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Research review

Effects of polydextrose on different levels of energy intake. A systematic review and meta-analysis ☆

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ABSTRACT

Introduction: Dietary fibers help to control energy intake and reduce the risk of developing obesity. Recent studies show that the consumption of polydextrose reduces energy intake at a subsequent meal. In this systematic review and meta-analysis we examine the subsequent effects of polydextrose on different levels of energy intake (EI). *Method:* The review followed the PRISMA methodology. Meta-analyses were expressed as Standardized Mean Difference (SMD). A linear regression approach was used to model the relationship between the polydextrose dose and the different levels of EI expressed as a relative change (%). *Results:* All the studies included in this review administered polydextrose as part of a mid-morning snack. Six studies were included in the analysis of EI at an *ad libitum* lunch; and three were included in the analysis of EI during the rest of the day, as well as total daily EI. The meta-analysis showed that the consumption of polydextrose is associated with a reduction in EI at lunch time (SMD = 0.35; $P < 0.01$; $I^2 = 0$). The dose of polydextrose consumed correlated significantly with this reduction in EI, EI_{Lunch} (%) = –0.67 Polydextrose (g/day) ($R^2 = 0.80$; $P < 0.01$). The meta-analysis of EI during the rest of the day and daily EI did not show any difference. Nevertheless, the regression equation indicates that there is a dose-dependent effect on the reduction of daily EI, EI_{Daily} (%) = –0.35 × Polydextrose (g/day) ($R^2 = 0.68$; $P < 0.05$). Sex-specific results are consistent with results for the whole group. *Conclusion:* The studies included in this meta-analysis support the notion that the consumption of polydextrose reduces voluntary energy intake at a subsequent meal. Furthermore, this reduction in energy intake occurs in a dose-dependent manner.

Contents

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Introduction

The prevalence of overweight and obesity is increasing at an alarming rate worldwide (Burton-Freeman, 2000; Kelly, Yang, Chen, Reynolds, & He, 2008). It is estimated that by 2030 there will be more than 2 billion overweight and 1 billion obese individuals (Kelly et al., 2008). Overweight and obesity are important risk factors for diabetes, cardiovascular disease, cancer, and premature death (Haslam & James, 2005). Epidemiological studies have found that the consumption of dietary fiber is associated with normal weight and less fat gain (Davis, Hodges, & Gillham, 2006; Tucker & Thomas, 2009). The role of dietary fiber in the regulation of energy intake and the development of obesity may be related to the fiber's unique physical and chemical properties that help to generate early signals of satiation as well as enhanced or prolonged signals of satiety (Burton-Freeman, 2000).

Polydextrose is a glucose polymer that is completely soluble in water. As a food additive it offers the texture of sucrose but provides only 25% of the equivalent energy, or 4 kJ/g (Achour et al., 1994; Auerbach, Craig, Howlett, & Hayes, 2007; Juhr & Franke, 1992). It has been approved for use in foods in over 60 nations and is recognized as a dietary fiber in more than 20 countries (FAO/WHO, 2009).

Recent studies have shown that polydextrose reduces energy intake at a subsequent meal, especially when administered as part of a mid-morning preload before an *ad libitum* lunch (Astbury, Taylor, & Macdonald, 2013; Hull, Re, Tiihonen, Viscione, & Wickham, 2012; Ranawana, Muller, & Henry, 2013). Although some studies which have examined the effects of polydextrose on appetite suppression have involved male participants only (Astbury, 2014; Astbury, Taylor, & Macdonald, 2008; Ranawana et al., 2013), several others have included both males and females (Astbury et al., 2013; Hull et al., 2012; King, Craig, Pepper, & Blundell, 2005; Konings, Schoffelen, Stegen, & Blaak, 2013; Monsivais, Carter, Christiansen, Perrigue, & Drewnowski, 2011; Schwab, Louheranta, Torronen, & Uusitupa, 2006; Timm, 2012). However, results are very rarely reported on a per-sex basis.

While these studies demonstrate the ability of polydextrose to reduce energy intake, to date there is no other such review which systematically gathers all the disparate evidence on this topic. Therefore, the aim of this review and meta-analysis is to investigate the effects of polydextrose on subsequent levels of energy intake. In addition, this study also aims to assess if there is a dose-dependent effect on the levels of reduction of subsequent energy intake caused by the consumption of polydextrose. This study also evaluates these effects by sexual category.

