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Case report

Improving cerebral oxygenation, cognition and autonomic nervous system control of a chronic alcohol abuser through a three-month running program

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ABSTRACT

The abusive use of alcohol has shown to be associated to cerebral damage, impaired cognition, poor autonomic nervous control, impaired cardiovascular health, increased levels of stress and anxiety, depression symptoms and poor quality of life. Aerobic exercise has shown to be an efficient tool to reduce and overcome these issues. In this case report, a patient (forty-four years old, male) under treatment in public psychiatric hospital, classified as having a substance use disorder, underwent a three-month running program. The maximal oxygen consumption increased from 24.2 ml/kg/min to 30.1 ml/kg/min, running time increased from 6 min to 45 min (650%) and distance covered from 765 m to 8700 m (1037.2%). In prefrontal cortex oxygenation, oxyhemoglobin levels improved by 76.1%, deoxyhemoglobin decreased 96.9% and total hemoglobin increased 78.8% during exercise. Reaction time in the cognitive test during rest decreased 23%, and the number of correct answers increased by 266.6%. Parasympathetic cardiac parameters increased in several heart rate variability indices. Thus, we conclude that running exercise performed by an alcoholic patient hospitalized in a psychiatric hospital improves cerebral function, cognition and cardiovascular health.

1. Introduction

According to the fifth edition of the Statistical Manual of Mental Illness (American Psychiatric Association, 2013), disorders related to alcohol abuse are defined as a set of psychosocial problems that occur repeatedly due to chronic use of a substance. In this integrative approach, the severity of the disorder varies according to the number of criteria that the subject fits, and may be classified as mild, moderate or severe. Currently, excessive consumption of alcohol is a serious public health problem worldwide with approximately 3.3 million deaths per year (Alcohol Facts and Statistics | National Institute on Alcohol Abuse and Alcoholism (NIAAA), n.d.). Moreover, it has been widely shown to causes liver diseases and cancer (Alcohol Consumption | Cancer Trends Progress Report, n.d.). In the brain, deterioration of prosencephalic regions caused by alcohol abuse has been reported (Asensio et al., 2016; Pahng, McGinn, Paulsen, & Edwards, 2017), with decreased oxygenation (Schecklmann et al., 2007) and reductions of gray matter volume in the anterior cingulate and in the medial, orbitofrontal and prefrontal cortices (Wang et al., 2016). Impairment in these structures has been accompanied by decreases in cognition (Volkow, Koob, & McLellan, 2016) with lower control of impulsivity and emotional regulation, leading to inappropriate decision-making with further alcohol seeking behavior (Goldstein & Volkow, 2011). Also, consuming alcohol can lead to withdrawal in vagal control of the sinoatrial node, increasing the sympathetic nervous system in the organism (Reed, Porges, & Newlin, 1999), and thus increasing the risk of cardiovascular and cerebrovascular events (Melillo et al., 2015; Süfke, Fiedler, Djonlagiç, & Kibbel, 2009). In addition, abusive alcohol ingestion can cause several psychological and social problems, such as anxiety, depression, antisocial and suicidal behaviors (Blanco-Gandía et al., 2015), as well as aggressiveness (Beck & Heinz, 2013). Pharmacotherapy has been indicated as the main option for treating these patients; however, there are inconsistencies in this practice (Thompson, Owens, Pushpakom, Faizal, & Pirmohamed, 2015), including side effects such as gastrointestinal distress, dizziness, drowsiness, altered libido, peripheral neuropathy and addiction (Connor, Haber, & Hall, 2016). Therefore, it is necessary to elaborate alternative strategies which are effective in rehabilitating and treating this multifactorial disorder, especially in public psychiatric hospitals in low income countries that have limited space and limited financial resources to treat a wide range of mental illnesses.

The practice of regular physical activity has been widely

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demonstrated as an effective tool for treating several physiological disorders (Galioto, Fedor, & Gunstad, 2015; Jeng, Chang, Liu, Hou, & Lin, 2016; O'Brien, Tynan, Nixon, & Glazier, 2016; Stephen, Hongisto, Solomon, & Lönnroos, 2017; Wilson, 2017). It has also been shown to improve self-esteem, well-being, emotions and mood (Bahrke & Morgan, 1978; Driver & Taylor, 2000). Physical activity has also been shown to benefit the autonomic nervous system (ANS) (Fu & Levine, 2013), cognitive functions (Hillman, Erickson, & Kramer, 2008), in addition to promote neuroplasticity and improve efficiency of some cerebral structures (Burzynska et al., 2016; Chaddock et al., 2010; Davis et al., 2011; Dishman et al., 2006). Furthermore, studies have shown that aerobic exercise performed by healthy individuals acutely increases prefrontal cortex (PFC) oxygenation (Bediz et al., 2016; Chang et al., 2013; G. Tempest & Parfitt, 2016), however, it is unclear if individuals with an impaired PFC, such as in alcoholics, will have similar benefits. As a matter of fact, some studies have suggested physical exercise as treatment and rehabilitation of alcoholics (Georgakouli et al., 2017; Jamurtas et al., 2014; Manthou et al., 2016), but not using a neurobiological marker such as brain oxygenation. Moreover, the long-term effects of exercise on cerebral hemodynamics, either in healthy or pathological individuals, remain unclear. Thus, in the present study a male alcohol abuser admitted to a public psychiatric hospital completed a three-month running program and we measured its effects on running performance, cerebral oxygenation, cognition, ANS control and psychosocial parameters.

