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The effect of preload/meal energy density on energy intake in a subsequent meal: A systematic review and meta-analysis☆

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A B S T R A C T

Objective: To conduct a systematic review and meta-analysis of the effects of preload/meal energy density on energy intake in a subsequent meal(s).
Methods: Multiple databases were searched for studies published through December 2016 on the effects of preload/meal energy density on energy intake in a subsequent meal(s). We extracted information on mean energy intake in a subsequent meal(s) and on variables that could contribute to between-subject heterogeneity.
Results: Forty and Thirty nine eligible studies were identified for our systematic review and meta-analysis, respectively. The meta-analysis showed that preload/meal energy density did not affect energy intake in a subsequent meal(s) (95% CI: −21.21, 21.29). As heterogeneity was remarkable among studies, we stratified the studies by intervention type into "meal" or "preload" classifications. In the "preload" subgroup, studies used either fixed energy or fixed weight preloads. The results reveal that in comparison to a high energy-dense (HED) preload, consuming a low energy-dense (LED) preload with same weight resulted in higher energy intake in a subsequent meal (95% CI: 9.72, 56.19). On the other hand, decreased energy intake was observed after consuming an LED preload compared to after consumption of an HED preload with same energy content (95% CI: −138.71, −57.33). In the "meal" subgroup, studies were categorized by different subsequent meal (i.e., "afternoon or evening", "lunch" and "dinner or post-dinner"). Meta-analysis showed that an LED meal resulted in more energy intake only in afternoon or evening meals (95% CI: 14.82, 31.22).
Conclusion: In summary, the current analysis revealed that we can restrict the energy intake by consuming an LED preload. Moreover, consuming an LED preload could favorably affect preload + meal energy intake.

Contents

Abbreviations: ED, energy density; HED, high energy-dense; LED, low energy-dense.
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1. Introduction

Obesity is one of the most important cardiovascular risk factors (Rouhani et al., 2013a) and has been dramatically increasing in prevalence globally since 1980 (Stevens et al., 2012). As physical activity and nutritional interventions have been recommended for the prevention and treatment of obesity (Rouhani et al., 2013a), dietary energy intake has an important influence on the association between dietary intake and obesity. Even a modest imbalance in daily energy (3–4%) can result in weight gain of 1 kg per year in adults (Rouhani et al., 2013b). The composition of a meal preload (usually consumed 15–30 min before a main course), snack, or glycemic index of a meal may affect energy intake in the next meal(s) (Rouhani et al., 2013b).

The energy content (in kilocalories) of one weight unit (in grams) of a food is defined as its energy density (Vernarelli et al., 2013). Energy density is a common indicator of dietary quality (Rouhani et al., 2012; Maillot et al., 2007; Azadbakht et al., 2012). Macronutrient composition and water content of foods are determinants of energy density (Vernarelli et al., 2013). According to the Atwater factors, among macronutrients, fat has the strongest capacity to increase the energy density of a food (Kruskall et al., 2003). Another determinant of energy density is the water content of food, which can increase the weight of a food consumed without adding energy (Rolls et al., 1999a). Adding water into a preload may favorably affect subsequent energy intake (Rolls et al., 1998). Also, it has been observed that the incorporation of air into a snack can result in lower energy intake (Osterholt et al., 2007). However, research suggests that changing the macronutrient composition to manipulate preload/meal energy density may have a larger effect on energy intake than adding water (Westerterp-Plantenga, 2001).

Higher dietary energy density is directly associated with weight gain (Bes-Rastrollo et al., 2008) and risk of abdominal adiposity (Esmaillzadeh & Azadbakht, 2011). The relation between energy density and obesity may be mediated by energy intake. Several studies have assessed the effects of meal energy density on energy intake in that meal, showing fairly consistent results revealing consumption of HED meals resulted in more energy intake during the meal (de Oliveira et al., 2008; Devitt & Mattes, 2004). Results of other studies, however, have differed regarding the effects of preload/meal energy density on energy intake in a subsequent meal(s) (Rolls et al., 1998; Blatt et al., 2012; Chang et al., 2010; Araya et al., 1999; Birch et al., 1990; Isaksson et al., 2008; Johnson et al., 1991). While one study found that consuming a low energy-dense (LED) meal may decrease energy intake in a subsequent meal(s) (Chang et al., 2010), others have not supported this result (Araya et al., 1999; Isaksson et al., 2008). Similarly, results of research on the effects of preload energy density on energy intake in subsequent meals has been conflicting, with some studies finding that consumption of a low-energy dense preload resulting in greater energy intake in a subsequent meal (Birch et al., 1990), while others have reported the opposite (Rolls et al., 1998; Blatt et al., 2012). It seems that observed inconsistency is mediated by several variables such as age, gender, manipulated preload/meal, type of diet manipulation and body weight. Inconsistent findings and potential sources of heterogeneity have not yet been synthesized in the form of a systematic review or meta-analysis. Therefore, the aim of the current study was to perform a systematic review and meta-analysis of clinical trials to assess the effect of preload/meal energy density on energy intake in a subsequent meal(s).

2. Material and methods

2.1. Search strategy and inclusion criteria

We searched ScienceDirect (www.sciencedirect.com/science/journals) EMBASE (www.elsevier.com/online-tools/embase), MEDLINE (www.pubmed.com) and Google Scholar (scholar.google.com) databases to identify articles published until December 2016. We included articles that used "energy density" or "energy-density" or "energy dense" or "calorie density" or "caloric density" or "calorie dense" or "energy concentration" or "calorie concentration" in the title, abstract or keywords ("Energy density" was not defined as a MeSH term).

2.2. Exclusion criteria

We excluded studies in which the manipulated meal and ad libitum meal was not subsequently consumed, studies that included elderly (>60 years old), children <2 years old, or individuals with eating disorders. The search was not restricted by language or time published. Inclusion and exclusion criteria were checked by a review of titles, abstracts, and then the full text of the articles. Additional relevant studies were obtained by hand searching the references of the articles included.

2.3. Data extraction

We extracted and tabulated the following data from eligible studies: first author's name, publication year, total and gender stratified sample size, mean age of subjects, study design, energy density in each group studied, characteristics of the test meal and the mean and standard error or standard deviation of energy intake in a subsequent meal(s). According to the "term" used in the articles, subsequent meals were categorized into afternoon and evening, lunch and dinner or post dinner.

2.4. Statistical analysis

Extracted standard errors were converted to standard deviations. In some cases, we extracted several effect sizes from one study. Therefore, a pooled effect was calculated using a random effects model for each study. Because of the high between study heterogeneity, the overall effect was calculated using a random effects model. Between study heterogeneity was assessed by performing I square (I^2) tests. Potential sources of between study heterogeneity were identified through subgroup analysis. Between subgroup heterogeneity was detected by using fixed-effect model. Sensitivity analysis was performed to evaluate the effect of each study on the pooled effect size. To assess publication bias, we used Egger's regression asymmetry test and Begg's adjusted rank correlation test.

The present systematic review and meta-analysis was conducted according to the PRISMA statement.