Nuts and Body Weight - An Overview

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Abstract

Since obesity and overweight became health issues, tree nuts became considered as unhealthy, due to their high fat content. Their high energy density has been pointed as a major factor in body weight gain. However, nuts have been part of the traditional diet in many geographical areas for centuries and in the last decades various laboratory assays, as well as epidemiological and clinical studies, substantiate that the regular intake of nuts is not a relevant factor influencing body lipid accumulation. This paper describes various mechanisms of action proposed to explain the effect of nuts on the regulation of body weight that are currently under examination.

Keywords: Nuts; Body weight; Obesity; Chronic diseases; Nutrition

Introduction

Energy homeostasis is a highly complex process that has not been completely understood. In subjects chronically exposed to a high fat intake, the regulatory mechanisms for body weight maintenance are lost. Lipids accumulate in the abdominal zone and adipokines secretion by adipocytes is altered [1]. Lipids also accumulate in metabolically active tissues such as liver, muscle, and pancreas, all of which constitute the basis for the development of metabolic syndrome (MetS) [2].

Historical evidence on the nutritional benefits of consumption of nuts

Nuts are fruits composed of a hard shell and a seed, which is generally edible. In a botanical context, they are indehiscent, since the shell does not open to release the seed, although the term often refers to any hard-walled, edible kernel as a nut. Tree nuts have been a major part of the human diet around the world for millennia. The remains of seven types of 780,000-year-old nuts were found at the Gesher Benot Yaaqov site in the Dead Sea rift, in Israel [3]. The nuts and the stone tools found with them demonstrate that nuts formed a major part of the diet of prehistoric humans and that they had developed various tools to crack open nuts during the Early-Middle Pleistocene [3]. In fact, cracking nuts is a subsistence activity of contemporary hunter–gatherer societies worldwide, as substantiated by extensive data on the taxonomy, seasonality, gathering, cracking, consumption, and nutritional value of nuts. "Nutting stones" which archeologists date back 4,000 to 8,000 years have been found in the United States and Europe, where ancient Romans gave sugared almonds as gifts at weddings, a custom still used today in some regions [4]. According to Brufau, et al., nuts originate from Anatolia [5]. From there, the cultivation of tree nuts was introduced in Greece, then in Italy during the Roman Empire, and finally it was extended to all of Europe during the Middle Ages.

The origins of the "Mediterranean Diet" are lost in time; however, they are related to the eating habits of the Middle Ages, in which the ancient Roman tradition identified bread, wine and oil products as symbols of their culture. The traditional Mediterranean diet includes a high intake of vegetables, legumes, fruits, nuts, and cereals; high to moderate intake of fish; moderate to low intake of dairy products; low intake of red meats, and moderate intake of red wine. This represents a low intake of saturated fatty acids and high intake of unsaturated fatty acids. Tree nuts are part of this dietary pattern and the most commonly consumed include almonds, hazelnuts, walnuts, pine nuts, pistachios, macadamia, and cashews [6]. Although not real nuts, peanuts (a legume) are usually included in this group [7].

Nuts intake and chronic diseases

Nuts contain high levels of fats and proteins, theoretically providing a range of 550 to 750 kcal/100 g, so they are high energy density foods (Table 1). Because of this, nuts became considered as unhealthy; however, in the last decades their nutritional value is being re-recognized. In spite of being energy dense foods, nut intake has been associated with the reduction of risk factors of chronic diseases. Epidemiological evidence indicates that people consuming five servings or more of nuts per week do not weigh...
more than people who consume less than one serving of nuts per week [8]. This is of major importance, since overweight, obesity and related chronic diseases constitute serious public health problems and a high proportion of individuals are attempting to maintain or reduce their BMI, and the roles dietary nuts play to accomplish this goal have to be acknowledged. Some of the mechanisms by which nuts may influence body weight are presented.

Several clinical trials indicate that nuts can modulate blood lipids, including total cholesterol, LDL cholesterol, ApoB, and triglycerides [22,23], endothelial function [24], insulin resistance [25,26], and ameliorate glycemic control in patients with diabetes [27]. MohammadiFard, et al. observed that total nut consumption lowered blood pressure in participants without type 2 diabetes [28]. All these situations are involved in the development of MetS, a multifactorial syndrome that represents a cluster of abnormalities, including obesity, insulin resistance, dyslipidemia, and associated comorbidities that increase the risk of developing CVD and leads to substantially increased morbidity of CVD and diabetes mellitus type 2 [29]. Inclusion of nuts as part of a healthy diet is inversely and independently associated with a decreased risk of MetS as well as overall and vascular-disease mortality, particularly in women [30,31].