Methodology

Protocol registration

This review was conducted according to the methodology described by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses: PRISMA Statement (Moher, Liberati, Tetzlaff, Altman, & Group, 2009). The Protocol was registered at the International Prospective Register of Systematic Reviews (PROSPERO) with number CRD42013005261 on August 9, 2013.

The methodology was used to analyze the available data on the subsequent effects of polydextrose on subjective feelings of appetite and levels of energy intake. This report communicates the results of levels of energy intake. Results on the subjective feelings of appetite are communicated in a separate report.

Eligibility criteria and information sources

Eligible study designs were either acute or chronic, randomized, and placebo-controlled nutritional interventions where polydextrose was administered alone or in combination with other food or food ingredients, including supplements. Participants were either normal, overweight, or obese, but otherwise healthy men and women. Interventions were those intended to assess the subsequent effects of polydextrose on subjective feelings of appetite and levels of energy intake. Subjective feelings of appetite included, but were not limited to: hunger; satiety; fullness; prospective food consumption; and the desire to eat. The different levels of energy intake were those calculated at any given time of the day when a nutrient was measured and administered, including at times of breakfast, lunch, dinner, and snacks between meals.

Eligible reports included papers from scientific journals, conference abstracts and theses reported in English-language literature before July 31, 2013, except for two original manuscripts kindly provided by Dr. Nerys Astbury (Astbury, 2014) and M.Sc. Kaisa Olli (Olli et al., 2014) before their publication in scientific journals. Searches were conducted on the following databases: BIOSIS Previews, CAB Abstracts, Foodline:Science, FSTA, Medline, SciSearch, Science Direct, Wiley Online Library, and www.ClinicalTrials.gov. An example of the generic search strategy is shown in Appendix 1 of the supplementary data file. Further information on recently completed trials, unpublished research, and research reported in gray literature was identified by searches for relevant documents in Google Scholar.

Study selection and quality assessment

One researcher (Dr. Alvin Ibarra) screened and selected the records. The authors of the selected articles were contacted and asked to provide any missing information and the full data sets on anthropometric measurements, subjective feelings of appetite and the levels of energy intake. A second independent researcher (M.Sc. Kaisa Olli) checked the assessment and any discrepancies were resolved by consulting a third researcher (Dr. Kirsti Tiihonen). The reviewed articles which were considered not relevant for this study were recorded along with the reason for their exclusion.

A similar system was followed to assess the risk bias of each included study. The assessment followed the procedure described in

the Cochrane Handbook for Systematic Reviews of Interventions (Higgins, Altman, & Sterne, 2011).

Strategy for data synthesis

The data analysis was divided into three main sections. First, a narrative synthesis describing the levels of energy intake was conducted to compare methodologies used. For example, the description of the way that energy intake was measured, the kinds of foods that were used in each study, and the manner in which the polydextrose was administered, were all considered. The second section included a meta-analysis of the levels of energy intake reported at a subsequent *ad libitum* test meal at lunch time, during the rest of the day or 'dinner', as well as the daily energy intake. Finally, correlations using a linear regression model were reported.

Meta-analysis

Where relevant, the recorded energy intake levels were converted to kilojoules (kJ) in order to homogenize results.

Data-sets were investigated using a random-effects model, which views our chosen studies as a sample of a larger universe of studies. The model was chosen because there were minor differences in both study design and the participants' characteristics. The treatment-effect size was analyzed using Standardized Mean Difference (SMD) with a 95% confidence interval. The between-study variation was estimated using a restricted maximum likelihood approach. The results of the meta-analysis were visualized using a forest plot which illustrates the results of the individual studies as well as the summary random effect. The heterogeneity of the sum of studies was tested using the Higgins I^2 statistic. Publication bias was analyzed visually using a funnel plot, and assessed using the Egger's test.

Analyses were performed using the statistical software 'R', version 3.0.2 (Team, 2005) and the metafor package version 1.9–2 (Viechtbauer, 2010).

Linear regression

Linear regression modeling was applied to the doses of polydextrose used in the studies versus their corresponding energy intake levels in order to assess if there is a dose-dependent effect on the levels of reduction of energy intake caused by the consumption of polydextrose. In each case the following formula was used to calculate the appropriate linear regression values:

$$\text{Relative change}\,(\%) = 100 \times \frac{\text{EIX}\,(\text{kJ}) - \text{EIC}\,(\text{kJ})}{\text{EIC}\,(\text{kJ})}$$

where the relative change is expressed as a percentage, EIX represents the energy intake level for the polydextrose sample, and EIC represents the level of energy intake for the control sample.

