CLINICAL SCIENCE

Acute exercise improves cognition in the depressed elderly: the effect of dual-tasks

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OBJECTIVE: The goal of this study was to assess the acute effect of physical exercise on the cognitive function of depressed elderly patients in a dual-task experiment.

INTRODUCTION: Physical exercise has a positive effect on the brain and may even act as a treatment for major depressive disorder. However, the effects of acute cardiovascular exercise on cognitive function during and after one session of aerobic training in elderly depressive patients are not known.

METHODS: Ten elderly subjects diagnosed with major depressive disorder performed neuropsychological tests during and after a moderate physical exercise session (65-75% HR_{max}). A Digit Span Test (Forward and Backward) and a Stroop Color-Word Test were used to assess cognitive function. The elderly participants walked on an electric treadmill for 30 minutes and underwent the same cognitive testing before, during, immediately after, and 15 minutes after the exercise session. In the control session, the same cognitive testing was conducted, but without exercise training.

RESULTS: The results of the Digit Span Test did not change between the control and the exercise sessions. The results of the Stroop Color-Word Test improved after physical exercise, indicating a positive effect of exercise on cognition.

CONCLUSIONS: These data suggest that the cognitive functions of depressed elderly persons, especially attention and inhibitory control, are not impaired during and after an acute session of physical exercise. In contrast, the effect of dual-tasks showed beneficial results for these subjects, mainly after exercise. The dual-task may be a safe and useful tool for assessing cognitive function.

KEYWORDS: Aerobic exercise; Major depression; Attention; Memory; Older.

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INTRODUCTION

Depression is one of the most common disorders associated with aging. Depression has a high prevalence of symptoms related to social, physical, and neurophysiological factors.[1] Cognition is a function that is altered in depression and has received increasing interest.[2] Neurophysiological changes that occur in depressive states, such as prefrontal cortex and cingulate activation, are partly responsible for reduced attention, memory, and visuospatial capacities. Depression also affects executive processing, causing difficulties in planning strategies and mental flexibility, which, in turn, lead to impaired motivational and decision-making functions.[2] Impaired cognition is thus intimately associated with the severity of disease and the impairment of daily activities during and after a depressive crisis, including during remission.

In addition to the various treatments proposed for depression, physical exercise may have beneficial effects as an add-on therapy.[3,4] However, activities that demand divided attention in daily life (e.g., walking) present an increased risk of falls and impaired cognition. Combined concurrent tasks (dual-task interventions) have been studied in subjects with neuropsychiatric disorders and in normal subjects, although few data exist on depression in the elderly. Studies have produced divergent results regarding other variables such as age and the presence of motor or neuropsychiatric disorders.[5-8]

Some hypotheses and theories attempt to explain cognitive and motor performance for the dual-task paradigm. Dietrich proposed the transient hypofrontality hypothesis,[9] which suggests that the cognitive functions associated with the frontal areas are impaired during physical exercise because the brain prioritizes motor control and the maintenance of vital functions (e.g., blood pressure and temperature control). In contrast, the bottleneck theory assumes that dual tasks are processed by the same neural networks, resulting in impaired execution of the second task.[10] Indeed, Bloem et al. noted that young adults adopt a ''posture first'' strategy, in which they automatically prioritize motor tasks rather than cognitive tasks.[11] Conversely, elderly subjects and neurological patients (Alzheimer's disease, Parkinson's disease, and stroke patients) focus on the cognitive task when performing dual-tasks, thereby increasing the risk of falls.[8]

An increasing body of data has shown that moderate physical exercise has preventive and therapeutic effects on several clinical and mental disorders,[3,12] especially mild to moderate depression.[4,13] Although much is already known about the effects of routine exercise on cognitive function, the acute effect of exercise remains to be studied in depth. Diverging results might be partly explained by factors such as the following: the time of assessment (during or after exercise); the type, intensity, and duration of the exercise; and the type of cognitive task under study.[14,15] Studies with young subjects have shown that reaction time, attention, and working memory improve after one session of aerobic exercise.[16,17] However, little is known about the effect of acute exercise in the elderly with or without psychiatric disorders. Hoffman et al. observed that routine physical exercise did not improve the cognition of depressed elderly.[18] Another study examined the effect of acute exercise on the cognition of adults with depression[19] and showed that patients improved their attention and inhibitory control immediately after an exercise session. To the best of our knowledge, however, there are no studies on combined cognitive and motor tasks in depressed elderly individuals. The present study aimed to assess cognitive performance during and after one session of physical exercise among elderly persons with major depression. We hypothesized that the most complex cognitive functions would worsen during and improve after moderate physical exercise.

