Journal of Affective Disorders 224 (2017) 76–86

Contents lists available at ScienceDirect

Journal of Affective Disorders

journal homepage: www.elsevier.com/locate/jad

Review article

Sugars, exercise and health

Roberto Codella[a,b], Ileana Terruzzi[c], Livio Luzi[a,b,*]

[a] Department of Biomedical Sciences for Health, Università degli Studi di Milano, Milan, Italy
[b] Metabolism Research Center, IRCCS Policlinico San Donato, San Donato Milanese, Italy
[c] Diabetes Research Institute, Metabolism, Nutrigenomics and Cellular Differentiation Unit, San Raffaele Scientific Institute, Milan, Italy

ARTICLE INFO

Keywords:
Sugar addiction
Exercise therapy
Binge/addictive eating behaviors

ABSTRACT

Background: There is a direct link between a variety of addictions and mood states to which exercise could be relieving. Sugar addiction has been recently counted as another binge/compulsive/addictive eating behavior, differently induced, leading to a high-significant health problem. Regularly exercising at moderate intensity has been shown to efficiently and positively impact upon physiological imbalances caused by several morbid conditions, including affective disorders. Even in a wider set of physchiatric diseases, physical exercise has been prescribed as a complementary therapeutic strategy.
Method: A comprehensive literature search was carried out in the Cochrane Library and MEDLINE databases (search terms: sugar addiction, food craving, exercise therapy, training, physical fitness, physical activity, rehabilitation and aerobic).
Results: Seeking high-sugar diets, also in a reward- or craving-addiction fashion, can generate drastic metabolic derangements, often interpolated with affective disorders, for which exercise may represent a valuable, universal, non-pharmachological barrier.
Limitations: More research in humans is needed to confirm potential exercise-mechanisms that may break the bond between sugar over-consumption and affective disorders.
Conclusions: The purpose of this review is to address the importance of physical exercise in reversing the gloomy scenario of unhealthy diets and sedentary lifestyles in our modern society.

1. Introduction

Highly processed foods may be associated with “food addiction”, and therefore considered “addictive”, as they share common features with drugs of abuse (Schulte et al., 2015). In fact, due to the high concentrated doses and the rapid rate by which refined carbohydrates are absorbed into the system, highly processed foods, rich in sugar content, are implicated in addictive-like eating behavior (Henningfield and Keenan, 1993; Monteiro et al., 2010). A growing body of neurochemical and genetic evidence suggests that food addiction is similar to psychoactive drug addiction (Ahmed et al., 2013; Salamone and Correa, 2013). Some recent experimental research in laboratory rats has revealed that sugar and sweet reward can be even more addictive than traditional substances of dependence and abuse, like cocaine (Lenoir et al., 2007; Volkow et al., 2013). Rats allowed to choose between cocaine and sweet fluids (sucrose or saccharine solutions) in discrete trials procedures have a strong preference for the non-drug reinforcer (Cantin et al., 2010; Kendig, 2014). In addition, food has both homeostatic and hedonic components, therefore emerging as a potent, natural, conditioning stimulus to the brain's reward pathways (Rada et al., 2010; Volkow et al., 2011). However, there is a wide spectrum of overeating, ranging from casual over-indulgences to pathological drives to consume palatable food. Either way, the resulting addictive appetite behavior (up to bingeing) might be coupled to the contemporary obesity pandemic, with obesity being reinforced by this surge of palatable reward (Hone-Blanchet and Fecteau, 2014).