For the regression model, each value was weighted according to its corresponding number of subjects. The linear regression model equations were expressed as:

$$\text{EI}\,(\%) = b \times \text{Polydextrose}\,(\text{g/day})$$

where EI is the relative change of energy intake expressed as a percentage at a subsequent *ad libitum* test meal (EI_{Lunch}), during the rest of the day or 'dinner' (EI_{Dinner}), or daily energy intake (EI_{Daily}); b is the slope of the equation; and the dose of polydextrose is expressed in grams per day. The coefficient of determination R^2 was calculated for each equation. The level of statistical significance of the equation was set at $P < 0.05$.

These analyses were performed using the same statistical software as used for the meta-analysis.

Results

Study selection

In total, 1,509,923 entries were detected during the search. Figure 1 shows the flow of information through the different phases of the systematic review. Twenty-two full studies were assessed for eligibility, of which sixteen were excluded from this review and meta-analysis.

The study of polydextrose as an appetite-suppressing agent is a relatively new topic. Polydextrose has been used in appetite suppression trials for more than two decades (Shaffer & Tepper, 1994). However, these early studies tended to use polydextrose with the aim of balancing the caloric content of treatments, and not to assess its ability to affect subjective feelings of appetite, or reduce subsequent energy intake levels. This is the main reason why many of these early studies were not included in this systematic review and meta-analysis; *i.e.* Shaffer and Tepper (1994), Rolls et al. (1998), Rolls and Roe (2002), and Bell, Roe, and Rolls (2003). In addition, some studies were also excluded due to large discrepancies in the caloric composition between the test products; *i.e.* Lummela et al. (2009).

The study from Astbury, Taylor, and Macdonald (2010) was not included because the products under investigation also contained whey protein which is reported to have an effect on appetite suppression and subsequent energy intake. It is worth noting that the full report of this study was recently published (Astbury, Taylor, French, & Macdonald, 2014). The same exclusion criterion was applied to the treatment containing a combination of 12.5 g of polydextrose and 12.5 g of xylitol in the study conducted by King et al. (2005).

Other studies, such as those conducted by Blundell, King, and Smith (2003), Kekkonen et al. (2007), King and Blundell (2003), Konings et al. (2013), Kunz et al. (2012), Monsivais et al. (2011), Timm (2012), and Willis, Eldridge, Beiseigel, Thomas, and Slavin (2009) were not included due to the lack of relevant data for this review.

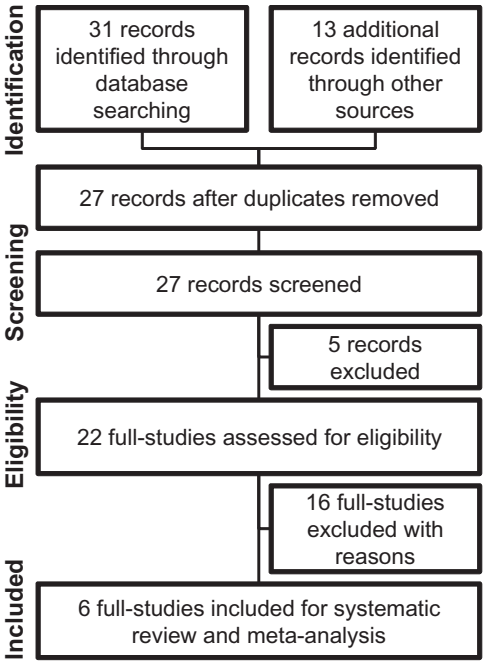

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow information diagram to include studies on the effects of polydextrose on levels of energy intake.

In addition to the above mentioned studies, the studies by Olli et al. (2014) and Schwab et al. (2006) did not measure energy intake levels and were therefore excluded from this report. However, they were included in a separate review and meta-analysis of the effects of polydextrose on subjective feelings of appetite (not reported here).

Included studies

Six studies were included to assess the different levels of energy intake at the time of the *ad libitum* lunch: Astbury et al. (2014), Astbury et al. (2013), Ranawana et al. (2013), Hull et al. (2012) Astbury et al. (2008), and King et al. (2005). Of these studies only three measured energy intake consumption during the rest of the day or at 'dinner' time: Astbury et al. (2013), Hull et al. (2012), and Astbury et al. (2008). Therefore, total daily energy intake could be estimated using only these three studies.