MATERIALS AND METHODS

This study included a series of elderly subjects (n = 10) diagnosed according to the DSM-IV criteria[20] with major depression with mild to moderate severity who had already been participating in a exercise program for at least six months. Exclusion criteria consisted of illiteracy, any presentation of degenerative neurological dementia, history of stoke, or any limitation of gait. All patients were weighed and measured for height using a mechanic anthropometric scale (Welmy®, Brazil).

Depressive mood was assessed using the Brazilian validated version of the Hamilton Depression Scale (HAMD).[21,22] The HAMD evaluates the severity of 17 depressive symptoms with a range of zero to 49. Patients with scores from seven to 13 are considered mildly depressed, from 14 to 18 moderately depressed, from 19 to 22 severely depressed, and more than 23 very severely depressed.

Cognition was assessed by a battery of tests including the Mini Mental State Examination (MMSE), the Digit Span Test (DST)[23] and the Stroop Color-Word Test (SCW).

The MMSE Brazilian validated version assesses global cognitive functions, with scores ranging from zero to 30.[24,25] The DST assesses short-term memory, working memory, and attention. It consists of two subtests, one of which requires the patient to orally repeat a sequence of digits forward and another one that requires that the patient repeat a sequence backward. The SCW is a test of selective attention[26] in which patients are required to name the ink color in which incongruent color names are printed. The Victoria version was used because of its short administration time (the approximate time required is 5 minutes) and its sensitivity to frontal lobe disorders. The Victoria version uses three 21.5×14 cm cards presented in the following order: part D, part W, and part C. Each card has six rows of four items. Part D contains colored dots (red, green, blue, and yellow), and the task on this card is to name the colors as quickly as possible (congruence). Part W has words printed in the following colors: red, green, blue, or yellow. The examinee must name the colored ink in which each word is printed as quickly as possible. In part C, the words *red*, *green*, *blue* and *yellow* are printed in a color not denoted by the word (e.g., the word *red* is printed in green ink, etc.), and the examinee must name the colored ink in which the word is printed as quickly as possible (incongruence). For each part, time, and number of errors are considered in the score. A ratio index (C/D) of interference was used.[27,28]

Experimental Procedure

The subjects were tested on two different occasions. In the first session, all cognitive tests were conducted, followed by a 30-minute walk on an electric treadmill (BH Fitness® - Explorer Pro Action). After a 5-minute warm-up, subjects trained for 25 minutes at 65%-75% of the maximum heart rate estimated for their age (220-age).[29] The cognitive tests were conducted again at the 20th minute of the training, immediately after the completion of the training, and again 15 minutes later. One month after this first trial, the cognitive tests were conducted again using the same schedule without submitting the subjects to any physical exercise.

This project was approved by the Ethics Committee of the Institute of Psychiatry of the Federal University of Rio de Janeiro. All subjects signed informed consent forms before any procedure was undertaken.

Statistical Analysis

Descriptive data are shown as the mean and standard deviation (SD) or median and confidence intervals (CI). Shapiro-Wilk and Levene tests were used to assess the normality and the homogeneity of variances, respectively. Because the data were characteristically non-parametric, two analyses using Friedman's repeat measures were performed

Table 1 - Sociodemographic characteristics of the sample (n = 10).

	Mean (standard deviation)
Age (years)	71.5 (6.0)
Education (years)	7.4 (4.7)
Height (cm)	158.7 (8.0)
Weight (kg)	70.21 (7.8)
HAMD	14.1 (3.8)
MMSE	27.1 (2.2)

HAMD: Hamilton Depression Scale; MMSE: Mini Mental State Examination.

