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Dietary seaweeds and obesity

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Abstract

Potential therapeutic benefits of seaweed consumption have been reported in the management of body weight and obesity. *In vitro* and *in vivo* animal studies provide the majority of data available at present. The majority of studies assessing the short-term effects of alginate consumption indicate that alginate may increase satiety, reduce energy intake and support weight reduction. Mechanisms suggested for these effects include delayed gastric clearance, stimulation of gastric stretch receptors and attenuated nutrient absorption. Long-term studies in humans are required in order to allow firm conclusions. Animal studies have investigated potential anti-obesity effects of seaweeds on adipogenesis and the inhibition of major lipid hydrolyzing and metabolizing enzymes. The results of these studies suggest beneficial effects of seaweed components such as fucoxanthin on body weight and the percentage of abdominal white adipose tissue. It is premature to extrapolate these findings to humans since consistent findings are still lacking. There is at present no solid evidence indicating that seaweeds are effective in long-term weight management. However, available findings suggest potential benefits of seaweed components on obesity. Future investigations are required to establish the therapeutic efficacy in the management of overweight and obesity in humans and elucidate the underlying mechanisms of actions.

Keywords: Seaweed; Fucoxanthin; Functional food; Body weight; Obesity

1. Introduction

Obesity is a metabolic disorder and can be defined as increased body weight caused by excessive fat accumulation which presents a risk to health with an increase in health problems and/or reduced life expectancy [1,2]. Obesity is characterized by an increased storage of triglycerides in adipose tissues. In obese individuals, there is an increase in the incidence of various diseases such as cardiovascular disease, type 2 diabetes, certain types of cancer, and osteoarthritis [1]. Obesity has reached epidemic proportions in developed countries and is also increasing in developing countries [3]. The epidemic is a leading preventable cause of death worldwide and has been suggested to be one of the most serious public health problems of the 21st century [4]. In 2008, 35% of adults aged 20 or more were overweight (body mass index $\geq$25 kg/m^2) [5]. The worldwide prevalence of obesity has nearly doubled between 1980 and 2008. In 2008, 10% of men and 14% of women in the world were obese (BMI $\geq$30 kg/m^2), compared with 5% for men and 8% for women in 1980 [5]. An estimated total of more than half a billion adults over the age of 20 were obese. The prevalence of obesity was highest in the WHO Regions of the Americas (26% in both sexes) and lowest in the WHO Region for South East Asia (3% in both sexes) [5]. Worldwide, at least 2.8 million people die each year as a result of being overweight or obese, and an estimated 35.8 million (2.3%) of global disability-adjusted life years are caused by overweight or obesity [5].

Obesity is most commonly caused by a combination of excessive food energy intake, lack of physical activity, and genetic susceptibility. The epidemic reflects progressive secular and age-related decreases in physical activity, together with substantial dietary changes with passive over-consumption of energy despite the neurobiological processes controlling food intake [1]. The main treatments for obesity are dieting and exercising.

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Effective long-term weight loss depends on permanent changes in dietary quality, energy intake, and physical activity [1]. Diet quality can be improved by reducing the consumption of energy-dense foods and by increasing the intake of dietary fiber. However, behavioral interventions alone have been inconsistent in promoting sufficient and sustained weight loss. The identification of substances that are able to decrease or even prevent obesity has become a major goal of research. Consequently, pharmacological research has focused on the development of anti-obesity medications which may reduce appetite or decrease fat absorption [6]. Due to high costs and potentially hazardous adverse effects of these drugs, researchers have become interested in finding safe and therapeutically effective anti-obesity compounds derived from natural products [7], such as seaweeds.

Seaweeds are marine macroalgae and various seaweed types have traditionally been used as food additives or flavoring materials in many countries. For example, the Japanese use 88 seaweed species in cuisine and as healthcare foods according to the KNApSAcK Lunch Box Database [8–11]. Seaweeds are rich in minerals (e.g. iodine, magnesium, iron, zinc and calcium) and dietary fibers and are consumed mainly in East Asia, e.g., Japan, China, Korea, etc. In Japan, for example, over 20 species of red (Rhodophyta), green (Chlorophyta), and brown (Phaeophyta) algae are popular in meals [12]. The three most common seaweed products in Japan are nori (Porphyra, 33 species), wakame (Undaria, 2 species) and kombu (Laminaria, 12 species).

