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EFFECT OF AMINO ACID SUPPLEMENTATION ON SATIETY AND FOOT INTAKE: A CASE-CONTROL STUDY

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ABSTRACT

Lifestyle, especially diet, has been identified to have a variety of effects on different health indices of an individual and recent studies have shown that some certain dietary changes are capable of producing conspicuous changes in different facets of physiological well-being. Nevertheless, nowadays, much attention has been paid to the effect of dietary interventions still a considerable literature gap persists in how meal timing and composition influence postprandial processes in various groups of the population. The evidence from this research has aimed at understanding the health gains likely to occur from some of the dietary modifications among a culturally diverse population group. One hundred participants were involved in the study, and information such as age, sex, height, weight, and BMI for each participant was taken.

The participants disclosed the simple demographic measurements regarding their health, and it was concluded that none of them had life-threatening health conditions prior to the study. Major comorbidities, current medications, dietary restrictions, and precautionary measures were recorded. Outcome measures were systematically recorded both pre-meal and post-meal (30 minutes after meal completion) across three daily meals: breakfast, lunch, and dinner. This design made it easier to assess the various effects of dieting on physiological characteristics. The evidence thus presents substantial differences in the effects on health from diets and supplementation, underpinning the concepts of personalized nutrition. The results also show the effect of diet as one of the components of the quality of human health and the need for further research in the field of nutrition.

KEYWORDS

Obesity; Protein Supplement; Amino Acid Supplement; Dietary interventions; Food consumption patterns; Overeating; Satiety; Food Intake

INTRODUCTION

Being overweight and consuming too much food are significant health issues worldwide, causing an increase in metabolic disorders such as type 2 diabetes and heart conditions. According to the WHO, global obesity rates have tripled in the last forty years, with more than 650 million adults now classified as obese. Being connected to the intake of high-calorie foods is a major factor contributing to this outbreak, impacting the body's usual hunger cues. A lack of interest and eating habits play a key role in obesity as well, as disruptions in controlled processes lead to overeating and eventual weight increase (2). Regulation of hunger and portion sizes is controlled by hormonal signals from the gut to the brain, which is a key focus in the strategy to combat obesity.

Hunger, which is the opposite of feeling full, plays a significant role in determining how much energy we consume and is essential in strategies for successful weight loss through diet. Physiological processes control this through gut hormones, neural pathways, and nutrient absorption mechanisms within the body (4). Proteins, particularly those high in branched-chain amino acids (BCAA), are more likely to induce a feeling of fullness compared to other macronutrients. This is because they are effective in enhancing the secretion of hormones that promote feelings of fullness, such as cholecystokinin (CCK), glucagon-like peptide-1 (GLP-1), and peptide YY (PYY) (2,5). One study found that consuming a high-protein breakfast can result in a reduction in total calories consumed in subsequent meals and increased feelings of fullness.

Satiety regulation occurs at both peripheral and central levels. It releases artificial hormones such as CCK, GLP-1, and PYY, which send messages to the brain, including feelings of fullness. The hypothalamus plays a key role in regulating eating and feeling full by responding to hormonal signals (6). Amino acid substances such as leucine found in food products play a vital role in signalling the neural circuits responsible for regulating appetite. Comprehending these processes is beneficial in developing strategies to manage dieting and prevent binge eating.

Satiety signalling of amino acids: Leucine; tryptophan; phenylalanine; arginine. Among amino acids, BCAA–leucine stimulates anorexigenic hormones such as CCK and GLP-1, causing fullness and decreasing hunger (7). Research on animals and people demonstrates that Leucine intake decreases energy intake while increasing satiety levels (8). Tryptophan, which is an essential amino acid, is involved in causing satiety feelings since it increases the synthesis of serotonin in the brain. Clinical trials also demonstrate that tryptophan administration decreases food consumption in both normal-weight and overweight persons through increasing plasma tryptophan concentration and increasing serotonin turnover (9).

Phenylalanine has also been noted to have functions in the regulation of appetite. Phenylalanine increases the release of GLP-1, which plays a role in increasing satiety and has an effect on insulin release, glucose, and food intake (8). Through the nitric oxide pathway, Arginine slows down the rate of the stomach's ability to empty food, and this resulted in the cooked macaroni giving the participants the full feeling for a longer time, as observed by (8). These results justify the possibility of using amino acids in modulating appetite and support the further application of amino acids in the regulation of food intake.