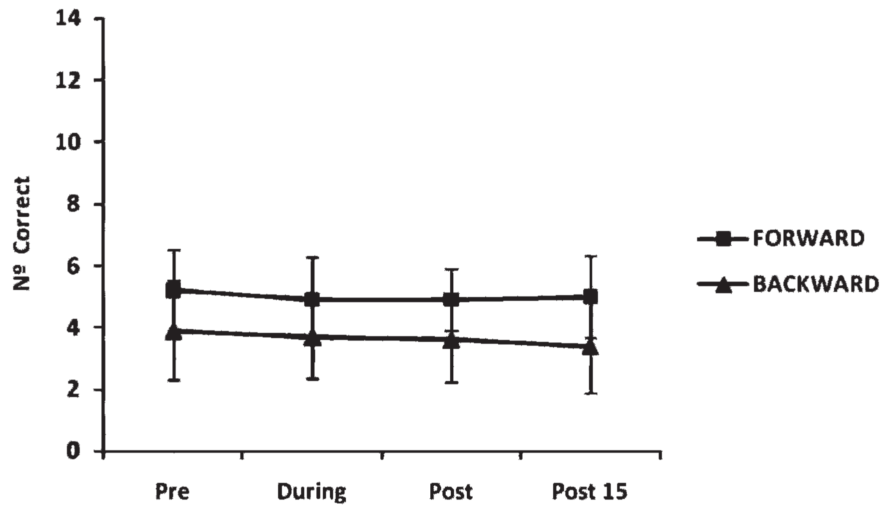

Figure 1 - Comparison of the performance in the Digit Span Test among different time points (means ± SD).

for the exercise and control sessions. This analysis compared the cognitive test results among the time points (before, during, immediately after, and 15 minutes after exercising or at the corresponding times during the control session). Statistical Package for Social Sciences (SPSS) version 15.0 was used, and the level of significance was $p<0.05$.

RESULTS

The patients had a mean age of 71.5 (6.0) years and a mean HAMD score of 14.1 (3.8). The descriptive statistics for the sample are listed in Table 1.

Exercise Session: There were no statistically significant differences among the time points with regard to the results of the DST Forward and Backward ($p=0.692$, $x^2=1.456$; $p=0.569$, $x^2=2.016$, respectively) (Figure 1). The SCW results were statistically significantly different among the time points for both the congruent and incongruent subtests ($p=0.038$, $x^2=8.400$; $p=0.011$, $x^2=11{,}160$, respectively). There was improvement in the results for the post-15 minutes time point *vs.* the before exercise time point ($p=0.009$) and for the post-15 minutes time point *vs.* the during-exercise time point ($p=0.013$) for the congruent subitem, whereas in the incongruent trial, there was improvement in the results for the immediately after time point *vs.* the before exercise time point (0.017), for the post-15 minutes time point *vs.* the before exercise time point ($p=0.005$) and for the post-15 time point *vs.* the immediately after time point ($p=0.028$) (Figure 2). Furthermore, there was a trend toward improvement for the post-15 time point *vs.* the during-exercise time point ($p=0.059$).

Control Session: There were no statistically significant differences in the DST results for the different time points (forward $p=0.069$, $x^2=7.091$; backward $p=0.857$, $x^2=0.767$). Although the congruent subitem of the SCW did not present a statistically significant difference ($p=0.062$, $x^2=7.320$), the incongruent task showed a difference among the time points ($p=0.015$, $x^2=10.440$), with improvement in the immediately after time point *vs.* the before exercise time point ($p=0.005$) and a trend toward improvement for the during exercise time point vs. the before exercise time point ($p=0.059$).