A total of one hundred and twenty individuals participated in this review from across all six included studies, of which seventy-nine were male and forty-one were female. Appendices 2 and 3 of the supplementary data file summarize the design, procedures, and results of energy intake levels of these studies.

Quality assessment and risk of bias

All included studies had ethical approval and all participants had given their informed consent prior to the start of each trial. Experiments were carried out by trained professionals in adequate facilities at universities (Astbury, 2014; Astbury et al., 2008, 2013; King & Blundell, 2003; Ranawana et al., 2013), or in a private contract research organization (Hull et al., 2012). When applicable, the energy intake evaluations continued outside the research facilities by the participants themselves who maintained their own dietary records, except with the study by Hull et al. (2012) where an *ad libitum* dinner was served at the laboratory.

All studies had followed the correct trial randomization processes and procedures.

All studies were single-blinded, meaning that volunteers did not know which treatments they were being given, although the investigators who collected the measurements did. Therefore, these studies are considered to be highly susceptible to a risk of bias.

In most of these studies, all enrolled participants completed the experimental plan; however, Ranawana et al. (2013) and Hull et al. (2012) had one and two subject dropouts respectively. Reasons for these cases were unrelated to the study and were appropriately reported. King et al. (2005) communicated that sixteen volunteers were enrolled in the study, but a revised clinical report revealed that the results of subjective feelings of appetite were calculated on only fourteen participants (7 men and 7 women), and results on energy intake reported on fifteen subjects – see Appendix 2 in the supplementary data file. Reasons for these discrepancies in numbers were not clarified which gives rise to a high risk of bias with this study.

All studies included in this review used the commercial polydextrose known as Litesse Ultra® or Litesse Two®, both manufactured by the company DuPont. The studies conducted by Astbury (2014) and Astbury et al. (2008, 2013) were sponsored by the Biotechnology and Biological Sciences Research Council (BBSRC) of the United Kingdom and Mars UK acting as a private partner. All other studies were sponsored, at least in part, by DuPont.

Meta-analysis

The results of the random-effects model on energy intake at a subsequent *ad libitum* meal at lunch time (SMD = 0.35) indicate that the meta-analysis significantly ($P < 0.01$) favors polydextrose over the placebo (Fig. 2A). The Higgins I^2 statistic for this variable was zero, evidencing the high consistency of data. In addition, the indicator from the Egger's test was not significant ($P = 0.25$), confirming a low level of bias.

Table 1
Meta-analysis of energy intake levels at *ad libitum* lunch, during the rest of the day or 'dinner', and daily energy intake of the studies included in the review, for males and females.

	n	SMD [95% CI]	*P*-value	I^2	Egger's test
Males					
EI at *ad libitum* lunch	79	0.47 [0.21, 0.73]	<0.01	<0.01	0.34
EI during the rest of the day or 'dinner'	36	0.04 [–0.29, 0.38]	0.80	<0.01	0.86
Daily EI	36	0.30 [–0.03, 0.64]	0.08	<0.01	0.92
Females					
EI at *ad libitum* lunch	41	0.44 [0.14, 0.74]	<0.01	<0.01	0.28
EI during the rest of the day or 'dinner'	33	–0.01 [–0.33, 0.32]	0.97	<0.01	0.01
Daily EI	33	0.17 [–0.15, 0.49]	0.29	<0.01	0.11

EI, Energy intake; *n*, Number of participants in the included studies; SMD (95% CI), Standardized Mean Difference at 95% Confidence Interval; I^2, Higgins statistic.

Similarly, the random-effects results which were calculated for the levels of energy intake during the rest of the day or 'dinner' (SMD = –0.01) and the total daily energy intake (SMD = 0.18), were not statistically significant (Fig. 2B and C). Nevertheless, the Higgins I^2 statistics for these variables were also zero and the results of the Egger's statistical test were also deemed not significant.

When data-sets from males and females were examined separately, the findings were consistent with the results of the whole group (Table 1) indicating that sex is not an influencing factor.