Seaweed is served in approximately 21% of meals in Japan [13], with 20–38% of the population aged 40–79 years consuming seaweed more than five times per week, 29–35% three to four times per week, 25–35% one to two times per week, 6–13% one to two times per month, and 1–2% rarely consuming seaweed [14]. Estimating the amount of seaweed consumption is difficult due to dietary differences between age groups and geographical regions. Seaweed consumption has been estimated to vary between 4 and 7 g/day dried weight [12,15–17] and 12 g/day using both dry and wet weight [18]. Daily seaweed consumption per person in Japan has been reported to have remained relatively consistent between 1955 (4.3 g/day) and 1995 (5.3 g/day) [15], while the type of seaweed consumed changed over 40 years with an increase in the intake of wakame and nori and a decrease in kombu consumption [19].

Seaweeds contain a variety of potentially bioactive compounds some of which are not present in terrestrial plants. These compounds include, for example, proteins such as lectins or phycobiliproteins, carotenoids, pigments, polyphenols, phlorotannins and certain polysaccharides. They may have health-promoting properties and play a role in modulating chronic disease [20]. Epidemiological studies comparing Southeast Asian and Western-style diets have reported an association between dietary intake of seaweeds and a reduced prevalence of chronic diseases including cardiovascular disease, hyperlipidemia and cancer [21,22]. In Japan, the recent spread of a Western diet including an increase in the consumption of meat and dairy products has coincided with an increase in the incidence of chronic diseases [23,24]. A reduction in regular seaweed consumption and other dietary changes are particularly obvious in young Japanese people [14,25].

2. Effects of seaweed fiber on appetite and body weight

A diet rich in fiber has been demonstrated to prolong the gastric emptying rate and thereby increasing satiety and reducing food consumption [26]. Since seaweeds are a good source of dietary fiber [27] several studies have assessed the ability of sodium alginate extracted from brown seaweed to enhance satiety and to decrease energy intake (see Table 1).

Pelkman and her colleagues [28] tested the effects of a novel beverage, consisting of alginate-pectin and calcium components, which forms a stable, fibrous gel in the stomach, on subjective satiety and food intake in overweight and obese women (see Table 1). Twenty-nine individuals drank a 2-part beverage twice per day (once before breakfast and once midafternoon) for 7 days. Three alginate-pectin formulations were tested, i.e. 1.0 g, 2.8 g, and control without fiber. Subjective satiety and ad libitum food intake were measured on days 1 and 7 of each 1-week treatment period with a 1-week washout between testings. A decrease in energy consumption was observed in overweight and obese women with low dietary restraint following a 7-day supplementation with alginate-pectin drinks compared to a control drink. Increased stimulation of endogenous satiety signaling is supposed to be the reason for the decrease in energy intake [28]. Future research needs to assess how dietary restraint affects this observation.

Paxman et al. [29] investigated the effects of alginate on appetite control in free-living healthy normal-weight, overweight and obese adults using a randomized, controlled two-way crossover intervention (see Table 1). They compared the effects of a 7-day daily intake of a strong-gelling sodium alginate formulation with a control group. Daily preprandial ingestion of sodium alginate led to a significant reduction by 7% (134.8 kcal) in mean daily energy intake. In addition, significant reductions in the mean daily ingestion of carbohydrate, fat, saturated fat and protein were found [29]. These results suggest a role for a strong-gelling sodium alginate in the treatment of overweight and obesity. The potential efficacy of this therapeutic approach for individuals in different settings was suggested by the absence of any significant interaction effects between the main effect of preload type and those of gender, classification of body mass index and/or timing of preload delivery.

In a further crossover study performed by Paxman and colleagues [30], the uptake of glucose, cholesterol, and triacylglycerols in humans with normal and high body mass index was investigated (see Table 1). The uptake of these substances increased with increasing body fat. The administration of a beverage containing 1.5 g of strong-gelling alginate restored uptake of glucose and cholesterol in overweight and obese subjects to the levels of healthy participants whose uptake was not affected by the alginate drink. This data also indicates a potential efficacy of gelling fibers.

Jensen and his co-authors [31] studied the effects on postprandial satiety feelings, energy intake, and gastric emptying rate, of two different volumes of an alginate-based preload in normal-weight subjects (see Table 1). Twenty individuals were randomly assigned to receive a 3% preload concentration of either low volume (9.9 g alginate in 330 mL) or high volume (15.0 g alginate