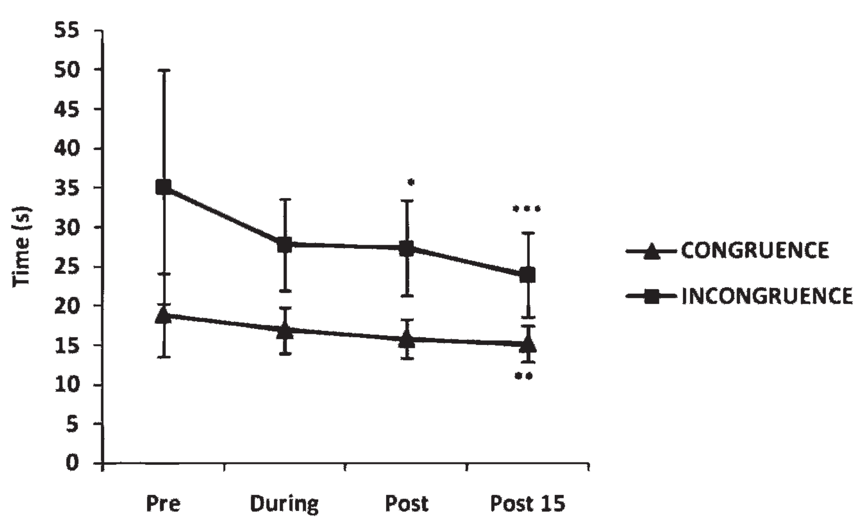

Figure 2 - Comparison of performance in the Stroop Test among different time points (means ± SD). * $p<0.05$ compared to before exercise, ** $p<0.05$ compared to before and during exercise, *** $p<0.05$ compared to before and immediately after exercise.

DISCUSSION

This study aimed to assess changes in cognitive performance in depressed elderly persons during and after a session of physical exercise. To the best of our knowledge, this is the first study to examine this issue using a dual-task paradigm (motor and cognitive stimuli). We found an improvement in attention and inhibitory control but not in working memory after a 30-minute moderately intense walk on a treadmill. These results only partially confirmed our hypothesis because we found changes only after but not during the exercise.

Our results corroborate those of other studies of depressive subjects that have found improvements in attention and inhibitory control and no change in working memory.[19] The improvements in attention and inhibitory control immediately after and 15 minutes after exercise can be associated with activated brain areas such as the anterior cingulate, which present impaired activation in depressive subjects. Moreover, exercise may promote the activation of the reticular formation that is responsible for the modulation of attention and arousal. Bartholomew et al.[30] have shown that acute exercise can improve the mood of depressed individuals in addition to yielding cognitive improvement. Studies with young and elderly healthy subjects have observed that cognitive function is immediately improved after physical exercise.[16,19] This effect appears to occur only when aerobic exercise is applied.[16] The improvement in cognition and mood after exercise in depressive and healthy subjects has been attributed to the acute release of neurotransmitters.[31] However, recent data have confirmed that acute exercise also increases the levels of neurotrophic factors, such as BDNF (Brain-Derived Neurotrophic Factor).[32] Higher levels of BDNF immediately after exercise may enhance neurogenesis, neuronal plasticity, learning abilities, memory, and mood.[33]

Dual tasks that comprise only cognitive tasks are more difficult to perform than dual tasks that include one physical task, especially for depressive subjects.[34] Cognitive performance during exercise is still a matter of debate. Some studies have shown an impaired performance in complex tasks that depend on frontal functions,[7,35] whereas other studies have shown improvement.[5,6] Contrary to our expectations, we did not observe differences in cognitive function during exercise. However, this study was conducted with physically active patients, which might explain why we observed no impairment during exercise. Because the subjects included in this study were trained and adapted to the motor tasks, the processing demand required to perform the task was reduced (Task Automatization Hypothesis), thus minimizing the detrimental effect of the dual task.

In the present study, we used a session with no exercise to control for possible responses generated by the learning effect. However, we did not observe significant changes in the test scores during this session except for the SCW incongruence subitem for the immediately after time point vs. the before exercise time point. This response may not be explained by the learning effect because the post-15 and during test results were not different. Hence, we suggest that the responses were influenced by physical exercise.

This study has some limitations that should be taken into consideration. As a preliminary report, we assessed a small number of patients. Further studies that focus on healthy controls and that use direct markers of exercise intensity such as oxygen consumption are warranted.

