Immediate pre-meal water ingestion decreases voluntary food intake in lean young males

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Key words

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Abstract

Purpose: Consuming 375-500 ml of water 30 min before a meal has been shown to reduce energy intake in older, but not younger adults. This study investigated the effects of ingesting a water preload immediately pre-meal (<1 min before eating) on within-meal *ad-libitum* energy intake in non-obese young males.

Methods: Fourteen healthy males (mean (SD) age 27 (3) y, Height 1.83 (0.05) m, body weight 80.47 (9.89) kg, body fat 17.5 (4.0) %, body mass index 24.0 (2.5) kg/m^2) completed a familiarisation trial and two experimental trials in randomised counterbalanced order. Subjects arrived at the laboratory overnight fasted and consumed an *ad-libitum* porridge breakfast. Immediately prior to the meal, subjects consumed either a 568 ml (1 pint) water preload (preload trial) or no preload (control trial). Visual analogue scale questionnaires to assess hunger, fullness and satisfaction were completed before and after the meal in both trials, as well as after the water preload.

Results: Ad-libitum energy intake was greater ($P<0.001$) during control (2551 (562) kJ) than preload (1967 (454) kJ). *Ad-libitum* water intake was also greater ($P<0.001$) during control (318 (226-975) ml) than preload (116 (0-581) ml). The water preload increased fullness and satisfaction and decreased hunger compared to pre-trial ($P<0.001$) and the control trial ($P<0.001$).

Conclusion: This study demonstrates that consumption of a 568 ml water preload immediately before a meal reduces energy intake in non-obese young males. This might therefore be an effective strategy to suppress energy intake in this population and possibly assist with weight management.

Introduction

The global prevalence of obesity and its co-morbidities means that there is a growing need to identify strategies to facilitate appropriate energy balance. In overweight and obese populations, strategies that promote a negative energy balance and subsequent weight loss might be required. However, to prevent the continued rise in obesity prevalence, interventions that attenuate or prevent a positive energy balance and weight gain among healthy weight individuals might also be important [1]. Whilst much research has focused on the effects of the energy containing macronutrients on energy balance [2-4] more recent evidence suggests water might play an important role in facilitating weight management [5]. Consistent with this, a recent systematic review [6] concluded that increased water consumption in combination with a program for weight maintenance/ weight loss, reduced body weight to a greater extent than the program alone.

A number of studies have investigated the effects of ingesting water before a meal on subsequent voluntary food intake [7-9]. Studies have reported that ingestion of a water preload 30 minutes before an *ad-libitum* meal leads to a reduction in energy intake at the meal in non-obese older [8] and obese older adults [9], but not younger adults [7, 8]. The mechanism by which water ingestion before a meal reduces acute energy intake is not fully understood, but might be related to increased gastric distention, producing increased feelings of satiety and decreased hunger. In line with this, data from animal studies suggests that increased gastric distension reduces energy intake [10], possibly via activation of gastric stretch receptors [11]. The provision of water 30 minutes before a meal allows time for the water to empty from the stomach, which will reduce the amount of gastric distention present at the onset of feeding. Given that the rate of gastric emptying for liquid meals is slower in older vs. younger adults [12], reducing the time between preload ingestion and feeding in young adults might increase gastric distention during feeding and reduce *ad-libitum* food intake.

Therefore the purpose of the current study was to investigate the effects of a water preload consumed immediately before an *ad-libitum* meal on subjective appetite sensations and energy intake. The preload was consumed immediately pre-meal to maximise its impact on gastric distension. It was hypothesised that pre-meal water ingestion would suppress appetite and energy intake compared to a no preload control trial.

Methods

Subjects

Fourteen healthy, lean males with age 27 (3) y, height 1.83 (0.05) m, body weight 80.47 (9.89) kg, body fat 17.5 (4.0) %, body mass index 24.0 (2.5) kg·m^{-2} volunteered for this study, which was approved by the University's Ethical Advisory Committee. Subjects were habitual breakfast consumers, non-smokers and had not been on any weight loss/ gain diet during the previous 6 months. Subjects completed a health-screening questionnaire, a three factor-eating questionnaire [13] and provided written consent. G*Power 3.1.6 [14] and unpublished data from our laboratory using the same porridge breakfast with a between trial correlation of 0.83 was used to estimate the required sample size. We estimated an expected difference between trials of ~420 kJ, and using an α of 0.05 and statistical power of 0.8, it was determined that 11 subjects would be required to reject the null hypothesis.

