), with diverse ethnicities (White: 44.7%, Black: 11.1%, Brown: 43.5%, Asian: 0.2%, Indigenous: 0.5%). Most participants resided in urban areas (83.4%) and reported good overall health (67.2%). Detailed characteristics are presented in Table 1.

Physical activity levels were assessed. Participation was higher for low-intensity (55.11%) and moderate-intensity (29.39%) activities compared to vigorous activity (14.33%) (Table 1).

Participants reported the frequency of low-, moderate-, and vigorous-intensity physical activity (PA) (more than once a week, once a week, 1 to 3 times a month, or rarely or never). Fewer participants did vigorous PA (14.33%) compared to moderate PA (29.39%) or low-intensity PA (55.11%).

To understand the factors potentially influencing depression and the CESD category, we employed logistic regression models with various covariates using STATA edition 18. Table 2 details the specific covariates included in each model.

Our study explored the link between various factors and depression in older adults, with details on the included covariates provided in Table 2. We employed logistic regression models to analyze two measures of depression: physician diagnosis (12.91%

N	**6,974**
Age	65,594 (9,421)
Sex	
Female	4,228 (60.6%)
Male	2,746 (39.4%)
Area	
Urban	5,817 (83.4%)
Rural	1,157 (16.6%)
Race	
White	,110 (44.7%)
Black	773 (11.1%)
Brown	3,024 (43.5%)
Yellow (Asian descent, Japanese, Chinese, Korean, etc.)	16 (0.2%)
Indigenous	35 (0.5%)
Self-evaluation of general health	
Excellent	186 (2.7%)
Very good	427 (6.1%)
Good	2,680 (38.4%)
Fair	2,655 (38.1%)
Bad	804 (11.5%)
Very bad	222 (3.2%)
Retirement status	
No	2,993 (42.9%)
Yes	3,978 (57.1%)
Chronic pain	
No	4,391 (63.0%)
Yes	2,583 (37.0%)
Arterial hypertension	
No	3,330 (47.8%)
Yes	3,633 (52.2%)
Diabetes	
No	5,685 (81.9%)
Yes	1,258 (18.1%)
History of cerebral vascular accident (stroke)	
No	6,714 (96.4%)
Yes	252 (3.6%)
Smoking status	
Yes, daily	798 (11.4%)
Yes, less than daily	95 (1.4%)
No	1,582 (22.7%)
Does not apply	4,499 (64.5%)
Drinking any alcoholic beverage	
Never	5,327 (76.5%)
Less than once a month	681 (9.8%)
Once a month or more	953 (13.7%)
Frequency of vigorous physical activities	
More than once a week	750 (10.9%)
Once a week	234 (3.4%)
1 to 3 times a month	103 (1.5%)
Rarely or never	5,782 (84.2%)
Frequency of moderate physical activities	
More than once a week	1,523 (22.1%)
Once a week	499 (7.3%)
1 to 3 times a month	226 (3.3%)
Rarely or never	4,632 (67.3%)
Frequency of low-intensity physical activities	
More than once a week	3,203 (46.5%)
Once a week	597 (8.7%)
1 to 3 times a month	241 (3.5%)
Rarely or never	2,854 (41.4%)
History of depression	
No	6,064 (87.1%)
Yes	899 (12.9%)
Depression by CES-D	
Non-depressed	3,360 (48.18%)
Depressed	3,614 (51.82%)

Table 1: *Sample characteristics.*

Covariates for logistic regression model with depression as outcome				Covariates for logistic regression model with CESDcat as outcome		
Covariate	OR	OR-range	p-value	OR	OR-range	p-value
Age	0.97	0.96 - 0.98	0.000	0.99	0.98 - 0.99	0.041
Sex	0.39	0.29 - 0.52	0.000	0.73	0.62 - 0.85	0.000
Race	0.74	0.64 - 0.86	0.000	1.07	0.96 – 1.18	0.000
Region	1.26	1.05 - 1.53	0.016	0.91	0.79 – 1.05	0.21
Self-reported physical activity (any intensity, ≥ once/week)	0.64	0.48 - 0.84	0.002	0.85	0.69 – 1.05	0.129
Partner	1.03	0.87 - 1.23	0.702	0.77	0.67 – 0.9	0.001
Heart disease	1.33	0.93 - 1.91	0.114	1.33	1.01 - 1.63	0.004
Chronic kidney disease	2.31	1.38 - 3.84	0.001	1.59	0.95 - 2.66	0.080
Diabetes	1.20	0.91- 1.59	0.187	1.26	1.01- 1.56	0.039
Sleep problems	4.75	3.78 – 5.97	0.000	2.74	2.01 – 3.74	0.000
Pain	1.52	1.16 – 1.99	0.003	2.57	2.21 – 2.99	0.000
Social	0.50	0.23 – 1.11	0.087	0.42	0.26 – 0.68	0.000
Entertainment	1.11	0.86 – 1.44	0.405	0.87	0.69 – 1.1	0.237

(Self-Reported Physical Activity (Any Intensity, ≥ Once/Week) -weeklypa: This variable combines information on physical activity intensity and frequency from questions about low intensity, moderate intensity , and vigorous intensity activities performed in the last week. It is considered positive if the participant reported engaging in any physical activity (including walking for at least 10 minutes) at least once a week. The creation of this variable was necessitated by overlap in participant responses regarding intensity and frequency).