Linear regression equations

The levels of energy intake were reduced at an *ad libitum* lunch in a dose-dependent manner according to the equation of the regression model (Fig. 3A):

$$EI_{Lunch}\,(\%) = -0.67 \times \text{Polydextrose}\,(\text{g/day})\,[R^2 = 0.80; P < 0.01]$$

Changes in energy intake levels during the rest of the day were disparate (Fig. 3B). Consequently, the equation of the regression model for energy intake levels during the rest of the day or 'dinner' was not statistically significant:

$$EI_{Dinner}\,(\%) = 0.09 \times \text{Polydextrose}\,(\text{g/day})\,[R^2 = 0.10; P = 0.48]$$

Daily levels of energy intake were reduced in a dose-dependent manner according to the equation of the regression model (Fig. 3C):

$$EI_{Daily}\,(\%) = -0.35 \times \text{Polydextrose}\,(\text{g/day})\,[R^2 = 0.68; P < 0.05]$$

Again, when data-sets for males and females were examined separately, the findings were consistent with the results of the whole group (Table 2).

Discussion

The reduction of energy intake – whether by pharmacological, surgical, or behavioral means – remains at the heart of the majority of corrective treatments for obesity (Blundell & Gillett, 2001). Therefore, there is a great interest in identifying ingredients that suppress appetite and reduce subsequent voluntary energy intake. Dietary fibers represent a potential aid to help control subsequent energy intake (Burton-Freeman, 2000; Davis et al., 2006; Tucker & Thomas, 2009).

Polydextrose is recognized as a dietary fiber (FAO/WHO, 2009). Six full reports were included in this systematic review and meta-analysis on energy intake levels. The doses of polydextrose tested

