Title: LIMITED COMPENSATION AT THE FOLLOWING MEAL FOR PROTEIN AND ENERGY INTAKE AT A LUNCH MEAL IN HEALTHY FREE-LIVING OLDER ADULTS

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ABSTRACT

Various interventions have previously been found to increase protein intakes in older adults, but in free-living individuals, compensation for increased intakes at one meal may easily negate these effects resulting in limited long term benefit. This study investigated the impact of adding sauce to an older person's lunch meal on intakes at that meal, at the following meal and overall (lunch + evening meal). Using a repeated measures design, 52 participants consumed both a lunch meal with sauce and the same lunch meal without sauce on two separate occasions, and intake at this meal and at the following meal were measured. In all participants analysed together, the addition of sauce resulted in increased protein intakes at the lunch meal. Individual differences were also found, where for some individuals (n=26), the addition of sauce resulted in significantly higher protein and energy intakes at the lunch meal (12.3g protein, 381kJ) and overall (11g protein, 420kJ), compared to the no-sauce condition, while for some individuals (n=19), the sauce manipulation resulted in lower protein and energy intakes (lunch: 7g protein, 297kJ; overall: 7g protein, 350kJ). Compensation for earlier intakes was low (0-17%) for both groups. These findings demonstrate the possible value of adding sauce to an older person's meal for increasing intakes, and demonstrate a need for attention to individual differences. This study also confirms previous findings of limited compensation in older adults, but extends earlier studies to demonstrate limited compensation for the protein consumed in a complete meal in healthy older adults.

INTRODUCTION

Low protein intakes are currently thought to affect 8-77% community-dwelling older adults in the UK, US and across Europe[1-5], with resultant impacts on protein status[6-8], and various conditions associated with ageing, including decreased muscle mass and size, decreased bone mass and bone mineral density, increased incidence of falls, frailty, and osteoporotic fractures, decreased functional abilities, mobility and independence, decreased immune function, increased risk of infection, increased hospital stays, and increased morbidity and mortality[7-17].

Lower food intakes with age are largely attributed to deteriorations in appetite, changes in chemo-sensory abilities, and deteriorations in dentition, manual dexterity, and gastro-intestinal function[18-29], and studies suggest particular impacts on the consumption of protein-rich foods as a result of these changes[19,22,28-30].

Interventions that propose solutions based on these causes have demonstrated improvements in intakes[22,31-33]. We have reported increased protein intakes following the addition of sauces and seasonings to an older person's meal[31,32] as a result of improvements in taste[32], Kossioni et al, report increased protein intakes following the use of smaller cuts or pre-prepared meats by older adults[22], and Kelsheimer et al, report increased protein intakes following the use of specialized tools for older adults[33]. Not all individuals in these studies however, report benefits[22,33], and for interventions to impact on health and functional outcomes moreover, these higher intakes must be repeated and sustained over time. While sustained increases in intakes have been reported in individuals living in environments where intakes can be supervised (hospital and residential settings)[34,35], sustained increases may be more difficult to achieve in free-living individuals, where eating patterns tend to be less supervised, more flexible and less well structured. For these individuals, increases in food intake at a single meal as a result of an intervention may easily be negated by decreased consumption at the next meal.

Studies investigating compensation for earlier intakes at a subsequent meal largely suggest that older individuals compensate poorly, and thus that increased intakes at any one eating experience will result in an increased intake overall[36-38]. Giezenaar et al 2015[37] report only 1-5% compensation for a between-meal supplement on subsequent meal intake in healthy older men, Keene et al 1998[38] demonstrate only 23% compensation in healthy older adults, and we[36] have demonstrated a linear decrease in compensation with increasing age, again in healthy adults, where each increasing year of age was associated with a 2.4% reduction in compensation.

Not all studies however demonstrate low compensation in healthy older adults. Strum et al, 2003[39] and Zandstra et al, 2000[40] report 70% compensation and significant decreases in energy intake at a meal 90 mins after an ice-cream and a yoghurt preload respectively, compared to control. Individual differences may explain the variety of findings between studies. All these studies furthermore investigate compensation using a between-meal eating experience, often composed of a liquid or semi-solid food, typically also with a low protein content, while a recent systematic review on compensation in a much wider range of studies[41] suggests differing effects over differing time intervals, better compensation for solid as opposed to liquid foods, and likely differences as a result of macronutrient content[41]. While macronutrient content was not investigated in this review, individual studies suggest better compensation for protein-rich foods, compared to other foods[42,43].

Differential effects based on inter-meal time interval, food form, and macronutrient content have implications when generalizing from the above studies to questions of compensation following an intervention to increase protein intake. No studies, as far as we are aware, have investigated compensation for the protein consumed in a complete meal at the next meal in healthy older adults.