On a side, high glycemic food is coupled with postprandial

Abbreviations: Akt, protein kinase B; ACC, anterior cingulate cortex; ADHA, attention-deficit hyperactivity disorder; BED, binge eating disorder; BDNF, brain-derived neurotrophic factors; CREB, cAMP response element-binding protein; Ca^{2+}MK, Ca^{2+}calmodulin-dependent protein kinases; CVD, cardiovascular diseases; DA, dopamine; DD2R, dopamine receptors; DSM, diagnostic and statistical manual of mental disorders; ERK, extracellular signal–regulated kinase; fMRI, functional magnetic resonance; FNDC5, fibronectin type III domain containing 5; HbA1c, glycosylated hemoglobin; NCDs, noncommunicable diseases; PET, positron emission topography; PGC-1α, peroxisome proliferator receptor γ coactivator 1α; PI3-kinase, phosphoinositide 3-kinase; POMS, profile of mood states; RCT, randomized controlled trial; OFC, orbitofrontal cortex; SSRI, selective serotonin reuptake inhibitors; SUD, substance use disorder; TrkB, tropomyosin-related kinase B; YFSA, Yale Food Scale Addiction

* Correspondence to: Department of Biomedical Sciences for Health, IRCCS Policlinico San Donato Milanese, Università degli Studi di Milano, Piazza Edmondo Malan 1, 20097 San Donato Milanese, Milano, Italy.
E-mail address: livio.luzi@unimi.it (L. Luzi).

http://dx.doi.org/10.1016/j.jad.2016.10.035
Received 14 July 2016; Received in revised form 19 October 2016; Accepted 23 October 2016
Available online 27 October 2016
0165-0327/

hyperglycemia and hyperinsulinemia which, in turn, could trigger hunger and ultimately result in weight gain (Benedini et al., 2011). Despite multiple studies have questioned whether sugar is the unique cause of diabetes (not specifically addressed in any randomized-controlled-trial) or obesity (putatively resulting from high sucrose-, high-fructose corn syrup-, sweetened beverages consumption), most of them have failed in ratifying a sole linkage (Rippe and Angelopoulos, 2016). It is rather likely that the primary pathological event is excess energy intake leading to overweight, obesity, and type 2 diabetes. Neither sugar consumption per se, nor a single nutrient would uniquely cause these morbid conditions (Hall et al., 2012). Once adjustments for total energy intake are made, in fact, typically many published studies have shown no relation between sugar consumption and body weight. In meta-analyses of randomized controlled trials, when sugar is replaced with energy-equivalent macronutrients, no increase in body weight occurs (Kaiser et al., 2013; Malik et al., 2013; Te Morenga et al., 2013). Simply, especially in modern westernized countries, large availability (ubiquity, affordability) of any sort of palatable food becomes more and more responsible for the dramatically increasing rate of obesity. According to animal evidence, the sugar-bingeing model mimics addiction-like phenotype but does not necessarily induce obesity (Avena, 2007; Colantuoni et al., 2002; Rada et al., 2005; Wideman et al., 2005). In this model, there is still presence of tolerance, withdrawal, cross-sensitization and neurochemical modulation (Hone-Blanchet and Fecteau, 2014). Both food and drug rewards foresee the activation of the dopamine-systems.

On the other extreme of the overeating continuum, in the *Reward Deficiency Syndrome*, genetic and epigenetic phenomena lead to impairment of the brain reward circuitry that causes hypo-dopaminergic function and abnormal craving behavior (Blum et al., 2014). Dopamine (DA), a powerful neurotransmitter, controls feeling of well-being ant it is activated by a variety of conditions like over-consumption of carbohydrates and alcohol, intake of crack cocaine, cocaine, opioids, abuse of nicotine, aggressive behaviors, sexual arousal. So too does physical exercise, especially sustained endurance exercise.

Animal studies (Colantuoni et al., 2002; Cottone et al., 2009; Hernandez and Hoebel, 1988) and fMRI in humans (Wang et al., 2001) support the hypothesis that similar brain circuits are disrupted in obesity and drug dependence, implicating a specific DA-modulation of reward circuits in pathological eating behaviors (Murray et al., 2014).

Compulsive overeating and binge eating disorders are treated with pharmachological (e.g. antidepressant, topiramate) and behavioral strategies, providing variable results. One approach is to increase the amount of physical activity.