While particular individual amino acids have been identified to exert satiety effects, little is known about the synergistic manners in which these amino acids within combinations affect food intake. This could be due to the fact that these targets usually isolate individual amino acids in anatomical ways, although there might be synergy where certain combinations can produce higher or prolonged satiety effects if several functions are stimulated. For instance, as leucine and phenylalanine affect gut peptide secretion, few research has been done on a combined insight of the two amino acids (7).

In addition, it has been shown that amino acids such as leucine and lysine can raise plasma concentrations of CCK and decrease food consumption, but whether the stimulation of other hormonal pathways exists and is synergistic with the effects of amino acids is still a matter of question. Perhaps the simultaneous action of leucine on CCK release and tryptophan on serotonin synthesis could give a better picture of the effect of these amino acids on appetite regulation, though the hypothesis has not been investigated in detail (9).

This research aims to address these gaps by investigating the effects of L- leucine, L-tryptophan, and L- phenylalanine on satiety and feeding in an experimental design. The first main purpose is to establish the role played by amino acid supplementation in controlling satiety and food intake among a group of undergraduate students. A case-control study will look into the differences between participants who have been taking amino acids and those who have been taking an isocaloric whey-protein supplement to draw the efficiency of dietary supplementation on the aspect of appetite suppression.

This approach minimizes confounding factors; meal intake and supplementation can be well monitored within college-hostel settings on the aspect of external factors such as physical activities and stress, their effects can also be well measured within college-hostel settings making this study valid.

METHODS

Study Setting

The research was carried out in the women's hostel of an undergraduate college from January-May 2024, and participants were selected from the college's various course offerings. Participants were recruited from the hostel through fliers pasted around the hostel announcing the availability of students for the study. All the meals were prepared, and all the outcome assessments were done in the Department of Zoology because it had facilities and resources for data collection and analysis.

Study Population

The targeted participants included, healthy adults of both sexes with an age range of 18 to 60 years drawn from Health facilities and through social media platforms. In order to control for generalization bias, participants were screened and recruited according to predefined inclusion and exclusion criteria.

Inclusion Criteria: The inclusion criteria included BMI of normal and overweight (from 18.5 to 29.9 kg/m^2), the absence of taking medications that affect appetite and lipid metabolism, a history of metabolic diseases, and food intolerance.

Exclusion Criteria: Unfortunately, pregnant or breastfeeding women, clients on weight loss or restricted diets, and people with recent major diseases or operations were not included in the study.

Lastly, the sample size of 50 patients allocated to the intervention and control groups provided adequate power for statistical testing.

Study Groups

Intervention Supplement: Participants in the interventional study were provided with a special amino acid replenishment that consisted of Leucine, Tryptophan, Glutamine, Arginine, and Phenylalanine. The supplement was given in the morning, afternoon and evening thrice daily for the total duration of the study. Each dose was prepared to contain a specific amount of each of the amino acids serving as the active procedural posit for determining the independent and interactive impact of the nutrients on satiety and food intake.

Control Supplement: Participants in the control group consumed an isocaloric whey protein supplement, which contained a well-balanced distribution of amino acids and, therefore, provided a similar amount of protein as the amino acid supplementation group.

Intervention details

The precise time and day decisions about the administration of the free amino acid supplement or the whey protein supplement (control) were made with regard to the participants. Consumers took their supplement thrice daily, in the morning before breakfast, in the middle of the day before lunch and in the evening before dinner for 14 days. It was also important to note the time of taking the supplement, The particular time taken as supplement was also documented in order to identify any variation. In addition, there was a daily log that had to be filled, in which a participant had to put down time when a supplement was taken. This means that the participants were reminded through phone or text messages for them to stick to the laid down schedule.

Compliance was measured in terms of percentages calculated from the number of doses that the patient has taken from the total doses advised. Adherence was measured by the percentage of prescribed doses ingested and nonadherence was considered when the percentage was below 70%. In situations where it was found that the level of compliance was below the required standard, participants were asked the reasons for non-compliance; and steps were taken to enhance compliance.

Outcome Measures

Data collected with participants included their age and sex, height, weight and Calculation of the Body Mass Index (BMI). The participants' medical history was first assessed to help exclude any participant with possibly a serious medical complaint. The details included herein comprised of any health issues, the current prescribed medication, and the dietary requirements if any.

Besides the demographical and clinical parameters, several outcome measures were documented before (fasting, meaning no food or supplements had been ingested) and after (30 min after meal) each of the three meals comprised in a day: breakfast, lunch, and dinner.