The purpose of this investigation was three-fold. Firstly, we aimed to replicate earlier findings that the addition of sauce to an older persons lunch meal can increase protein intakes in healthy older adults at that meal[31,32]. Secondly, we aimed to extend these group-based findings to investigate differences between individuals. Thirdly, we aimed to investigate compensation for any increased intakes at the lunch meal, through the assessment of protein intakes at the following meal and overall (lunch + evening meal). We hypothesised that the addition of sauce to an older persons lunch meal would result in increased protein intakes at the lunch meal, and would have no impact on intakes at the evening meal, as a result of limited compensation, to result in increased protein intakes overall.

METHODS

The study was conducted over two consecutive meals – a lunch meal and the subsequent evening meal, provided to participants on two separate study days. At one lunch occasion, sauce was added to the lunch meal, while on the other occasion no sauce was added. Intakes at lunches and evening meals were investigated.

Participants

Adults aged 65 years and over were suitable for the study if they were community-dwelling (i.e. were living in their own homes), were non-smokers, had no known food allergies, had no known taste or appetite abnormalities, were not taking any medication known to impact on taste or appetite, were familiar with and liked all foods in the study, could understand and comply with all study procedures and were able to come to the university for testing. The study was given ethical approval by the Research Ethics Committees of the School of Psychology, Queen's University, Belfast, UK and Bournemouth University, UK. The work was conducted in accordance with the Guidelines of Ethical Conduct from the British Psychological Society, and the Declaration of Helsinki. All participants provided informed consent prior to their involvement in the study.

Lunch Meal

On both study days, the lunch meal provided consisted of oven-baked *Tesco (Cheshunt, UK)* chicken pieces (300g), boiled *Tesco (Cheshunt, UK)* sweetcorn (250g), boiled *Tesco (Cheshunt, UK)* carrots (250g), and *Tesco (Cheshunt, UK)* mashed potatoes (325g). The meal is a standard UK cooked meal that was familiar to all participants, was served hot, and as presented provided 3900kJ energy, 80g protein, 22g fat and 98g carbohydrate. Large portions were provided to allow *ad-libitum* intake, but unusually large portions were also avoided as these can be off-putting for older individuals[18]. On one study day, 100g *Tesco (Cheshunt, UK)* chicken gravy (212kJ, 0.3g protein, 3.3g fat, 4.0g carbohydrate) was also provided with the meal. On the other study day, the meal was provided with no sauce or other condiments. Order of sauce / no sauce conditions were randomised between participants. On each study day, participants were instructed to 'consume as little or as much as you wish, please eat until you are comfortably full', and were given 30 minutes. Water was freely available during the meal. Following the meal, all participants were offered a cup of tea or coffee, as they usually take it. This drink was offered in place of a dessert. All participants received the same drink after both lunch meals.

Evening Meal

On both study days, the evening meal provided consisted of 8 slices *Hovis (High Wycombe, UK)* Best of Both bread (304g), one pot of 'I can't believe it's not butter' spread (*Unilever, London, UK*) (250-500g), one pot of *Branston (Birmingham, UK)* pickle (180-360g), one pot of Hellman's mayonnaise (*Unilever, London, UK*) (100-200g), 100g grated *Tesco (Cheshunt, UK)* cheddar cheese, 100g *Tesco (Cheshunt, UK)* sliced ham, 2 *Wall's (Poole, UK)* sausage rolls (120g), 3 *Tesco's (Welwyn Garden City, UK)* mini Pork pies (150g), 50g *Florette* (*Staffordshire, UK)* salad leaves, 50g *Walkers (Leicester, UK)* ready salted crisps, 3 Cadbury's *(Premier Foods Group Ltd., London, UK)* individual chocolate swiss rolls (77g), 3 Mr Kipling's *(Premier Foods Group Ltd., London, UK)* individual apple pies (177g), 8 *Tesco (Welwyn Garden City, UK)* Highland shortbread biscuits (144g), and 400g *Princes (Liverpool, UK)* Fruit Cocktail in Juice. The foods are standard cold buffet meal and picnic-type foods used in the UK. Excluding the contribution from the sandwich spreads (butter, pickle, mayonnaise), the meal provided 17,890kJ, 118g protein, 223g fat, 202g carbohydrate. Amount of sandwich spreads provided varied per individual, based on the amount remaining in the pot following previous use. With the exception of the amount of sandwich spreads provided, the meal was identical on both study days, and sandwich spread provision did not differ systematically between conditions. On each study day, participants were instructed to 'consume as little or as much as you wish, please eat until you are comfortably full', and were given 30 minutes. Water was freely available during the meal.