CONCLUSION

In conclusion, our study provides evidence that the cognitive function of depressed elderly persons is enhanced immediately after and 15 minutes following a session of physical exercise. Moreover, cognitive function is not impaired during the dual-task activity (motor and cognitive tasks). The dual task may be a safe and useful tool to assess cognitive function during and after exercise.

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REFERENCES

1. Laks J, Engelhardt E. Peculiarities of geriatric psychiatry: a focus on aging and depression. CNS Neurosci Ther. 2010;16:374-9, doi: 10.1111/j.1755-5949.2010.00196.x.
2. Davidson RJ, Lewis DA, Alloy LB, Amaral DG, Bush G, Cohen JD, et al. Neural and behavioral substrates of mood and mood regulation. Biol Psychiatry. 2002;52:478-502, doi: 10.1016/S0006-3223(02)01458-0.
3. Deslandes A, Moraes H, Ferreira C, Veiga H, Silveira H, Mouta R, et al. Exercise and mental health: many reasons to move. Neuropsychobiology. 2009;59:191-8, doi: 10.1159/000223730.
4. Deslandes AC, Moraes H, Alves H, Pompeu FAMS, Silveira H, Mouta R, et al. Effect of aerobic training on EEG alpha asymmetry and depressive symptoms in the elderly: a 1-year follow-up study. Braz J Med Biol Res. 2010;43:585-92, doi: 10.1590/S0100-879X2010007500041.
5. Pesce C, Cereatti L, Casella R, Baldari C, Capranica L. Preservation of visual attention in older expert orienteers at rest and under physical effort. J Sport Exerc Psychol. 2007;29:78-99.
6. Davranche K, Audiffren M. Facilitating effects of exercise on information processing. J Sports Sci. 2004;22:419-28, doi: 10.1080/02640410410001675289.
7. Dietrich A, Sparling PB. Endurance exercise selectively impairs prefrontal-dependent cognition. Brain Cogn. 2004;55:516-24, doi: 10.1016/j.bandc.2004.03.002.
8. Yogev-Seligmann G, Hausdorff JM, Giladi N. The role of executive function and attention in gait. Mov Disord. 2008;15;23:329-42, doi: 10.1002/mds.21720.
9. Dietrich A. Functional neuroanatomy of altered states of consciousness: the transient hypofrontality hypothesis. Conscious Cogn. 2003;12:231-56, doi: 10.1016/S1053-8100(02)00046-6.
10. Pashler H. Dual-task interference in simple tasks: data and theory. Psychol Bull. 1994;116:220-44, doi: 10.1037/0033-2909.116.2.220.
11. Bloem BR, Valkenburg VV, Slabbekoorn M, Willemsen MD. The Multiple Tasks Test: development and normal strategies. Gait Posture. 2001;14:191-202, doi: 10.1016/S0966-6362(01)00141-2.
12. Wichi RB, Angelis K, Jones L, Irigoyen MC. A brief review of chronic exercise intervention to prevent autonomic nervous system changes during the aging process. Clinics. 2009;64:253-8, doi: 10.1590/S1807-59322009000300017.
13. Silveira H, Deslandes AC, Moraes H, Mouta R, Ribeiro P, Piedade R, et al. Effects of exercise on electroencephalographic mean frequency in depressed elderly subjects. Neuropsychobiology. 2010;61:141-7, doi: 10.1159/000279304.
14. Brisswalter J, Collardeau M, René A. Effects of acute physical exercise characteristics on cognitive performance. Sports Med. 2002;32:555-66, doi: 10.2165/00007256-200232090-00002.
15. Tomporowski PD. Effects of acute bouts of exercise on cognition. Acta Psychol (Amst). 2003;112:297-324, doi: 10.1016/S0001-6918(02)00134-8.
16. Pontifex MB, Hillman CH, Fernhall B, Thompson KM, Valentini TA. The effect of acute aerobic and resistance exercise on working memory. Med Sci Sports Exerc. 2009;41:927-34, doi: 10.1249/MSS.0b013e3181907d69.
17. Pesce C, Capranica L, Tessitore A, Figura F. Focusing of visual attention under submaximal physical load. Int J Sport Exerc Psychology. 2003;1:275-92.
18. Hoffman BM, Blumenthal JA, Babyak MA, Smith PJ, Rogers SD, Doraiswamy PM, et al. Exercise fails to improve neurocognition in depressed middle-aged and older adults. Med Sci Sports Exerc. 2008;40:1344-52, doi: 10.1249/MSS.0b013e31816b877c.
19. Kubesch S, Bretschneider V, Freudenmann R, Weidenhammer N, Lehmann M, Spitzer M, et al. Aerobic endurance exercise improves executive functions in depressed patients. J Clin Psychiatry. 2003;64:1005-12, doi: 10.4088/JCP.v64n0905.