Satiety Assessment: Hunger and satiety were measured using a visual analog scale (VAS), a self-report tool that measures the participant's visual assessment of the amount of hunger and fullness. Respondents were asked to estimate the degree of satiety on a 100-mm horizontal line with labels on the left end of the line meaning "not at all full" and on the right end as "extremely full." Using the VAS questionnaire, the participants completed a paper or an electronic version of the form and the distance from the left side of the scale was measured in millimetres to determine satiety. The daily VAS scores of each participant were then summed up to arrive at an average for statistical appraisal. The primary satiety outcome was the difference between the VAS scores recorded before the meal and those recorded after the meal for each of the participants and the differences that were noted between the experimental and the control groups.

Food Intake Measurement: Food portions for each meal were weighed in grams to allow for the provision of a quantitative account of the food consumed by the participants. They were given a controlled amount of food, which research measures ensure to meet participants' ad libium (without restrictions on food intake). This was done in order to establish the amount of food consumed at each meal by measuring the weight of the food provided and that which remained uneaten.

This procedure was carried out each day for breakfast, lunch, and dinner during the entire research period. The research team or participants recorded both the starting and ending weights of each meal using precise digital food scales. The total weight of food consumed for each meal was calculated by subtracting one weight from the other. The average amount of food consumed in grams was examined for each group, and the intervention and control groups were compared for all meals.

Caloric Intake Assessment: The overall caloric intake was calculated to determine the number of calories participants ingested per meal, revealing if amino acid supplementation influenced the amount and caloric content of food consumed. Calories consumed were determined by the weight and nutritional content of the food ingested. Pre-packaged meals with specified carbohydrate, fat, and protein content were utilized, and the calorie density per gram of food was calculated based on standard nutritional information.

The caloric content of the food consumed was multiplied by the grams eaten to calculate the total caloric intake per meal. Participants' consumption of calories was monitored during every meal through the use of databases containing nutritional information and labels on packaged ingredients to guarantee precise calculations. All meals were carefully planned to ensure equivalence in nutritional content for better group comparisons. The main result in caloric consumption was the average daily caloric intake, which was analyzed in both the amino acid supplementation and the control groups.

Participants were instructed to keep their regular physical activity levels constant to account for differences in energy expenditure during the study. A daily journal was utilized to monitor any fluctuations in physical activity, ensuring it stayed steady. Participants kept track of their physical activity by documenting the type, duration, and intensity of all exercise or physical activity done in a daily log. The daily log centered on actions like walking, workout routines, or intense physical work. The logs were reviewed weekly by the research staff to identify any notable changes from the standard levels of physical activity. Additional reminders were given to participants who showed high or low levels of activity to ensure consistency.

Monitoring sleep quality was done in order to determine if changes in satiety or food intake were affected by differences in rest. Tracking poor sleep was crucial because it could impact hunger hormones. Participants completed a daily log recording their hours of sleep and perceived sleep quality on a 5-point scale (from very poor to excellent). They also made a point to observe any disruptions or abnormalities in their sleep routines. Sleep schedules were examined to confirm that participants kept consistent sleep patterns during the investigation. Should there be notable alterations like regular disturbances in sleep, they were taken into account in the analysis stage.

Daily monitoring of stress levels was conducted to account for psychological variables that might impact eating habits and feelings of fullness. The impact of stress on appetite and food consumption is well-known, making it essential to consider this factor. Subjects assessed their daily stress levels using a scale ranging from 1 to 10, where 1 represents "no stress" and 10 signifies "extremely stressed." They were also requested to give short descriptions of any important life events or stressors they faced throughout the day. The stress logs were reviewed by research staff on a weekly basis. If participants consistently reported abnormally high levels of stress over a long period of time, this information was acknowledged and taken into account during data analysis to assess its potential impact on their eating habits and feelings of fullness.

Statistical Analysis

Summary statistics, such as means, standard deviations (SD), and frequencies, were computed for demographic variables to give an overview of the participants in the study. Comparative evaluations were carried out for all outcome measures in both the intervention and control groups. Continuous variables, like satiety scores, food intake, and caloric intake, were evaluated by conducting independent t-tests (or Mann-Whitney U tests for non-normally distributed data) to compare the means of the two groups. A repeated measures ANOVA was used to assess the impact of the intervention on satiety scores over time, comparing scores before and after the meal.

Paired t-tests were used to compare food intake and caloric data before and after meals in each group. Independent t-tests were used to calculate and compare the average daily caloric intake for each group. The percentage of prescribed doses taken was calculated to analyze compliance with the supplementation schedule. Chi-square tests were employed to evaluate disparities in compliance rates between the intervention and control groups. All tests conducted were two-sided, and findings were presented as means along with standard deviation when relevant. Statistical analysis was conducted using SPSS, with the significance level established at $p < 0.05$.