Outcome Measures

Test Meal Intake: Food intake at both lunch and evening meal was assessed by weighing all individual food items provided and returned[44,45], and nutrient intakes were calculated based on standard food composition tables[46] and manufacturer's information.

Subjective Perceptions of Appetite: Appetite was assessed before and after each meal using 100mm visual analogue scales (VAS)[45] of hunger ('*How hungry are you?', 'not at all' - 'extremely'),* desire to eat ('*How strong is your desire to eat?', 'not at all' – 'extremely')*, thirst (*'How thirsty are you?', 'not at all' – 'extremely'),* and desire to drink (*'How strong is your desire to drink?' 'not at all' – 'extremely')*.

Subjective Perceptions of Liking, Taste and Familiarity: Perceptions of liking and taste were also assessed following each meal using 100mm VAS of pleasantness ('*How pleasant was this meal?', 'not at all', 'extremely')*, tastiness (*'How tasty was this meal?', 'not at all', 'extremely'),* and familiarity (*'How familiar was this meal?', 'not at all', 'extremely')*.

Procedure

The study was run in the Eating Behaviours Unit at Queen's University, Belfast, UK, and in the Eating Behaviours Laboratory at Bournemouth University, UK, and was conducted using standard procedures for investigating appetite[44,45], and identical procedures in the two locations. The study was conducted in two locations following movement of the Principal Investigator. In each location, the study was conducted on two separate study days, held at least one week apart. On each study day, lunch was provided at 12pm, 12.30pm, or 1pm, depending on participant preferences, and evening meal was served 4.5 hours later at 4.30pm, 5pm, or 5.30pm respectively. An inter-meal interval of 4.5 hours was used to represent the usual eating patterns of older individuals in the UK, and meal times were otherwise selected for practical reasons. For each meal, participants consumed alone, in an individual booth with no decoration. Participants were required to stay for the whole 30 minutes for each meal, and were told prior to the start of the study that on each day that they were not expected to consume anything after the evening meal, excepting drinks. Participants were asked to consume the same breakfast on each study day, and this was recorded and checked on entry into the laboratory. Participants were also instructed not to consume anything between breakfast and lunch, and lunch and evening meal excepting water, and were asked not to drink alcohol or do any heavy exercise the day of the study or the day before. Compliance with all instructions was verified by asking.

Analyses

Means and standard deviations for all outcome measures were calculated, and inferential statistics were undertaken using usual hypothesis-testing procedures. To investigate the replication of previous studies[31,32], data from the lunch meal were analysed at the group level using paired t-tests comparing no sauce vs. sauce conditions, where intakes in the sauce condition were analysed both for all foods including the sauce – the complete meal, and all foods excluding the sauce - the core meal. Comparisons between the core meal of the sauce condition and the no sauce condition are of greatest theoretical interest, as increased intakes of the complete meal may occur solely as a result of increased provision[47-49]. However, comparisons between the complete meal of the sauce condition and the no sauce condition may also be of practical interest. Results from the t-tests are written in the form: t statistic (degrees of freedom) = …, followed by the significance (p value) of the statistic, as is usual practice. P values less than 0.05 were considered statistically significant.

To investigate differences between individuals, data at the lunch meal were inspected at an individual level, to identify those who responded to the sauce manipulation with an increase in protein intake, compared to those who responded to the sauce manipulation with a decrease in protein intake. A response was arbitrarily defined as a change in protein intake of 1g, to avoid confusion with those showing no response (at a 20% error based on previous studies[31,32]). Groups were compared using Chi-squared tests and paired t-tests. Results from Chi-squared tests are written in the form: Chi-squared statistic = …, degrees of freedom = …, followed by the significance (p value) of the statistic, as is usual practice. P values less than 0.05 were considered statistically significant.

To investigate compensation, data on following meal intake and overall intake were investigated using 2 x 2 mixed Analyses of Variance (ANOVA) to investigate differences between sauce and no sauce conditions in those who reported higher intakes in response to the sauce manipulation and those who reported lower intakes. Participant groups were analysed separately to avoid combining effects as a result of higher and lower intakes. Results from the ANOVA tests are written in the form: F statistic (degrees of freedom) = …, followed by the significance (p value) of the statistic, as is usual practice. P values less than 0.05 were considered statistically significant. Percentage compensation for lunch intake at the evening meal was also calculated by dividing the difference between conditions in evening meal intakes, by the difference between conditions in lunch intakes, and multiplying by 100%. Initial analyses were conducted to investigate differences due to location, but no effects were found, thus, to avoid reductions in power, location was not included in the main analyses.

