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ORIGINAL ARTICLE

Acute effect of vigorous aerobic exercise on the inhibitory control in adolescents

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Abstract
Objective: To assess the acute effect of vigorous aerobic exercise on the inhibitory control in adolescents.
Methods: Controlled, randomized study with crossover design. Twenty pubertal individuals underwent two 30-minute sessions: (1) aerobic exercise session performed between 65% and 75% of heart rate reserve, divided into 5 min of warm-up, 20 min at the target intensity and 5 min of cool down; and (2) control session watching a cartoon. Before and after the sessions, the computerized Stroop test–Testinpacs™ was applied to evaluate the inhibitory control. Reaction time (ms) and errors (*n*) were recorded.
Results: The control session reaction time showed no significant difference. On the other hand, the reaction time of the exercise session decreased after the intervention ($p<0.001$). The number of errors made at the exercise session were lower than in the control session ($p=0.011$). Additionally, there was a positive association between reaction time (Δ) of the exercise session and age ($r^2=0.404$, $p=0.003$).
Conclusions: Vigorous aerobic exercise seems to promote acute improvement in the inhibitory control in adolescents. The effect of exercise on the inhibitory control performance was associated with age, showing that it was reduced at older age ranges.

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Efeito agudo do exercício aeróbio vigoroso sobre o controle inibitório em adolescentes

Resumo

Objetivo: Verificar o efeito agudo do exercício aeróbio vigoroso sobre o controle inibitório em adolescentes.

Métodos: Estudo controlado e randomizado com delineamento cruzado. Vinte púberes foram submetidos a duas sessões de 30 minutos: 1) sessão exercício aeróbio feito entre 65–75% da frequência cardíaca de reserva, com cinco minutos para aquecimento, 20 minutos na intensidade alvo e cinco minutos de volta à calma; e 2) sessão controle assistindo a desenho animado. Previamente e após as sessões, o teste de Stroop computadorizado (Testinpacs®) foi aplicado para avaliar o controle inibitório. O tempo de reação (ms) e os erros cometidos (*n*) foram registrados.

Resultados: O tempo de reação da sessão controle não apresentou diferença significativa. Por outro lado, o tempo de reação da sessão exercício diminuiu após a intervenção ($p<0,001$). Os erros cometidos na sessão exercício foram menores do que na sessão controle ($p=0,011$). Adicionalmente, houve associação positiva do tempo de reação (Δ) da sessão exercício com a idade ($r^2=0,404$; $p=0,003$).

Conclusões: O exercício aeróbio vigoroso parece promover melhoria aguda no controle inibitório em adolescentes. O efeito do exercício sobre o desempenho do controle inibitório foi associado à idade e demonstrou ser reduzido em faixas etárias mais altas.

Introduction

Executive control (or executive functions) refers to higher cognitive processes that manage the control of other, more basic cognitive functions and direct the ideal behavior to achieve goal-oriented behaviors.[1] In general, executive control is subdivided into inhibitory control (IC), working memory and cognitive flexibility.[1] The IC is considered the main domain of executive control and a determinant of academic success, as it controls attention, behavior, thought and/or emotion to override a strong internal predisposition or external attraction and adapt itself to conflicting situations.[1]

School activities constitute a model of environmental request regarding the autonomy and control of attentional, organization and planning functions, which requires an efficient performance of the IC.[2] Evidence suggests that the development of IC skills during childhood promotes an increased capacity for success in the development of the theory of mind – facilitates thinking and learning[3] – as well as a better performance in counterfactual[4] reasoning and strategic[5] tasks. The IC also has been strongly associated with intelligence level[6] and school performance.[7]

Both frontal regions, cortical and subcortical, subserve the executive control.[8] The prefrontal cortex (PFC) is the one that plays a key role.[8] Increased brain activity of the PFC was observed during the task making of the IC (Stroop Test).[9] The PFC comprises from a quarter to a third of the cerebral cortex and contains rich reciprocal connections with itself, with other cortical areas and subcortical and limbic regions.[10] The performance of executive control develops from early childhood, throughout adolescence, to adulthood,[11] concurrently with the neuroanatomical, functional[12] and brain blood perfusion[13] changes, including the PFC regions.

Physical exercise has been considered an important environmental factor for neurodevelopment,[14] to promote cognitive and brain health,[15] as well as for a better performance of the executive and school control.[7] A single session of aerobic exercises has been shown to improve the efficiency of the IC in children[16] and young adults,[17–19] in contrast to what was observed in adolescents after 20 min of aerobic exercise performed on a cycle ergometer at 60% of maximum heart rate (HR_{max}).[20] Cognitive performance after acute exercise seems to be dependent on the intensity.[21] In the meta-analysis of Chang et al.,[21] the studies that used low intensity, <50% of HR_{max}, had a negative effect on cognitive performance. On the other hand, in studies with intensities >64% of HR_{max}, the effects were positive.

A possible physiological hypothesis that may explain the acute effect of exercise intensity on the IC is increased cerebral blood flow generated by exercise effort, which can have an impact on post-exercise cognitive performance.[17–19] In the study by Yanagisawa et al.,[19] there was an increase in cerebral blood flow (↑ oxygenated hemoglobin) in the PFC and improved performance in the Stroop test in young adults after 10 min of aerobic exercise at 50% of the peak oxygen consumption (peak VO_2). The same effect was observed in similar experiments carried out with young adults after 20 min of exercise between 60% and 70% of HR_{max}[18] and after 15 min of exercise at 40% of maximum load, respectively,[17] and in children after 20 min of aerobic exercise between 65% and 75% of HR_{max}.[16]

However, there is still a gap of knowledge whether a vigorous aerobic exercise session can improve the IC in adolescents, which may be important, as their PFC is still undergoing the maturation phase. It is a period of structural, functional[12] and blood perfusion[13] changes. The study hypothesis is that the use of a prescription of aerobic exercise with control of the intensity, volume and other