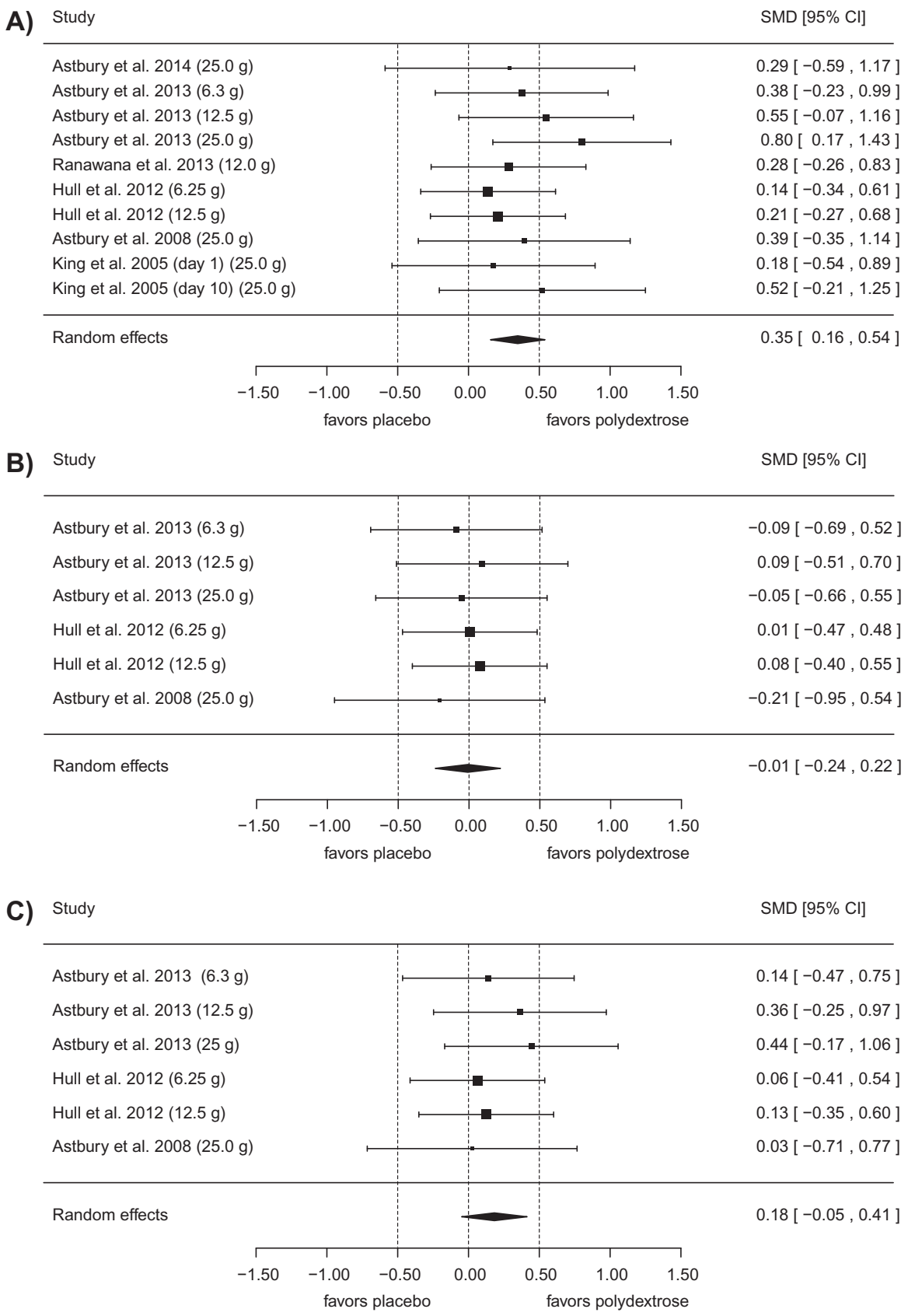

Fig. 2. Meta-analysis comparing doses of polydextrose versus control in the studies included in the review of levels of energy intake (A) at *ad libitum* lunch, (B) during the rest of the day or 'dinner', and (C) daily energy intake. Doses of polydextrose per day used in each treatment are presented in brackets next to each reference.

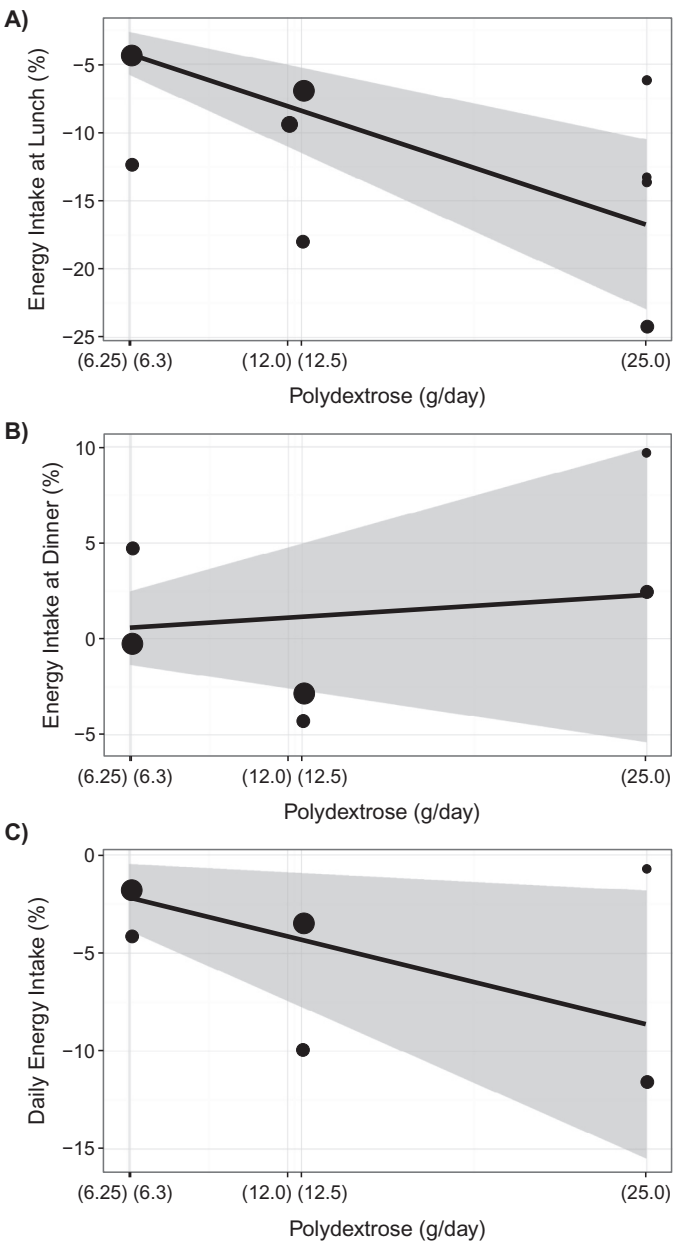

Fig. 3. Linear regression equations for relative changes in energy intake (%) versus doses of polydextrose per day that were used in the studies included in the review of energy intake levels (A) at *ad libitum* lunch, EI_{Lunch} (%) = −0.67 × Polydextrose (g/day), [R^2 = 0.80; $P < 0.01$]; (B) during the rest of the day or 'dinner', EI_{Dinner} (%) = 0.09 × Polydextrose (g/day), [R^2 = 0.10; $P = 0.48$]; and (C) daily energy intake, EI_{Daily} (%) = −0.35 × Polydextrose (g/day), [R^2 = 0.68; $P < 0.05$]. The regression line is represented using a solid black line. The grey area around the line is the 95% confidence interval of the fit. The values used in the regression are shown using black circles and the size of each circle is proportional to the number of participants.

in these studies ranged from between 6.25 g and 25.0 g. This range is below the daily laxative threshold for polydextrose which is estimated to be 90 g/day (Flood, Auerbach, & Craig, 2004).