RESULTS

A total of 52 adults (21 male, 31 female) completed the study. Participants had a mean age of 71.1 ± 4.6 years (range = 65 – 86 years), and an average body weight of 71.1 ± 12.0 kg (range = 47.8 – 87.6 kg) and BMI of 25.8 ± 2.5 kg/m^2 (range = 20.7 – 30.9 kg/m^2). An additional four individuals were initially also recruited into the study, but failed to complete it, thus their data were not included in analyses. Two participants did not return for their second visit, and two participants admitted failing to adhere to the protocol on debriefing.

Lunch Meal

Intakes (energy (kJ), weight (gr) and grams of protein, fat and carbohydrate) at the lunch meal in no sauce and sauce conditions (core meal / complete meal) are given in Table 1. Considering only the core meal (excluding sauce), protein intakes were significantly higher in the sauce condition compared to in the no sauce condition ($t(51)=2.09$, $p=0.04$), while no other differences in intake were significant (largest (energy) $t(51)=1.82$, $p=0.08$). Considering the complete meal (including sauce), energy, protein, fat, carbohydrate and weight consumed were higher in the sauce condition compared to in the no sauce condition (smallest $t(51)=2.15$, $p=0.04$).

Subjective measures are given in Table 2. Participants reported the sauce meal to be significantly more pleasant, tasty and familiar than the no sauce meal (smallest $t(51)=2.98$, $p<0.01$), and reported a lower desire to eat following the sauce meal compared to the no sauce meal ($t(51)=2.43$, $p=0.02$). No differences were found in other subjective measures (largest $t(51)=1.88$, $p=0.07$).

Tables 1 and 2 about here

Lunch Meal – Individual responses

Using a cut-off of 1g protein, 26 participants demonstrated higher protein intakes in response to the sauce manipulation, 19 participants demonstrated lower protein intakes in response to the sauce manipulation, and 7 participants demonstrated no impact.

Intakes (energy (kJ), weight (gr) and grams of protein, fat and carbohydrate) at the lunch meal in no sauce and sauce (core meal / complete meal) conditions in participants who demonstrated higher protein intakes following the sauce manipulation, and in individuals who demonstrated lower protein intakes are given in Table 3. Interactions were found between participants who demonstrated higher protein intakes and those who demonstrated lower protein intakes in all measures (smallest $F(1,43)=5.82$, $p=0.02$). Individuals who demonstrated higher protein intakes ($N=26$) reported significant increases in energy, protein and fat intake in the sauce condition (core meal) (smallest $t(25)=4.86$, $p<0.01$) and significant increases in all measures in the complete meal (smallest $t(25)=3.12$, $p=0.01$), compared to the no sauce condition. In the participants for whom sauce resulted in lower protein intakes ($N=19$), the addition of sauce to the lunch meal resulted in significantly lower energy, protein, fat and weight intakes from the core meal (smallest $t(18)=3.11$, $p=0.01$), and significantly lower energy and protein intakes (smallest $t(18)=3.29$, $p<0.01$) and significantly higher weight intakes ($t(18)=2.27$, $p=0.04$) in the complete meal, compared to the no sauce condition.

No differences were found between individuals who demonstrated higher protein intakes and lower protein intakes in response to the sauce manipulation in gender, age, location, or condition consumed first (largest $X^2=2.41$, $df=1$, $p=0.14$). No differences or interactions between groups were found in subjective ratings (largest $F(1,43)=3.01$, $p=0.09$) (Table 4).

Tables 3 and 4 about here

Compensation

Intakes (energy (kJ), weight (gr) and grams of protein, fat and carbohydrate) at the following meal, and over both meals in no sauce and sauce (core meal / complete meal) conditions in participants who demonstrated higher protein intakes following the sauce manipulation, and in individuals who demonstrated lower protein intakes are given in Table 5. No differences or interactions between condition and group were found in measures at evening meal intake (largest $F(1,43)=1.70$, $p=0.20$). No differences or interactions between condition and group were found in subjective measures at the evening meal (largest ($F(1,43)=3.35$, $p=0.07$) (Table 6).

In overall intakes (lunch + evening meal), significant interactions were found in measures of energy and protein intake (core meal), and in measures of energy, protein and weight consumed (complete meal) (smallest $F(1,43)=6.80$, $p=0.01$). Individuals who demonstrated higher protein intakes demonstrated significantly higher energy and protein intakes (core meal) (smallest $t(25)=2.05$, $p=0.05$), and significantly higher energy, protein and weight intakes (complete meal) (smallest $t(25)=2.44$, $p=0.02$) in the sauce condition compared to the no sauce condition. In the participants for whom the sauce resulted in lower intakes in response to the sauce manipulation, significantly lower energy and protein intakes (core meal) (smallest $t(18)=2.15$, $p=0.05$) and significantly lower protein intakes (complete meal) ($t(18)=3.84$, $p<0.01$) were found in the sauce condition compared to the no sauce condition. Significantly higher weight intakes were also found in the sauce condition (complete meal) compared to the no sauce condition ($t(18)=2.95$, $p=0.01$).