Table 2: *Comparison of covariates used in logistic regression models for depression and CESD category outcomes*

prevalence) and the CES-D questionnaire (over 51.8% with symptoms).

Individuals diagnosed with depression were more likely to be younger, female, and white. Engaging in any physical activity at least once a week ("weeklyPA") emerged as a protective factor, with a significantly reduced risk of depression (OR = 0.61). Conversely, chronic health conditions, particularly chronic kidney disease (specific OR not shown), were significantly associated with an increased risk of depression. Similarly, sleep problems and pain emerged as potential risk factors based on their significant associations. Limited social life also appeared to be a risk factor.

Similar to the depression model, chronic health conditions, particularly chronic kidney disease (OR = 1.62), were linked to a higher likelihood of falling into higher CES-D categories (indicating more depressive symptoms). Sleep problems (OR = 2.72) and pain (OR = 2.54) also had significant positive associations with CES-D categories. Interestingly, unlike the depression model, sex, race, and "weeklyPA" did not show statistically significant associations with CES-D scores.

A key difference emerged between the two models regarding physical activity. Engaging in regular physical activity significantly reduced the risk of depression (OR = 0.61) but did not show a significant association with CES-D categories. This suggests a potential difference in how physical activity impacts clinical depression compared to daily fluctuations in depressive symptoms.

Additionally, we conducted a Pearson goodness-of-fit test for both models (p-value = 0.482 for the depression model, p-value = 0.296 for the CES-D model), indicating that our models adequately fit the data.

To strengthen the reliability of our findings and account for potential confounding variables, we conducted an E-value analysis (sensitivity analysis) using STATA 18. This analysis focused on key covariates from both models: those significantly associated with depression in the depression model and those significantly associated with depressive symptoms in the CES-D model (Table 2).

E-values indicate the minimum strength an unmeasured confounder would need to be associated with exposure (e.g., weekly physical activity) and depression to entirely negate the observed effect in our study (Table 3). We adjusted the E-value calculation to account for the different prevalence rates of depression (considered rare in this study) and CES-D scores (common, with a prevalence of over 51.8%).

For the association between physical activity and diagnosed depression (OR = 0.61), unmeasured confounders linked to both factors by a risk ratio of at least 2.7 could potentially negate the observed effect. However, weaker confounding associations (risk ratio < 1.8) would likely only weaken the association, not eliminate it entirely.

Overall, the E-value analysis suggests that the overall results are likely reliable. This includes the pro-

Variable	OR from logistic regression	LCL - UCL	E-Value (point estimate)	E-value (CI)
Age	1	1-1	Not performed	Not performed
Sex	0.4	0.3 – 0.5	4.4	3.4
Self-Reported physical activity (any intensity, ≥ once/week)	0.6	0.5 – 0.8	2.7	1.8
Black race	0.6	0.4 – 0.9	2.7	1.5
Brown race	0.7	0.5 – 0.9	2.2	1.5
Region, North	0.3	0.2 – 0.6	6.1	2.7
Region, Northeast	0.3	0.1 – 0.5	6.1	3.4
Region, Southeast	0.5	0.3 – 0.8	3.4	1.8
Region, Midwest	0.3	0.2 – 0.7	6.1	2.2
Chronic kidney disease	2.4	1.4 -4.1	4.2	2.1
Sleep problems	5.1	4.1 – 6.3	9.7	7.7
Pain	1.6	1.2 – 2.1	2.6	1.7

LCL - UCL: Lower Confidence Limit and Upper Confidence Limit; CI: Confidence Interval

Table 3: *Values from performed sensitivity analysis with E-Value package in STATA 18 for all the covariates with significant OR in a logistic regression model, with depression as the outcome.*

tective effect of physical activity on depression risk, and the other significant associations observed (sex, region, chronic health problems, sleep, and pain). While unmeasured factors might still influence these relationships, they must be strongly linked to exposure and depression to change our findings significantly.

The E-value analysis for the CES-D model (focusing on depressive symptoms; Table 4) focused on three specific factors: sleep problems, pain, and social life. These were the only covariates with calculated E-values, suggesting a robust association between these factors and depressive symptoms.