In the last decades much evidence has been accumulated documenting the many health benefits of physical activity: regular exercise offers protection against all-cause mortality, primarily by lowering the atherogenic profiles (Blair et al., 2001), reduces rates of CVD, hypertension, metabolic syndrome, type 2 diabetes, breast cancer and colon cancer. Furthermore, physical training has been proved to be effective in the treatment of several of these diseases, including ischemic heart diseases (Jolliffe et al., 2000) and heart failure (Piepoli et al., 2011).

Beyond its frank anti-inflammatory effects (Codella et al., 2015), exercise has been extensively debated as a natural anti-depressant. The psychological benefits of long-term exercise adherence in both clinical and community individuals are well established (Berger and Motl, 2008; Martinsen, 1994; Weyerer and Kupfer, 1994). Exercise can increase resistance to the development of depression and other stress-related psychiatric disorders, such as anxiety and stress itself (Greenwood and Fleshner, 2011). Central reward circuitry, including neurotrasmitters and neurotrophic factors, are implicated in the pathophysiology and treatment of stress-related disorders (Nestler and Carlezon, 2006). Even though there is limited knowledge on the effects of physical activity as a treatment of psychological stress-related symptoms, multiple physiological and neuroendocrine mechanisms have been theorized (Greenwood and Fleshner, 2011; Trost and Hauber, 2014). Exercise was found to be a naturally reinforcing and rewarding activity (Trost and Hauber, 2014).

Here, we want to review how physical exercise might exert a number of health benefits that can promote positive well-being, particularly by neuromodulation, so to counter many of the negative addictive behaviors, specifically over-consumption of refined carbohydrates.

2. Methods

A systematic literature search was carried out in the Cochrane Library and MEDLINE databases for studies published in English (1996 January to 2016 June) combining the terms “sugar addiction”, “food craving”, “exercise therapy”, “training”, “physical fitness”, “physical activity”, “rehabilitation and aerobic”. We examined reference lists in original articles and reviews. Study search was performed both electronically and by following up references quoted in relevant paper. We have primarily identified systematic reviews and meta-analyses and thereafter selected additional controlled trials. Case reports, expert opinions, article unavailable in English were excluded.

3. Results

3.1. Study selection

The initial electronic database search yielded 1.284 hits. Three additional studies were found from other sources. Following first screening, 788 studies were excluded: 311 were duplicated; 473 focused on other subjects; 4 case-reports.

Thereafter, 499 remaining studies were further examined for final consideration: 2 studies were removed because unavailable in English and 2 studies were not located. Finally, 495 studies were selected (Fig. 1). A synoptic table of the studies analyzed is offered (Table 1).

3.2. Added-sugars food consumption and addictive-like eating behaviours

3.2.1. Sugar consumption

World Health Organization (WHO) defines overweight and obesity as abnormal or excessive fat accumulation that may impair health (WHO | Obesity and overweight, 2016). Diverse causes may contribute to the obesity pandemic: energy over-intake, easy availability to hyper-palatable foods, physical inactivity amongst others. In the past, sugars and refined carbohydrates were proposed, with modest evidence, as more obesogenic than other nutrients (Yudkin, 1971), however it

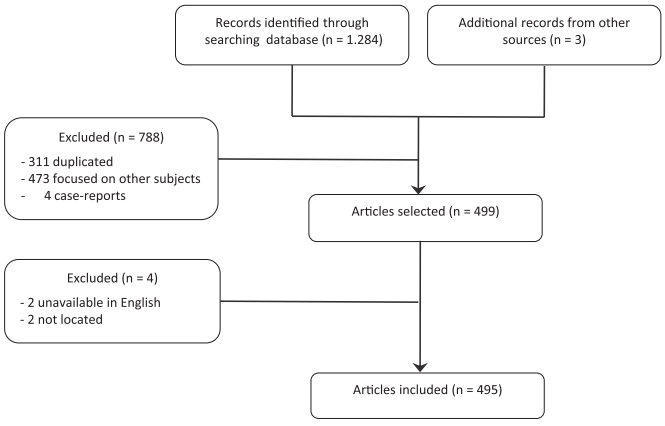

Fig. 1. Flow diagram for progressive identification and selection of studies.