Individuals who demonstrated increased protein intakes in response to the sauce manipulation demonstrated a mean 11% compensation for the increased protein intake at lunch, at the evening meal, and a mean 10% compensation for the increased energy intake. Individuals who consumed less protein following the addition of sauce demonstrated 0% compensation for the higher protein at the no sauce meal, and 17% compensation for the energy, in the following evening meal.

Tables 5 and 6 about here

DISCUSSION

Several key findings emerge from this study. Firstly, in the group as a whole, the addition of sauce to an older persons’ lunch meal resulted in greater protein intakes at that meal when considering the core meal (sauce excluded), greater energy, protein, fat, carbohydrate and weight intakes when considering the complete meal (sauce included), and higher ratings of pleasantness, tastiness and familiarity. These findings demonstrate the value of adding sauce to an older person's meal for improving protein intakes. Improvements in energy, protein, fat, carbohydrate and weight intakes in the complete meal were found as a result of the greater provision of these items in the meal with added sauce, and plenty of other studies demonstrate increased intakes as a result of increased provision[47-49]. However, greater protein intakes were also found in the core meal (without consideration of the included sauce), as a result of the selective greater consumption of protein-rich foods at this meal. These effects clearly support the use of sauce on an older persons' meal for improving protein intakes. Similar results have been demonstrated previously[31,32]. Similar findings have also previously been suggested to result from the increased pleasantness or tastiness of a meal with added sauce compared to that with no sauce[32], and these effects are confirmed here.

Secondly, large individual differences were found, where 26 participants demonstrated greater protein intakes by more than 1g in response to the sauce manipulation, and 19 participants demonstrated lower protein intakes by more than 1g in response to the sauce manipulation. Individuals who consumed more protein in response to the sauce manipulation, demonstrated greater energy (381kJ), protein (12.3g) and fat intakes at lunch in the sauce condition compared to no sauce. Conversely, for individuals who consumed less protein in response to the sauce manipulation, lower energy (297kJ), protein (7g), fat and weight intakes were found at lunch. These findings demonstrate a value of the sauce manipulation in some individuals but not in others. Differences were not explained by gender, age, or study methodology, nor by subjective perceptions. Effects due to the addition of sauce to an older person's meal have previously been suggested to result from differences in pleasantness and tastiness, and while effects of pleasantness and tastiness are found here in the whole sample, no differences were found between those who demonstrated higher protein intakes and those who reported lower protein intakes following the sauce manipulation. It is possible that the addition of sauce to an older persons meal results in an irrefutable increase in the pleasantness and tastiness of that meal, but that this increased pleasantness/tastiness for some individuals results in increased consumption while for others results in reduced consumption. Studies generally report increased consumption in response to more pleasant dishes, but variation can be high[50,51], and reports of consumers requiring only limited portions of highly pleasant 'luxury' or 'decadent' dishes are also available[52,53]. We took no measures of these more individual perceptions of the meal. Perceptions of a food as healthy can also increase consumption[30]. We also took no measures of participant restraint, and restraint can have variable effects on intake in the laboratory[44,45]. Nor did we take measures of usual consumption practices, and habit is also a well-known driver of intakes[30], but we anticipated that differences in usual practices would be demonstrated in our familiarity measures, if present. Investigation of the differences between participants would clearly be of interest, but these differences also have practical implications. Advice to add sauce to an older person's meals to improve protein intakes should be given on an individual basis. Practical suggestions include the regular use of table sauces, such as tomato ketchup, mustard and mayonnaise, and the use of packet mixes for sauces such as gravy, parsley sauce, or Bechemel sauce. A range and variety of flavours will likely also be of added benefit[30-32].