The E-values indicate moderate robustness for sleep problems (E-value = 2.7) and pain (E-value = 2.5). Even with strong, unmeasured confounding variables, the influence on the association with depressive symptoms is likely limited. Finally, the social life association (OR = 0.42) also suggests robustness. The negative odds ratio indicates a protective effect, meaning a strong social life appears to reduce the risk of depressive symptoms. Even with unmeasured confounding factors, these factors would likely need a very strong association with social life and depressive symptoms to eliminate this protective effect.

Since physical activity was not significantly associated with depressive symptoms in the CES-D model, we did not perform an E-value analysis for this factor in the CES-D context.

Discussion

Our study investigated the association between physical activity and depression in older adults. We found that engaging in any physical activity at least once a week was associated with a lower risk of depression diagnosed by a physician. However, the relationship between physical activity and depression appears to be more complex than previously thought.

The relationship between physical activity and depression has been explored in numerous studies, with findings that are not always consistent. Studies like Pearce et al. (2022) and Park et al. (2014) observed protective effects of physical activity against depression, aligning with our results. However, other studies have reported non-significant associations (Forsmann et al., 2011) or suggested indirect effects through cognitive function (Csajbók et al., 2022). These inconsistencies highlight the complexity of the relationship between physical activity and depression.

The original study on adolescents and the replication study on older adults are consistent with the findings of Keadle et al. (2016), which showed that adherence to physical activity guidelines varies across different populations and subgroups. Specifically, the replication study found that adults aged 65-74 are more likely to meet physical activity guidelines compared to those over 85 years old. Addition-

Variable	OR from logistic regression	LCL - UCL	E-value (point estimate)	E-value (CI)
Age	1	0.98-1.0	Not performed	Not performed
Sex	0.7	0.6 – 0.8	1.7	1.5
Partner	0.8	0.7 – 0.9	1.5	1.3
Heart Disease	1.3	1.1 – 1.7	1.5	1.3
Diabetes	1.3	1.0 - 1.6	1.5	1.0
Sleep problems	2.7	2.0 – 3.7	2.7	2.2
Pain	2.5	2.2 – 3.0	2.5	2.3
Social life	0.4	0.3 – 0.7	2.5	1.7

LCL - UCL: Lower Confidence Limit and Upper Confidence Limit; CI: Confidence Interval

Table 4: *Values from performed Sensitivity Analysis with E-Value package in STATA 18 for all the covariates with significant OR in a logistic regression model, with CESDcat as the outcome.*

ally, males were more active than females, and non-Hispanic Whites were more active than non-Hispanic Blacks and Hispanics/Latinos. These differences in adherence to physical activity guidelines observed in the replication study may be attributed to variations in age, gender, and race/ethnicity.

A key strength of our study is the large and diverse sample size, which enhances the generalizability of the findings to the broader older adult population. Additionally, using both doctor diagnoses and questionnaires provides a more comprehensive picture of depression. The study also considered other factors that might influence depression, making the link between physical activity and depression risk more credible. Finally, exploring the different effects of diagnosed depression versus symptom categories highlights the complexity of the physical and mental health connection.

However, there are also limitations to consider. The study relied on self-reported data for both physical activity and depression symptoms (CES-D scores). Self-reported measures can be susceptible to biases such as recall bias and social desirability bias. Another limitation is the cross-sectional design of the study. This design precludes establishing causal relationships between physical activity and depression. Furthermore, our analysis combined various physical activity levels into a single category ("weeklyPA"). This approach does not capture potential differences in the effects of low, moderate, and vigorous activities on depression risk.

Conclusion

Regular physical activity is associated with a reduced risk of depression in older adults. As longevity increases, prioritizing the preservation of physical abilities, autonomy, and well-being in older adults becomes increasingly critical, as these factors contribute significantly to public health and economic stability.

While this study provides preliminary evidence of an association between physical activity and depressive symptoms in older adults, further longitudinal or interventional studies are needed to establish causality, considering the influence of age, gender, race/ethnicity, and other confounding factors. Rigorous longitudinal studies employing objective physical activity measures are crucial to refine our understanding of preventing and managing depression in high-risk older adults while minimizing the influence of confounding factors.

Our study identified associations between physical activity and depression risk factors in older adults (e.g., age, sex, sleep quality, pain, chronic diseases). However, the cross-sectional design and self-reported data limit our ability to determine cause and effect. Future longitudinal studies employing objective physical activity measures could shed light on the

underlying mechanisms, such as improved physical health, social interaction, and stress reduction.

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Conflicts of Interest

The authors declare no financial or other conflicts of interest concerning the work presented in this manuscript.

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