Experimental protocol

Each subject completed a familiarisation trial followed by two experimental trials in a randomised, counterbalanced fashion, separated by ≥7 days. In the 24 h before the first experimental trial subjects weighed and recorded all dietary intake and recorded any habitual physical activity in a diary. They then replicated these diet and activity patterns in the 24 h preceding the second experimental trial. Subjects refrained from any strenuous physical activity, alcohol intake and dietary supplementation during the 24 h pre-trial.

During the familiarisation trial subjects arrived overnight fasted (~10 h) and after voiding, their body weight (in underwear) (Adam CFW 150 scale; Adam Equipment Co Ltd, Milton Keynes, UK) and height (Stadiometer, Seca Ltd, Germany) were measured. Subcutaneous skinfold measurements were obtained from the triceps, biceps, subscapular and suprailiac, and subsequently body fat percentage was estimated using the Siri equation [15]. Subjects then selected their preferred flavour (plain, golden syrup or chocolate) of porridge (Ready Brek, Weetabix, Kettering, UK made with semi-skimmed milk) and were familiarised with the *ad-libitum* meal as described for the control trial. They consumed their preferred flavour of porridge for the familiarisation trial and both experimental trials.

Experimental trials began overnight fasted (~10 h) and at a time typical for each subject to consume breakfast (7-10 am). Subjects voided before body weight (in underwear) was measured. Subjects then entered a custom built feeding booth within an isolated laboratory and ingested either 568 ml water (preload trial) or no water (control trial), before being provided with the *ad-libitum* breakfast meal. The time it took for subjects to consume the water preload was recorded, with subjects consuming the water in 13 (5) s (range 7-21 s). Subjects were provided with a bowl of porridge (90 g dry porridge oats: 420 ml semi-skimmed milk) and a glass of water. Once ½ to ¾ of the bowl had been consumed, it was replaced with a fresh bowl of porridge and this process continued until subjects indicated satiation. Similarly, the drinking water was replaced when required. New bowls of porridge were provided at times determined during familiarisation and specific to the speed of consumption of each subject (approximately every 3-6 min). This ensured that warm food was always available and that finishing a bowl did not act as a cue to stop eating. Subjects were instructed to eat until they were 'comfortably full and satisfied' and to indicate satiation by leaving the feeding booth and sitting in the adjoining laboratory. Subjects had a total time of 30 min in which to eat and remained in the laboratory in isolation for the entire 30 min. Warm food was continuously available throughout the 30 min and once they had left the feeding booth subjects could return and continue eating if they desired, although none did. All subjects had terminated eating within the 30 min. Energy intake was quantified using manufacturer values and by weighing the porridge before and after heating and cooling, as well as before and after the *ad-libitum* meal.

Subjects completed 100 mm visual analogue scale questionnaires [16] for hunger: "how hungry do you feel?", fullness: "how full do you feel?" and satisfaction: "how satisfied do you feel?" after body weight measurement (pre-trial), after the preload in the preload trial (post-drink) and after the 30 min feeding period (post-trial). Verbal anchors “not at all” and “extremely” were placed at 0 and 100 mm, respectively.

Statistical Analysis

Data were analysed using statistical package SPSS 22 (Chicago, USA), and checked for normality of distribution using a Shapiro Wilk test. Subjective appetite perceptions were analysed using two way repeated measures ANOVA, followed by Bonferroni adjusted Wilcoxon signed rank tests. For the purposes of statistical analysis, post-drink appetite perceptions were assumed to be the same as the pre-trial values during the control trial, as the pre-trial and post-drink questionnaires were completed <30 s apart during the preload trial. Food and water intake data were analysed using t-tests or Wilcoxon Signed Rank tests, as appropriate. Normally distributed data are presented as mean (SD), whilst non-normally distributed data are presented as median (range). Differences were accepted as being significant when $P<0.05$.

Results

Pre-trial

Pre-trial body weight was similar for the preload (81.08 (9.69) kg) and control (81.33 (9.49) kg) trials ($P=0.117$). Subjective appetite perceptions of fullness ($P=0.103$), hunger ($P=0.168$) and satisfaction ($P=0.965$) were also not different between trials.

Ad-libitum Meal

Energy intake at the *ad-libitum* meal was 1967 (454) kJ (preload) and 2551 (562) kJ (control) ($P<0.001$; Fig 1), a difference of 22 (14) %. There was no trial order effect, with similar energy intake during the first (2213 (633) kJ) and second (2305 (547) kJ) experimental trials ($P=0.658$). Water ingestion during the *ad-libitum* meal was also reduced during preload (116 (0-581) ml) compared to control (318 (226-975) ml) ($P<0.001$), although including the 568 ml water ingested immediately pre-meal during preload, total water intake was greater during preload (684 (568-1149) ml) ($P<0.001$).