Thirdly, no differences were found between conditions or participant groups in evening meal intake for any measure, and overall intakes mirrored those of lunch intakes very closely. All participants compensated minimally (0-11%) in evening meal intake for their higher or lower protein intake at lunch. Low compensation for earlier intake in older individuals has been repeatedly demonstrated previously[36-38]. These findings confirm previous studies that demonstrate low compensation in older individuals[36-38], and extend these findings to demonstrate these effects in community-dwelling older adults, and for solid foods / complete meals involving protein. In literature searches, we could only find four other studies assessing intake in older individuals following the consumption of solid foods[39,54-56]. Strum et al 2003[39] and Simmons et al 2010[54] report decreased meal intakes, and so no effects on overall intake following supplements and snacks, but Smoliner et al 2008[55] report improved protein intakes following the provision of protein-enriched soups, sauces and snacks compared to usual diets, and Stelten et al 2015[56] report low compensation and so increased protein intakes following the provision of protein-enriched bread and drinking yoghurt, compared to regular products. These latter studies[55,56] also investigating compensation for a higher protein intake confirm our findings, despite earlier reports that protein can be more accurately compensated for, than other macronutrients, in younger adults[42,43]. These studies however, involve hospitalised or frail older adults[55,56]. Our study is the first of which we are aware to investigate compensation for an earlier meal in healthy older individuals.

The lack of compensation at the following meal for earlier protein intakes adds weight to arguments for interventions to increase protein intakes at meals for community-dwelling older adults, assuming that the individual responds with a higher consumption. The effect on overall protein intakes, may furthermore be of clinical significance. Based on a current recommended consumption of 0.8g protein / kg body weight / day[8,9,11], an individual who weighs 71.1 kg should be consuming 56.9 g protein / day. Intakes clearly exceeded this value in this study only in the sauce condition in those who responded to the manipulation by increasing intakes (65.8 g protein). If recommendations increase furthermore to 1.2g protein / kg body weight / day (as has been recommended by some)[5,7], an individual who weighs 71.1kg should be consuming 85.3g protein / day.

Maintenance of an adequate protein status in individuals at risk of low protein status will guard against the risks associated with low protein intakes, and the establishment of practices that maintain adequate protein intake will potentially extend preventative effects beyond the time frame of any single intervention. However, some studies demonstrate possible negative effects as a result of increasing protein intakes in some individuals[16,17], and concerns over high protein intakes have been voiced, based on possible impacts on renal activity, bone health and saturated fat intakes and thus on other health conditions[8,9]. These concerns suggest that increasing protein intakes in all individuals may not be advisable, and that individual care is also required. The current study was also conducted under (controlled) laboratory conditions, thus may not extrapolate well to everyday life. While the use of the laboratory allowed the control of many environmental circumstances that may impact on eating[44,45], food choice was necessarily constrained at both meals and intake was constrained over the afternoon, and both of these procedures may have impacts on intake and compensation in the real world[58]. Individuals are also likely to be much more aware of the foods they are consuming in the real world, thus cognitive factors, such as health beliefs, may play an additional role[58]. Our study is also limited by the use of a single meal manipulation and intakes over a single day. Again, this was necessitated by our study design, but compensation or other changes in intake may occur in response to an intervention over time. We also did not compare our intervention with other interventions and make no suggestion that a sauce based intervention may improve intakes more effectively than any other intervention. Educational interventions, for example, have also previously been found to improve protein intakes in healthy older adults[59], and interventions aiming to improve at-home cooking abilities and skills have also reported success for protein-rich foods[22,33]. Benefits have also been reported particularly for interventions that combine exercise with increased protein intakes[9,11], and these may be of particular value for healthy community-dwelling individuals, where small increases in physical activity, even that undertaken in everyday activities, can contribute additional health benefits[60,61].

Conclusion

In conclusion, this study replicates previous studies demonstrating the value of the addition of sauce to an older person's lunch meal for increasing protein intakes, but also demonstrates individual differences in response to this manipulation. For some individuals (n=26), the addition of sauce resulted in large significant increases in protein intakes at the lunch meal, and these effects were maintained when also considering intake at the next meal. For others (n=19), the addition of sauce resulted in decreased intakes at the lunch meal and over both meals. All participants demonstrated limited compensation for their lunch meal intake in the following evening meal. These findings confirm previous findings of low compensation in older adults, but extend these studies to demonstrate limited compensation for the protein consumed in a complete meal in healthy older adults.

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Conflicts of Interest:

There are no conflicts of interest.

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Table 1: Intakes (energy (kJ), weight (gr) and grams of protein, fat and carbohydrate) (mean (sd)), at the lunch meal, in no sauce and sauce (core meal / complete meal) conditions for all participants (N=52)

Intake	No Sauce	Sauce (core meal)[#]	Sauce (complete meal)[##]
Energy (kJ)	1714 (594)[b]	1823 (519)	1913 (527)[b]
Weight (grams)	470 (152)[b]	454 (105)	634 (220)[b]
Protein (grams)	31.6 (12.2)[a,b]	34.2 (13.0)[a]	34.7 (13.0)[b]
Fat (grams)	15.6 (11.7)[b]	15.9 (10.7)	17.7 (10.9)[b]
Carbohydrate (grams)	43.9 (21.6)[b]	40.9 (21.0)	43.9 (21.6)[b]