Overall, the included studies had similar characteristics: they were randomized and crossover-designed and used similar methodologies to assess energy intake levels. The study by King et al. (2005) was the only chronic intervention; all other studies were acute trials.

The lack of a full-blinding procedure was the common reason why all the included studies were susceptible to a risk of bias, *i.e.* all participants were found to be only single-blinded to the preload. However, this is a common flaw in the design of appetite suppression trials where investigators have to prepare and administer experimental products on the day of the test. Under these circumstances it is difficult to organize a double-blinding system.

All included studies used procedures to homogenize the effects of energy intake from the previous meal prior to the consumption of the product under investigation. In all studies, except in King et al. (2005), participants were instructed to consume a standardized dinner the day before the test and to avoid excessive physical activity and alcohol. On the day of the test participants consumed a standardized breakfast at home (Astbury et al., 2008, 2013), or at the laboratory (Astbury, 2014; Hull et al., 2012; King et al., 2005; Ranawana et al., 2013). With the studies of Astbury (2014) and Astbury et al. (2008, 2013), the test-day breakfasts were designed to provide 10% of the estimated total daily energy requirement which was calculated by multiplying the basal metabolic rate by the physical activity level for each participant (Schofield, 1985). With the studies of Hull et al. (2012), Ranawana et al. (2013), and King et al. (2005) participants were asked to consume a typical breakfast on the first test day and the energy content was repeated at the subsequent test day to ensure a consistency in energy consumption.

In all the included studies, polydextrose was added as part of a mid-morning snack preload, administered between 1.0 h (Ranawana et al., 2013) and 1.5 h (Astbury, 2014; Astbury et al., 2008, 2013; Hull et al., 2012; King et al., 2005) before the subsequent *ad libitum* test meal at lunch time. In general, all preloads were typical food/beverage formulations, except in Astbury (2014) where 1500 mg of acetaminophen was mixed into each preload so that its presence in the blood could be used as a proxy measure for gastric emptying. The polydextrose and control preloads were isocaloric in all studies, except in King et al. (2005) where the four treatments had different caloric loads. In this last study, the authors had to add the caloric content of the preloads to the different levels of energy intake at the *ad libitum* lunch in order to observe statistical differences between the groups.

All the included studies assessed the subsequent levels of energy intake provided by an *ad libitum* test meal at lunch time. Ranawana et al. (2013) was the only study designed to measure food selection during a buffet lunch. This procedure confirmed that polydextrose reduces the energy intake of nutrients in a homogeneous way as compared with the control. In the other studies, the test meals were homogeneous.

The set-up characteristics of the studies and test meals influenced the energy intake levels at the *ad libitum* lunch. Thus, the studies conducted by Astbury (2014) and Astbury et al. (2008, 2013) showed a high average consumption of energy, between 4362 kJ and

Table 2
Linear regression equations of energy intake levels at an *ad libitum* lunch, during the rest of the day or 'dinner', and daily energy intake of the studies included in the review, for males and females.

	n	Equation	R^2	*P*-value
Males				
EI at *ad libitum* lunch	79	EI (%) = −0.70 × Polydextrose (g/day)	0.84	<0.01
EI during the rest of the day or "dinner"	36	EI (%) = −0.04 × Polydextrose (g/day)	0.01	0.84
Daily EI	36	EI (%) = −0.38 × Polydextrose (g/day)	0.50	0.08
Females				
EI at *ad libitum* lunch	41	EI (%) = −0.57 × Polydextrose (g/day)	0.63	<0.05
EI during the rest of the day or 'dinner'	33	EI (%) = 0.51 × Polydextrose (g/day)	0.25	0.31
Daily EI	33	EI (%) = −0.23 × Polydextrose (g/day)	0.58	0.08

EI, Energy intake; *n*, Number of participants in the included studies; g, Grams; R^2, Coefficient of determination.

5756 kJ among treatments; while energy intake levels recorded in the other three studies were lower at 2766 kJ and 4585 kJ (Hull et al., 2012; King et al., 2005; Ranawana et al., 2013). Overall, males consumed 59% more energy in a subsequent *ad libitum* meal at lunch time than females.