Subjective appetite perceptions

There were interaction effects for fullness, hunger and satisfaction ($P<0.001$) (Table 1). At post-drink, fullness and satisfaction were greater and hunger lower during preload than during control ($P<0.001$). Compared to pre-trial, fullness and satisfaction were increased and hunger decreased at post-trial during both trials ($P<0.001$), as well as at post-drink during preload ($P<0.001$).

Discussion

This study examined the effect of immediate pre-meal water ingestion on acute *ad-libitum* energy intake. The main finding was that consumption of 568 ml (1 pint) of water immediately before breakfast reduced *ad-libitum* energy intake at the breakfast by 22%. Furthermore, subjective feelings of hunger were decreased, whilst fullness and satisfaction were increased immediately after the water preload.

A number of previous studies have investigated the effect of pre-meal water ingestion on *ad-libitum* energy intake at a single meal [7-9], with water ingested either 30 min or 60 min before the *ad-libitum* meal. Studies of obese [9] and non-obese [8] older adults (~60 y of age) have reported that a water preload ingested 30 minutes before a meal, reduces *ad-libitum* energy intake at the meal compared to a no preload trial. In contrast, studies of young adults have observed no effect on *ad-libitum* energy intake compared to a no preload control trial when water preloads are provided 30 minutes before a meal [7, 8], 60 minutes before a meal [7] or during a meal [7].

What accounts for the divergent responses of young and old to a water preload ingested 30 min before feeding is not clear, but Van Walleghen et al. [8] suggest it might be related to differences in gastric emptying rates. Indeed, Clarkston et al. [12] demonstrated that gastric emptying of both liquids and solids is delayed by ~26% and 30%, respectively, in old compared to young subjects. The gastric emptying rate of a liquid is linearly related to the energy density of the liquid [17], with more energy dense liquids emptying from the stomach more slowly. Consequently, water empties from the stomach very rapidly and Vist and Maughan [18] reported that 30 min after ingesting 600 ml water, only 44 ml remained in the stomach of a group of young (21-44 y) males. Therefore a water preload ingested 30 min prior to an *ad-libitum* meal will be almost completely emptied from the stomach by the time of the meal, at least in healthy young populations, and thus is unlikely to influence *ad-libitum* energy intake.

The current study was designed to maximise feelings of gastric distention during feeding, and as such the water preload was provided immediately before the *ad-libitum* meal. The results of this study contrast with these previous studies in young populations [7, 8] and suggest that the preload-to-meal time interval might be an important consideration for the efficacy of a water preload in reducing acute energy intake. Research on energy containing preloads suggests that a preload-to-meal time interval of 30 minutes is optimal for maximising the impact of a preload on acute *ad-libitum* energy intake [19]. However, the mechanism by which an energy containing preload impacts *ad-libitum* energy intake is unlikely to be the same as for water. Therefore, the optimal time interval between preload ingestion and feeding is unlikely to be the same for energy-containing and energy-free preloads. The present study only tested one volume of preload (i.e. 568 ml) and one preload-to-meal time interval (i.e. immediately pre-meal). Future studies should manipulate the preload volume and preload-to-meal time interval to maximise the impact on energy intake.

The most plausible explanation by which pre-meal water intake reduced *ad-libitum* energy intake is likely to be gastric distension caused by increased gastric fill. Consistent with this hypothesis, animal studies have demonstrated that increased gastric distension, via an intra-gastric balloon, reduced *ad-libitum* energy intake [10], likely via vagal nerve stimulation [11]. The water preload ingested in the present study increased perceptions of stomach fullness from 16 (1-45) mm to 55 (2-75) mm, suggesting the volume was sufficient to produce, at least some, gastric distension. Water empties rapidly from the stomach, with a half emptying time of approximately 10 min [18]. Most subjects remained in the feeding booth for <10 min and thus a relatively large volume of water would be present in the stomach throughout feeding, resulting in increased feelings of gastric distention during feeding. Whilst *ad-libitum* energy intake appears to be suppressed at a single meal, future studies should extend these findings by examining whether this reduction in energy intake during feeding influences appetite perceptions in the hours after eating or energy intake at subsequent feeding opportunities. Furthermore, water intake was reduced during feeding following the water preload. Whilst we only provided water with the *ad-libitum* meal, in free living situations energy containing drinks might be consumed with a meal and if peri-prandial fluid intake is reduced, energy intake through energy containing drinks might also be reduced.