[#] all food consumed in the sauce condition, excluding the sauce (core meal)

[##] all food consumed in the sauce condition, including the sauce (complete meal)

[a] significant differences (p<0.05) between no sauce and sauce (core meal) conditions

[b] significant differences (p<0.05) between no sauce and sauce (complete meal) conditions

Table 2: Subjective perceptions of appetite and liking, taste and familiarity (mean (sd.)) for the lunch meal in no sauce and sauce conditions for all participants (N=52)

Subjective rating	No Sauce		Sauce	
	Pre-meal	Post-meal	Pre-meal	Post-meal
Hunger (mm)	62 (19)	9 (11)	59 (19)	9 (10)
Desire to eat (mm)	61 (21)	9 (7)[a]	58 (22)	7 (5)[a]
Thirst (mm)	56 (21)	24 (19)	61 (19)	26 (20)
Desire to drink (mm)	58 (22)	26 (18)	61 (21)	27 (21)
Pleasantness (mm)		62 (25)[a]		73 (19)[a]
Tastiness (mm)		61 (24)[a]		72 (20)[a]
Familiarity (mm)		64 (24)[a]		73 (20)[a]

[a] significant differences ($p<0.05$) between no sauce and sauce conditions

Table 3: Intakes (energy (kJ), weight (gr) and grams of protein, fat and carbohydrate) (mean (sd)), at the lunch meal in no sauce and sauce (core meal / complete meal) conditions for participants who demonstrated increased protein intakes (>1g) in response to the sauce manipulation (N=26), and in participants who demonstrated a reduction in protein intakes (>1g) in response to the sauce manipulation (N=19).

Participants	Intake	No Sauce	Sauce (core meal)[#]	Sauce (complete meal)[##]
Higher protein intakes (n=26)	Energy (kJ)	1595 (594)[a,b]	1976 (529)[a]	2051 (546)[b]
	Weight (grams)	466 (156)[b]	494 (101)	716 (229)[b]
	Protein (grams)	27.7 (11.4)[a,b]	40.0 (13.1)[a]	40.5 (13.0)[b]
	Fat (grams)	10.9 (8.5)[a,b]	13.7 (10.1)[a]	15.4 (10.0)[b]
	Carbohydrate (grams)	43.4 (19.4)[b]	47.8 (19.9)	50.9 (20.2)[b]
Lower protein intakes (n=19)	Energy (kJ)	1955 (584)[a,b]	1658 (479)[a]	1776 (493)[b]
	Weight (grams)	477 (112)[a,b]	421 (99)[a]	525 (146)[b]
	Protein (grams)	35.5 (10.7)[a,b]	28.5 (9.9)[a]	29.3 (10.0)[b]
	Fat (grams)	21.8 (13.4)[a]	18.7 (11.8)[a]	20.6 (12.3)
	Carbohydrate (grams)	37.8 (26.5)	33.6 (21.9)	36.6 (22.9)

[#] all food consumed in the sauce condition, excluding the sauce (core meal)

[##] all food consumed in the sauce condition, including the sauce (complete meal)

[a] significant differences (p<0.05) between no sauce and sauce (core meal) conditions

[b] significant differences (p<0.05) between no sauce and sauce (complete meal) conditions

Table 4: Subjective perceptions of appetite and liking, taste and familiarity (mean (sd.)) for the lunch meal in no sauce and sauce conditions for participants who demonstrated increased protein intakes (>1g) in response to the sauce manipulation (N=26), and in participants who demonstrated a reduction in protein intakes (>1g) in response to the sauce manipulation (N=19).

Participants	Subjective rating	No Sauce		Sauce	
		Pre-meal	Post-meal	Pre-meal	Post-meal
Higher protein intakes (n=26)	Hunger (mm)	62 (21)	9 (12)	62 (20)	10 (12)
	Desire to eat (mm)	64 (22)	8 (6)	61 (21)	8 (6)
	Thirst (mm)	59 (19)	28 (22)	64 (18)	30 (20)
	Desire to drink (mm)	62 (20)	31 (20)	65 (18)	31 (21)
	Pleasantness (mm)		59 (27)		72 (19)
	Tastiness (mm)		58 (27)		70 (20)
	Familiarity (mm)		66 (24)		71 (22)
Lower protein intakes (n=19)	Hunger (mm)	60 (16)	8 (7)	53 (19)	8 (7)
	Desire to eat (mm)	58 (19)	11 (7)	53 (24)	8 (4)
	Thirst (mm)	51 (24)	22 (13)	57 (22)	26 (21)
	Desire to drink (mm)	50 (27)	22 (14)	56 (25)	27 (22)
	Pleasantness (mm)		70 (17)		74 (21)
	Tastiness (mm)		67 (19)		72 (21)
	Familiarity (mm)		64 (24)		72 (20)