2. Methods

2.1. Subject

The subject is a forty-six years old public psychiatric hospital male patient, who has been alcohol and cigarette dependent for about thirty-three years, and has been hospitalized for twenty-two years. The subject was classified as having a substance use disorder (SUD) according to criteria in the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2013). Moreover, the patient was given 10 mg/day of Diazepam. Also, the Alcohol, Smoking and Substance Involvement Screening Test (ASSIST) was used to investigate the patient's preferred drug. In this questionnaire, the subject scored thirty-four points for alcohol, which means severe need for treatment intervention. It is worth mentioning that the evaluated person was allowed to go out of the hospital every weekend, so he could access alcoholic beverages. Additionally, he smoked cigarettes every day in the hospital. Besides alcohol and cigarettes, the individual had no other addictive behaviors. The study followed the guidelines of the Helsinki Declaration and it was properly accepted by the Federal University of Rio Grande do Norte local ethics committee (number: 51836215.3.0000.5537). The patient signed the informed consent term before the start of the first evaluation.

2.2. Experimental design

After the physician approved participation of the patient in this running program, he underwent an initial screening to evaluate his physical conditions to exercise. Blood pressure and questionnaires for physical activity readiness and the mini mental status exam were applied, as well as resting heart rate variability (HRV) recordings. Then, the patient performed an incremental cycling test with continuous measures of cardiorespiratory (heart rate and oxygen uptake) and PFC oxygenation. Moreover, the subject performed a cognitive test (short version of the Stroop test) every 2 min in this incremental test which rated his perceived exertion. This testing protocol was done before the running program (pre), after the 18th session (forty-five days) and after the 36th session (ninety days).

2.3. Running program

The proposed training program consisted of three weekly sessions in a space provided by the public psychiatric hospital. In the first training session, the subject was instructed to run between 3 and 6 min and the distance was recorded. In the next session, the task was to repeat the distance from the previous running and the duration was recorded. Finally, on the third day of training of the week, the subject ran the distance of the previous training in the shortest possible time. Lastly, with the week completed, the running time was increased between 3 and 5 min to start a new week. This progression procedure was applied throughout the running program. Furthermore, the training intensity was controlled by self-selected running method. It was chosen to use this method to prioritize a psychobiological perspective with higher involvement of the brain in regulating the patient's physical activity, and to develop the subject's autonomy to continue practicing running after the proposed program. Moreover, affect and perceived exertion scales were used. These scales were presented in every training session for self-monitoring. Internal conversations such as: "I can't do anymore", "I'm going to give up", "it's very difficult" were also used to discuss the emotions that arise during physical exercise and how to tolerate them to stay active (Hardy, Hall, & Alexander, 2001; St Clair Gibson et al., 2006). Always respecting biological individuality, the program seeked to allow the individual to achieve between 40 and 50 min of continuous running at the end of the program. The protocol lasted for about 1 h. The running time was increased along the weeks.

2.4. Incremental protocol test

As a form of physical and cognitive evaluation, we performed a maximal incremental test on a cycle ergometer with the subject completing the Stroop test at every exercise intensity. Initially, the patient was familiarized with the cycle ergometer and with the Stroop Test. Then, he rested for 6 min followed by baseline physiological and cognitive measurements. The cycling test started with an intensity of 25 watts (W) and had 25 W increases every 2 min. The subject performed the incremental protocol until exhaustion.

2.5. Ergospirometry

Ergospirometry was performed during the incremental maximal exercise test performed on a bicycle ergometer (model CG04, Inbrasport, Porto Alegre, Brazil). The initial intensity was 25 W with increments of 25 W every 2 min, and cadence was maintained between 60 and 70 r/min. Minute ventilation (VE), oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured by a metabolic analyzer (Metalyzer® 3B). Threshold determination and maximal oxygen consumption (VO_2max) was performed using software (Ergo PC Elite®) supplied by the manufacturer. Ventilatory threshold (VT) was determined by the equivalent method when the VE/VO_2 ratio presented its minimum value before presenting progressive increases. Respiration compensation point (RCP) was performed by the V-slope (Dafoe, 2007). The equipment for gas exchange analysis was calibrated prior to each analysis. Calibration was performed with ambient gas samples (20.9% O_2 and 0.04% CO_2) and samples obtained from a cylinder with a known concentration of O_2 (17%) and CO_2 (5%). In addition, the gas flow of the apparatus was calibrated using a three-liter syringe. All procedures were performed according to the manufacturer's standardization.

2.6. Stroop test

The test was applied through the Testinpacs® software, for which the volunteer had to make choices on a set of tasks (arrows: right and left) as fast as possible. The tests were viewed on a computer screen 90 cm away and in front of the patient during the exercise. The answers were given through two buttons attached on the bike handlebar. The