There is substantial epidemiological and clinical trial evidence suggesting that adherence to the Mediterranean diet relates to a reduced prevalence of the MetS [32]. Kastorini, et al. meta-analyzed 50 epidemiological studies and clinical trials concluding that adherence to the Mediterranean dietary pattern was associated with lower MetS prevalence and progress [33]. Blanco Mejia, et al. analyzed 49 reports of randomized controlled dietary trials of tree nuts matched for energy on at least one of the five criteria of the MetS (waist circumference, triglycerides, HDL-cholesterol, blood pressure and fasting blood glucose) [34]. They observed a MetS benefit of tree nuts through modest decreases in triglycerides and fasting blood glucose with no adverse effects on other criteria across nut types. In two cohort studies, nut intake related to reduced total, CVD and cancer and respiratory mortality [35]. These findings support recommendations to consume tree nuts alone or as part of heart healthy dietary patterns as a mean for improving metabolic control.

### Nuts intake and body weight

In 2003, Sabaté reported an association between nut consumption and body weight [36]. Results of the EPIC (European Prospective Investigation into Cancer) multicenter, prospective cohort study investigating the role of metabolic, dietary, lifestyle, and environmental factors in the development of chronic diseases indicated that a high adherence to the Mediterranean diet may reduce the likelihood of gaining weight and becoming overweight or obese after 5 y of follow-up [37]. Since then, evidence has accumulated, and ten years later Ibarrola-Jurado, et al. reported in a cohort of the PREDIMED study that nut consumption was inversely associated with the prevalence of general obesity, central obesity, MetS, and diabetes in subjects at high cardiovascular risk [38].

<table>
<thead>
<tr>
<th>Type of nut</th>
<th>Proteins</th>
<th>Lipids</th>
<th>Fiber</th>
<th>Saturated</th>
<th>Monounsaturated</th>
<th>Polyunsaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cashew</td>
<td>18.22</td>
<td>43.85</td>
<td>3.3</td>
<td>7.783</td>
<td>23.797</td>
<td>7.845</td>
</tr>
<tr>
<td>Pine nut</td>
<td>13.69</td>
<td>68.37</td>
<td>3.7</td>
<td>4.899</td>
<td>18.764</td>
<td>34.071</td>
</tr>
<tr>
<td>Macadamia</td>
<td>7.91</td>
<td>75.77</td>
<td>8.6</td>
<td>12.061</td>
<td>58.877</td>
<td>1.502</td>
</tr>
<tr>
<td>Pistachio</td>
<td>20.16</td>
<td>45.32</td>
<td>10.6</td>
<td>5.907</td>
<td>23.257</td>
<td>14.380</td>
</tr>
<tr>
<td>Almond</td>
<td>21.15</td>
<td>49.93</td>
<td>12.5</td>
<td>3.802</td>
<td>31.551</td>
<td>12.329</td>
</tr>
<tr>
<td>Hazelnut</td>
<td>14.95</td>
<td>60.75</td>
<td>9.7</td>
<td>4.464</td>
<td>45.652</td>
<td>7.920</td>
</tr>
<tr>
<td>Pecan</td>
<td>9.17</td>
<td>71.97</td>
<td>9.6</td>
<td>6.180</td>
<td>40.801</td>
<td>21.614</td>
</tr>
<tr>
<td>Walnut</td>
<td>15.23</td>
<td>65.21</td>
<td>6.7</td>
<td>6.126</td>
<td>8.933</td>
<td>47.174</td>
</tr>
<tr>
<td>Peanut</td>
<td>25.80</td>
<td>49.24</td>
<td>8.5</td>
<td>6.279</td>
<td>24.426</td>
<td>15.558</td>
</tr>
</tbody>
</table>

CVD are the first death cause in most developed and developing Western countries. Epidemiologic studies and clinical trials demonstrate that nut consumption has beneficial effects on cardiovascular health, they lower the risk of peripheral arterial disease, type 2 diabetes, inflammation, and a number of risk factors, which could collectively reduce chronic disease [9-18]. The PREDIMED study proved an association between the frequency of nut consumption and mortality risk [19] while van den Brandt and Schouten in a meta-analysis concluded that total nut intake was related to lower overall and cause-specific mortality (cancer, diabetes, cardiovascular, respiratory, neurodegenerative diseases, and other causes), with evidence for nonlinear dose-response relationships [20]. Similarly, Grosso, et al. in a revision of prospective studies through meta-analysis demonstrated that nut consumption is associated with improvements in a series of risk factors for chronic diseases and lower mortality risk [21].