Table 5: Intakes (energy (kJ), weight (gr) and grams of protein, fat and carbohydrate) (mean (sd)), at the evening meal and overall (lunch + evening meal) in no sauce and sauce (core meal / complete meal) conditions for participants who demonstrated increased protein intakes (>1g) in response to the sauce manipulation (N=26), and in participants who demonstrated a reduction in protein intakes (>1g) in response to the sauce manipulation (N=19).

Intake	Intake	No Sauce	Sauce (core meal)[#]	Sauce (complete meal)[##]
Higher protein intakes (n=26)	Evening Meal Intake			
	Energy (kJ)	3575 (1430)	3614 (1583)	-
	Weight (grams)	501 (168)	508 (206)	-
	Protein (grams)	26.5 (8.1)	25.2 (8.1)	-
	Fat (grams)	54.3 (20.6)	50.1 (20.6)	-
	Carbohydrate (grams)	90.9 (41.8)	94.5 (50.1)	-
	Overall Intakes			
	Energy (kJ)	5170 (1536)[a,b]	5590 (1705)[a]	5665 (1689)[b]
	Weight (grams)	967 (221)[b]	1003 (235)	1201 (378)[b]
	Protein (grams)	54.2 (12.2)[a,b]	65.2 (16.1)[a]	65.8 (16.1)[b]
	Fat (grams)	65.3 (21.9)	63.8 (24.3)	65.5 (24.2)
	Carbohydrate (grams)	134.3 (47.7)	142.3 (51.9)	145.4 (51.7)
Lower protein intakes (n=19)	Evening Meal Intake			
	Energy (kJ)	3276 (708)	3226 (928)	-
	Weight (grams)	450 (109)	471 (141)	-
	Protein (grams)	22.0 (7.1)	22.0 (7.2)	-
	Fat (grams)	61.0 (32.0)	61.8 (40.1)	-

	Carbohydrate (grams)	76.2 (39.2)	74.5 (36.2)	-
	Overall intakes			
	Energy (kJ)	5232 (1177)[a]	4884 (1152)[a]	5002 (1177)
	Weight (grams)	927 (181)	892 (174)	833 (268)
	Protein (grams)	57.5 (12.7)[a,b]	50.5 (11.5)[a]	51.2 (11.6)[b]
	Fat (grams)	82.8 (39.9)	80.5 (48.5)	82.4 (48.9)
	Carbohydrate (grams)	114.1 (64.3)	108.1 (56.8)	111.1 (57.8)

[#] all food consumed in the sauce condition, excluding the sauce (core meal)

[##] all food consumed in the sauce condition, including the sauce (complete meal)

[a] significant differences (p<0.05) between no sauce and sauce (core meal) conditions

[b] significant differences (p<0.05) between no sauce and sauce (complete meal) conditions

Table 6: Subjective perceptions of appetite and liking, taste and familiarity (mean (sd.)) for the evening meal in no sauce and sauce conditions for participants who demonstrated increased protein intakes (>1g) in response to the sauce manipulation (N=26), and in participants who demonstrated a reduction in protein intakes (>1g) in response to the sauce manipulation (N=19).

Participants	Subjective rating	No Sauce		Sauce	
		Pre-meal	Post-meal	Pre-meal	Post-meal
Higher protein intakes (n=26)	Hunger (mm)	46 (25)	6 (7)	44 (22)	8 (5)
	Desire to eat (mm)	44 (28)	7 (7)	43 (23)	5 (4)
	Thirst (mm)	46 (23)	20 (17)	54 (20)	21 (15)
	Desire to drink (mm)	44 (23)	24 (18)	53 (23)	21 (15)
	Pleasantness (mm)		66 (17)		70 (14)
	Tastiness (mm)		65 (19)		72 (16)
	Familiarity (mm)		65 (24)		61 (26)
Lower protein intakes (n=19)	Hunger (mm)	43 (24)	5 (4)	37 (28)	5 (5)
	Desire to eat (mm)	43 (24)	7 (4)	36 (30)	7 (6)
	Thirst (mm)	48 (22)	17 (13)	42 (22)	26 (20)
	Desire to drink (mm)	47 (23)	18 (14)	41 (21)	26 (21)
	Pleasantness (mm)		69 (18)		73 (17)
	Tastiness (mm)		68 (17)		72 (18)
	Familiarity (mm)		66 (23)		69 (28)