Taking into account the results of all included studies, polydextrose reduces the energy intake at a subsequent *ad libitum* meal at lunch time by 12.5% – as calculated using the overall average of the control and polydextrose groups (4388 kJ and 3839 kJ, respectively). The meta-analysis favors the effect of polydextrose to reduce energy intake at a subsequent *ad libitum* meal at lunch time. The regression equation shows that this effect is dose-dependent and the concentration range of polydextrose used in these studies, between 6.25 g and 25.0 g, allows for the results to be modeled.

The effect of polydextrose to reduce energy intake at a subsequent *ad libitum* meal at lunch time is similar across both sexes. Males reduce energy intake by 13.7% and females by 10.1%. These figures have been calculated using the overall averages obtained from the control and polydextrose groups, i.e. 5262 kJ and 4539 kJ for males and 3242 kJ and 2915 kJ for females, respectively. Accordingly, the meta-analysis favors the effect of polydextrose to reduce energy intake at a subsequent *ad libitum* test meal at lunch time for both sexes, and their regression equations are statistically significant.

Energy intake levels during the rest of the day or 'dinner' were assessed using different methodologies. The study by Hull et al. (2012) was unique in that it measured energy intake at a second *ad libitum* meal at dinner time. The studies of Astbury et al. (2008, 2013) made use of food diaries given to participants who self-reported their energy intake during the rest of the day. Astbury (2014) and Ranawana et al. (2013) did not control energy intake during the rest of the day. King et al. (2005) controlled energy intake levels during the rest of the day using dietary records, but it was not possible to locate the complete data set for this review.

This meta-analysis of the effects of polydextrose on energy intake levels during the rest of the day or 'dinner' did not show a significant difference. Accordingly, the regression equation for this parameter is also not significant and no differences were observed by sex. This confirms previous observations which demonstrate that the effect of polydextrose to reduce energy intake at an *ad libitum* lunch is not compensated for during the rest of the day (Hull et al., 2012).

Daily energy intake levels were calculated by using the sum of all caloric intake levels recorded throughout the day, including breakfast, mid-morning preload, *ad libitum* lunch, and the caloric intake registered during the rest of the day or at dinner. As this calculation is dependent on the use of data from all these highlighted time-points, only the three studies that used all these parameters could be included in the analysis: Astbury et al. (2008), Astbury et al. (2013), and Hull et al. (2012). The meta-analysis on the effects of polydextrose on daily energy intake levels did not show a significant difference. Nevertheless, there is a trend that favors polydextrose to reduce daily energy intake that was demonstrated by the regression equation for the whole group. This result is aligned with the findings of Astbury et al. (2013), who reported that daily energy intake levels were significantly reduced in those groups that consumed 12.5 g and 25 g of polydextrose compared with the control group. Future studies registering daily energy intake levels may help to confirm the efficacy of polydextrose.

It is well established that the menstrual cycle influences the physiology of eating (Asarian & Geary, 2013). Only three included studies enrolled female volunteers: Astbury et al. (2013), Hull et al. (2012), and King et al. (2005). In the study of Astbury et al. (2013), female participants were surveyed only on days 6–12 of their menstrual cycle to minimize hormonal fluctuations. Nevertheless, this review and meta-analysis shows that results by sex are comparable to the results of the entire group.

Epidemiological studies indicate that diets rich in fiber are associated with a lower body weight (Davis et al., 2006; Du et al., 2010; Tucker & Thomas, 2009). Howarth, Saltzman, and Roberts (2001) proposed that fibers may enhance satiety and decrease food intake. Therefore, the findings of this review may indicate that polydextrose, a dietary fiber, is a potential ingredient for developing future appetite suppressing products to reduce energy intake and manage body weight gain.

In conclusion, the measurement of levels of energy intake is a reliable method to evaluate the appetite-suppressing capacity of polydextrose. The studies included in this meta-analysis support the notion that the consumption of polydextrose reduces voluntary energy intake levels at a subsequent meal, which occurs in a dose-dependent manner. This meta-analysis did not show any differences in energy intake during the rest of the day or for the daily energy intake, perhaps due to the limited number of studies that estimated these parameters. Nevertheless, the regression equation demonstrates that there is a dose-dependent effect on the reduction of daily energy intake. Results showed that the effect of polydextrose is similar with both males and females.

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Appendix: Supplementary material

Supplementary data to this article can be found online at doi:10.1016/j.appet.2014.12.099.