#### Table 1: Total proteins, lipids, fiber and fatty acids content of raw nuts and peanuts reported in the USDA [67] (g/100 g)
Since several years, evidence shows an association between nut consumption and body weight including cross-sectional and prospective epidemiologic studies that indicate an inverse association between the frequency of nut consumption and BMI (kg/m²) and risk of obesity [8,25,36-51]. Casas-Agustench, et al. reported that results of multivariate analyses with adjustment for various confounders showed that nut intake was the sole dietary component consistently and inversely associated with adiposity measures [50]. In a meta-analysis of clinical trials, Flores-Mateo, et al. concluded that compared with control diets, diets enriched with nuts did not increase body weight, BMI, or waist circumference [51]. Besides, individuals who consume nuts regularly tend to eat less red meat and refined carbohydrates, and such a replacement that may be beneficial for the prevention of weight gain.

**Nuts intake and appetite**

The intake of almonds and peanuts suppresses hunger and desire to eat and increases fullness ratings after ingestion [52-54]. Various mechanisms have been involved to explain the effects of nut consumption on body weight [55]. The sensory, nutrient, and/or physical properties of tree nuts and peanuts affect gut hormone secretion and appetite responses by consumers: nuts induce satiation (reduction in the total amount of food eaten in a single meal) and satiety (reduction in the frequency of meals) [56-58]. Satiety is induced mainly by two gut hormones: cholecystokinin (CCK) and glucagon like peptide 1 (GLP-1). CCK is released from duodenal entero-endocrine cells into the blood stream in response to fatty acids or protein, while GLP-1 is produced in the ileum, induced by passing fatty acids (FA) and carbohydrates both playing major roles in food intake control as satiety hormones [59]. Besides, both CCK and GLP-1 release lead to a delay in gastric emptying, early satiety and a decrease in food consumption [60].

Chain length and the degree of saturation of the FA influence the satiating effect of fats. Only FA with chain lengths ≥ C12, as those prevailing in tree nuts, are capable of reducing food intake and releasing CCK and GLP-1 [61], being long-chain FA more effective than medium-chain FA [62]. Another mechanism that may be involved in the effect of nuts on weight gain is that their fat quality determines the thermogenic response to this fatty food [63,64]. Comparing the effect of two Mediterranean diets versus a low-fat diet Lasa, et al. observed increased values of the adipokines adiponectin to leptin ratio and decreased values of waist circumference, associated with a significant reduction in body weight for a nuts diet, which were not significant for a low-fat diet [65].

While the oil content of most nuts ranges from 44 to 76 g/100 g, nuts are also a good source of dietary plant protein, ranging from nearly 8 to 26 g/100g [10,66,67]. They also contain variable amounts of fiber, both known to increase the satiety of meals and prolong feelings of fullness following consumption (Table 1).

**Mastication and available energy**

Nuts contain high levels of fats, and are considered as high energy density foods. Nevertheless, Baer, et al. observed that the available energy from various nuts might be 9%–32% less than that predicted by the Atwater factors [68]. The digestibility of a given nut is nut-dependent, and since mastication affects the digestibility it is possible that different nuts elicit different amounts of chewing [58]. Various studies have evaluated the efficiency of energy absorption from tree nuts and peanuts through feeding trials, showing substantive increases in fecal fat loss with nut consumption [23,58]. Healthy subjects consuming 76 g of peanuts for 4–6 days excreted 18% of dietary fat per day and the stools contained intact portions of the nuts. This fat malabsorption was observed both when high and low-fiber diets containing whole peanuts were evaluated [69].

The physicochemical structure of lipid storing granules as well as various nut fiber components do not allow complete release of fatty acids during digestion, affecting fat absorption [25,70]. The inefficiency may be attributed to the resistance of the parenchymal cell walls of nuts to microbial and enzymatic degradation, passing through the gastrointestinal tract affecting the bioaccessibility of lipids and proteins. Another complimentary explanation for the less energy provided by a diet containing nuts is that the majority of the energy nuts provide is offset by spontaneous adjustments in the total diet [71,72].

Satiety may be induced by the fact that nuts intake require increased mastication [52]. Kirkmeyer, et al. observed that the satiating effects of nuts depend on their form: when peanuts are consumed as butter the induction of hunger suppression is lower and there is a greater hunger rebound (180 min post-ingestion) compared with whole nuts. In fact, chewing generates more potent satiation signals through various mechanisms [58,73,74].

The intake of almonds with a meal does not affect the appetite-modulating effects of that meal, whereas consuming almonds alone (as snacks) blunts hunger and desire-to-eat ratings [75]. Mechanical disruption of the parenchymal cell walls of nuts liberates the lipid and protein they contain in their matrix, promoting the release of intestinal peptide hormones that induce satiety [41]. An incomplete mastication of nuts is common and leads to increased fecal losses of lipids and proteins [50]. Hutchings, et al. observed that the physical properties of nuts influence their disintegration characteristics, so that the matrix in which they are embedded modifies chewing behavior, although without modifying the final nut particle size [76].
Among the nutrients of the Mediterranean diet, FA from olive oil, fish and nuts seem to modulate brain serotonin pathway, which may influence eating behavior [77]. Binge eating disorder implies the consumption of a large amount of food in a discrete period, with an associated sense of loss of control in the absence of regular compensatory behavior intended to prevent weight gain, such as vomiting or laxative abuse, which is also among the causes of weight gain. Bertoli, et al. postulated that olive oil and nut consumption are associated with less diagnosis of this disorder [78].