20. American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders,ed 4. Washington;American Psychiatric Association, 1994.
21. Hamilton M. Rating scale for depression. J Neurol Neurosurg Psychiatry. 1960;23:56-62, doi: 10.1136/jnnp.23.1.56.
22. Moreno RA, Moreno DH. Escalas de depressão de Montgomery & Asberg (MADRS) e de Hamilton (HAM-D). Revista de Psiquiatria Clínica. 1998;25:1-17.
23. Wechsler D. Wechsler Memorv Scale-Revised. New York: Psychological Corporation. 1987;1-150
24. Folstein MF, Folstein SE, McHugh PR. ''Mini-mental state''. A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res. 1975;12:189-98.
25. Brucki SM, Nitrini R, Caramelli P, Bertolucci PH, Okamoto IH. Suggestions for utilization of the mini-mental state examination in Brazil. Arq Neuropsiquiatr. 2003;61:777-81, doi: 10.1590/S0004-282X2003000500014.
26. Stroop JR. Studies of interference in serial verbal reactions. J Exp Psychol. 1935;18:643-62, doi: 10.1037/h0054651.
27. Spreen O., Strauss E.A. Compendium of Neuropsychological Tests. 3rd ed. New York; Administration, Norms, and Commentary; 1998.
28. Silberman CD, Laks J, Capitão CF, Rodrigues CS, Moreira I, Vasconcellos LFR, et al. Frontal functions in depressed and nondepressed Parkinson's disease patients: impact of severity stages. Psychiatry Res. 2007;149:285-89, doi: 10.1016/j.psychres.2006.04.020.
29. Karvonen MJ, Kentala E, Mustala O. The effects of training on heart rate: A longitudinal study. Ann Med Exp Biol Fenn. 1957;35:307-15.
30. Bartholomew JB, Morrison D, Ciccolo JT. Effects of Acute Exercise on Mood and Well-Being in Patients with Major depressive disorder. Med Sci Sports Exerc. 2005;37:2032-7, doi: 10.1249/01.mss.0000178101.78322.dd.
31. Boecker H, Henriksen G, Sprenger T, Miederer I, Willoch F, Valet M, et al. Positron emission tomography ligand activation studies in the sports sciences: measuring neurochemistry in vivo. Methods. 2008;45:307-18, doi: 10.1016/j.ymeth.2008.07.003.
32. Gustafsson G, Lira CM, Johansson J, Wisén A, Wohlfart B, Ekman R, et al. The acute response of plasma brain-derived neurotrophic factor as a result of exercise in major depressive disorder. Psychiatry Res. 2009;169:244-8, doi: 10.1016/j.psychres.2008.06.030.
33. Cotman CW, Berchtold NC, Christie LA. Exercise builds brain health: key roles of growth factor cascades and inflammation. Trends Neurosci. 2007;30:464-72, doi: 10.1016/j.tins.2007.06.011.
34. Nebes RD, Butters MA, Houck PR, Zmuda MD, Aizenstein H, Pollock BG, et al. Dual-task performance in depressed geriatric patients. Psychiatry Res. 2001;102:139-51, doi: 10.1016/S0165-1781(01)00244-X.
35. Davranche K, McMorris T. Specific effects of acute moderate exercise on cognitive control. Brain Cogn. 2009;69:565-70, doi: 10.1016/j.bandc.2008.12.001.