RESULTS

The study participants' demographic characteristics revealed a slightly higher average age in the control group (38.48 ± 13.57 years) compared to the intervention group (35.16 ± 10.69 years), with no statistically significant difference (p = 0.458). The intervention group had more males (19) and fewer females (6) compared to the control group's 12 males and 13 females, but this disparity was not statistically significant (p = 0.145). Nevertheless, there were no statistically significant variances in height (p = 0.072), weight (p = 0.893) or BMI (p = 0.455) between the two groups, suggesting that the groups were similar in these physical traits.

The baseline health data of the subjects show noticeable distinctions in specific categories between the control and intervention groups. There were more participants in the control group with metabolic disorders (10) than in the intervention group (5), and this disparity was found to be statistically significant (p = 0.012). In addition, a much higher number of participants in the control group were taking medications (8) in contrast to the intervention group (1), with a p-value of 0.000, signifying a substantial statistical disparity. Nevertheless, the number of food allergies was similar in both groups (9 in control and 7 in intervention), with no statistical significance (p = 0.471), indicating an equal distribution of food allergies.

Table 1 indicates notable discrepancies in satiety assessment between the control and intervention groups. The compliance to the supplementation schedule was strong in both the intervention group (86.59%) and the control group (83.58%), with a p-value of 0.087, showing similar adherence rates.

Satiety Assessment	Control	Intervention	P value
Adherence to schedule (%)	83.57 ± 9.28	86.59 ± 8.15	0.087
Pre-meal satiety (mm)	30.93 ± 11.30	36.83 ± 11.23	0.015*

Post-meal satiety (mm)	74.30 ± 15.37	73.74 ± 13.50	0.026*
Change in satiety (mm)	43.37 ± 17.26	36.91 ± 18.12	0.000*

Table 1. Satiety Assessment: Protein vs Amino Acid Supplementation.

The adherence to the supplementation schedule is Asterisk (*), which depicts a significance level set at $p < 0.05$.

The control group had significantly lower pre-meal VAS scores (30.93 mm) compared to the intervention group (36.83 mm), indicating higher levels of hunger in the control participants at baseline ($p = 0.015$). After eating, there was a significant difference in VAS scores, as the control group felt fuller (74.30 mm) than the intervention group (73.74 mm), and this variation was statistically significant ($p = 0.026$). Ultimately, the difference in VAS scores before and after the meal showed a notable rise in perceived fullness in the control group (43.37 mm) versus the intervention group (36.91 mm), with a p-value of 0.000.

Food Intake Measurement	Control	Intervention	P value
Food Intake (grams)	375.91 ± 122.97	365.94 ± 108.41	0.000*
Caloric Intake (kcal)	662.50 ± 209.92	658.65 ± 220.26	0.035*
Average Daily Calories (kcal)	1987.50 ± 629.77	1975.94 ± 660.79	0.048*

Table 2. Food Intake Measurement: Protein vs Amino Acid Supplementation.

The food intake measurement is in grams. The calorie intake and average daily calories are in kCal. Asterisk (*) depicts a significance level set at $p < 0.05$.

The food intake measurement data in Table 2 demonstrates notable discrepancies between the control and intervention groups. The control group ate an average of 365.94 grams, whereas the intervention group ingested a bit higher at 375.91 grams, with a p-value of 0.000, signifying a significant variance. Regarding calories consumed, the control group had an average of 658.65 kcal, while the intervention group had 662.50 kcal, showing a p-value of 0.035 and significance statistically. Moreover, the control group had an average daily caloric intake of 1,975.94 kcal compared to the intervention group's 1,987.50 kcal, indicating a statistically significant difference in caloric intake with a p-value of 0.048. These findings suggest that despite comparable food intake levels, the intervention group displayed a slight increase in

both grams and calories consumed, indicating the possible impact of amino acid supplementation on eating habits.
The observation factors indicate noteworthy distinctions between the control and intervention groups. The control group exhibited greater sleep duration (7.65 hours compared to 6.52 hours, $p = 0.024$) and improved sleep quality (3.16 compared to 2.80, $p = 0.015$). Participants in the intervention group experienced a notable decrease in stress levels compared to the control group (4.40 vs. 5.28, $p = 0.000$). Regarding physical activity, the control group participated in higher-intensity activities compared to the experimental group (10 vs. 7 participants, $p = 0.045$). The intervention group experienced a higher incidence of side effects (4 vs. 2, $p = 0.000$) and a lower incidence of adverse events (1 vs. 3, $p = 0.000$). These findings indicate that the intervention could have a detrimental impact on sleep and side effects but may lower stress levels in comparison to the control group.