Nut oil

Nuts are energy-dense foods mainly because they contain 44 to 74 g/100 g oil [8,10,79,80]. However, nut consumption improves blood lipid levels and reduce risk factors of CVD [81,82]. The cardio-protective constituents include unsaturated FA, phytosterols, tocopherols, and squalene [83-86]. The lipid fraction contains various tocopherols (α-, γ-, and δ-tocopherol) at remarkably high levels [87]. In 2002, the U.S. Food and Drug Administration approved a qualified health claim for tree nuts, which stated "Scientific evidence suggests, but does not prove, that eating 1.5 ounces per day of most nuts as part of a diet low in saturated fat and cholesterol may reduce the risk of heart disease" [88]. The types of nuts eligible for this claim are restricted to almonds, hazelnuts, peanuts, pecans, pine nuts, pistachios, and walnuts, that is, nuts that do not exceed 4 g saturated fat per 50 g. To date, various countries have health claims approved stating the health benefits afforded by tree nuts (including USA, Canada, and Spain).

Oleic acid (18:1n-9) is the prominent monounsaturated FA (MUFA) in most nut types, while polyunsaturated (PUFA) linoleic (18:2n-6) and α-linolenic (18:3n-3) acids are also represented [10]. While most tree nuts show a higher content of MUFA, pine nuts exhibit a FA profile in which PUFA are more abundant, prevailing linoleic acid [79,80,85,86,89].

Pine nut oils contains a unique class of unsaturated FA, the Δ5-unsaturated polymethylene-interrupted pinolenic acid (18:3-Δ5,9,12), found in Pinus koraiensis (11-15%), Pinus pinaster (7%), Pinus cembroides edulis (0.36%), and Pinus pinea (0.0-0.37%) [84,87,90-95]. This FA may suppress appetite by acting on CCK release [96]. Pasman, et al. observed that feeding 3 g of pine nut oil (as FA or triglycerides of Pinus koraiensis) decreased prospective food-intake ratings and increased the secretion of CCK [56]. Korean pine nut oil FA were approximately 8-fold more potent in releasing CCK than other pine nut oils FA, an effect attributed to pinolenic acid since the contents of other unsaturated FA is similar between pine nuts from different species.

Both a possible increment in resting energy expenditure and in fat oxidation have been described for nuts. In fact, consumption of pinolenic oil reduced weight gain in obese mice maintained on a high fat diet [97]. Le, et al. observed that this FA markedly reduced triglyceride accumulation in the muscles of mice exposed to a high-fat diet by activating the mitochondrial oxidative pathway [98]. The authors observed that pinolenic acid upregulated UCP1 transcription and expression in brown adipose tissue, that is, genes involved in the regulation of thermogenesis, mitochondrial biogenesis and oxidative metabolism. These findings led to the commercialization of a nutraceutical directed towards weight control, containing Korean pine nut with 92% free FA and triglycerides (PinnoThin”) [99]. However, in a clinical double blind, randomized, crossover design study, Verhoef and Westerterp concluded that a dosage of 6 g PinnoThin™ triglycerides is not sufficient to suppress appetite sensations and energy intake [100]. But when a health claim was applied for, the European Food Safety Agency (EFSA) Regulatory Expert Panel concluded that a cause and effect relationship has not been established between the consumption of "pine nut oil from Pinus koraiensis Siebold & Zucc." and a sustained increase in satiety leading to a reduction in energy intake [101]. This situation reflects the importance of eating whole foods (nuts) in their natural food matrix, containing all the nutrients and bioactives that may act synergistically to provide the beneficial health effects.

At the time, no claim on the association of nuts intake on body weight management has been approved, and a study is ongoing to conduct a series of systematic reviews and meta-analyses of the totality of the evidence from controlled trials and prospective cohort studies to investigate the effect of nut consumption on body weight and adiposity [102].

Concluding remarks

The substantial evidence for the beneficial role of nuts in risk reduction of non-chronic diseases has led to the development of public health recommendations (in the form of Dietary Guidelines or others) to include nuts regularly in the diet for general healthy eating. Moreover, there is a trend toward higher nut consumers being leaner than non-nut consumers. The effects of nuts on the regulation of body weight are currently under examination, including the various mechanisms that may be involved in this action.

It is important to consider that tree nuts and peanuts represent a variety of complex food matrices containing nutrients and bioactive compounds, and the beneficial effects of frequent nut consumption may be attributed to the synergistic action of these constituents, so a variety of these dietary seeds is recommended.

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