In a cross-sectional study Popkin et al [20] reported that those that consume water have a lower daily energy intake (~200 kcal/ day) than those that don't consume water [20]. Stookey et al. [21] conducted secondary analyses of a weight loss intervention trial and demonstrated that among dieters with a low baseline water intake, increasing water to >1 litre per day was associated with increased weight loss. These studies suggest that daily water intake appears to be important for weight management, but only one study has tested the chronic effects of pre-meal water preloads on weight loss [5]. Dennis et al. [5] examined the effect of ingesting a 500 ml water preload 30 min before breakfast, lunch and dinner in overweight and obese middle aged and older adults consuming a prescribed hypocaloric diet for 12 weeks. Compared to a no preload control group, the water preload group lost 44% more weight (~2 kg). The present study suggests that immediate pre-meal water ingestion might be a strategy that could help facilitate weight management among younger adults.

In conclusion, the results of the present study demonstrate that consuming a 568 ml water preload immediately before a meal reduced perceptions of hunger, increased perceptions of fullness and satisfaction and resulted in a 22% reduction in *ad-libitum* energy intake in young lean males. Future studies should investigate the acute energy intake effects of immediate pre-meal water ingestion in lean young females and overweight/ obese young males and females, as well as examining the chronic weight loss effects of such a dietary strategy.

Conflict of interest

The authors declare they have no conflict of interest.

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Figure legends

Figure 1. Energy intake (kJ) at an *ad-libitum* breakfast for each participant immediately after consuming 568 ml water (preload) or no water (control).

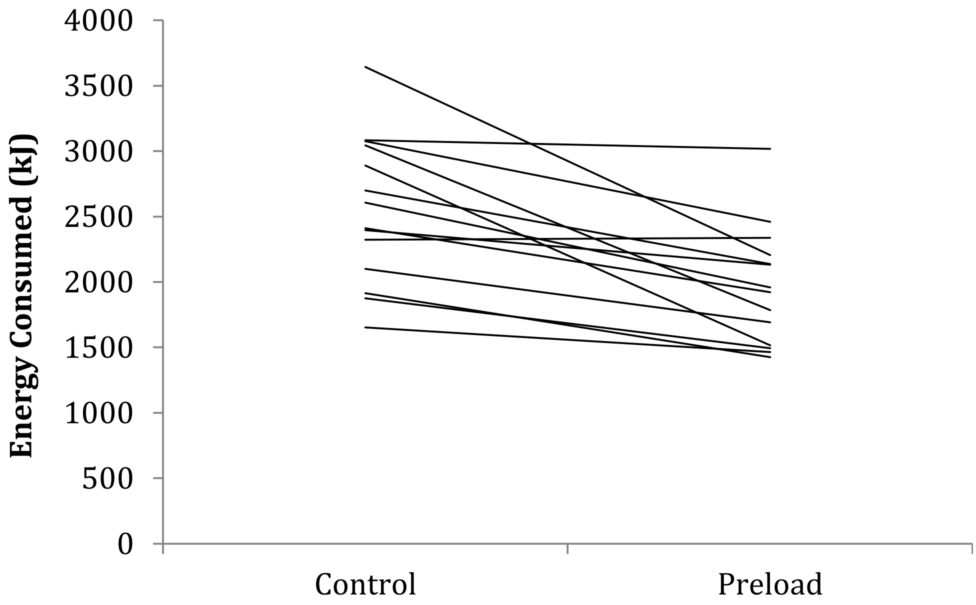
Table

Table 1. Subjective feelings of fullness, hunger and satisfaction rated on 100 mm visual analogue scales with verbal anchors “not at all” and “extremely” at 0 mm and 100 mm, respectively. Values are median (range).

		Pre-trial	*Post-Drink*	*Post-trial*
Fullness (mm)	Control	16 (1-43)	16 (1-43)	91 (74-100)*
	Preload	16 (1-45)	55 (2-75)*#	88 (67-100)*
Hunger (mm)	Control	74 (23-98)	74 (23-98)	5 (1-17)*
	Preload	77 (59-97)	63 (27-91)*#	7 (2-19)*
Satisfaction (mm)	Control	21 (4-46)	21 (4-46)	86 (54-96)*
	Preload	22 (5-47)	31 (12-67)*#	84 (62-99) *

* Significantly different from pre-trial (P<0.05). # Significantly different from control trial (P<0.05).

Figure 1



4000
3500
3000
2500
2000
1500
1000
500
0
Energy Consumed (kJ)
Control
Preload