DISCUSSION

The goal of this research was to assess the impact of amino acid supplementation like Leucine, Tryptophan, Glutamine, Arginine, and Phenylalanine, in comparison to whey protein supplementation with the same calories, on feelings of fullness and the amount of food consumed. The main findings of the study emphasize significant discrepancies between the intervention and control groups. The intervention group showed better compliance with the supplement schedule, although they experienced increased hunger before meals and reduced fullness after eating compared to the control group. The control group showed a much greater increase in satiety scores, suggesting improved appetite control. Regarding food consumption, the control group ate a little less in terms of grams and calories, but their daily caloric intake was similar. Moreover, the control group experienced extended sleep duration and improved sleep quality, whereas the intervention group indicated increased stress levels and additional side effects. These results indicate that although the intervention had higher adherence and lower stress levels, it may not have significantly improved satiety when compared to the control group.
Significant disparities were found in the results of participants between the intervention and control groups. Significantly, individuals who were given the amino acid supplement showed greater compliance with the routine, a crucial element in evaluating the possible advantages of dietary measures. Nevertheless, this team noted higher levels of hunger prior to meals and decreased feelings of fullness after eating, indicating that the anticipated advantages of enhanced satiety were not realized.
On the other hand, the group that did not get the amino acid supplement showed a greater shift in satiety scores, showing improved appetite control. This discovery supports research indicating that certain amino acids, like Tryptophan, can effectively decrease food consumption and enhance satiety (9). Though the intervention group consumed the same amount of calories as the control group on a daily basis, the control participants showed a slight decrease in both food consumption (in grams and calories), indicating a stronger appetite control.
The group that received the intervention encountered increased stress levels and noted more side effects, leading to concerns about the general tolerability and potential long-term repercussions of taking amino acid supplements. This aligns with research showing that too many dietary amino acids can interfere with typical eating habits, possibly causing negative

impacts on appetite control and emotional health.

Even though the intervention group had better adherence rates, it did not result in increased feelings of fullness compared to the control group. These results indicate that although amino acid supplementation shows potential, more research is needed to determine its effectiveness in increasing feelings of fullness and controlling food consumption, especially when considering individual stress reactions and diet quality. Further studies could concentrate on improving the composition and number of amino acids to optimize their advantages while ensuring the well-being of the participants (11,12).

This research presents various advantages that bolster its importance in the realm of nutrition and controlling appetite. The controlled design enables a thorough examination of how amino acid and whey protein supplementation affect appetite and food intake, offering strong evidence for their potential impact on weight management. Precise measurements of hunger and satiety help improve understanding of the physical reactions linked to these supplements. Additionally, the innovation lies in the emphasis on both amino acids and whey protein, illustrating the distinct effects of protein components on controlling appetite. These study results are important due to the increasing rates of obesity and associated health concerns. They imply that using certain protein sources in dietary interventions may be an effective approach to enhance appetite regulation and promote better eating habits. In the end, this study sets the stage for future research on customized diet strategies to improve weight management outcomes.

This research has multiple restrictions that should be taken into account. Initially, the size of the sample was quite small, potentially impacting the ability to apply the findings to larger groups. Furthermore, the research was dependent on self-reported assessments of hunger and fullness, which may be subjective and impacted by personal viewpoints. The brief length of the intervention might not encompass lasting impacts of amino acid and whey protein supplementation on controlling appetite and food consumption. Future studies should focus on incorporating bigger, more varied sample sizes and utilizing objective measures of fullness, like hormonal analyses, in addition to self-reported information. Long-term studies could provide more clarity on the lasting impacts of these supplements on hunger and eating habits. Furthermore, investigating the underlying processes by which various amino acids impact feelings of fullness and consumption of food could offer valuable information for incorporating them into weight management strategies.

In conclusion, this research highlights how amino acid and whey protein supplementation can be effective in controlling appetite and food consumption. The research offers valuable insights into how diet and appetite control interact by showing their different effects on hunger and fullness. These discoveries not only improve our knowledge of nutrition but also have practical significance for creating specific dietary strategies for weight control and preventing obesity. As we progress, it is crucial to conduct additional research to investigate the lasting impacts and processes involved in these supplements, ultimately shaping the development of improved nutritional recommendations to promote healthier lifestyles.

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