# A Dietary Supplement Containing Essential Amino Acids in Combination with Resistance Training Improves Body Composition and Physical Performance in Generally Healthy Adults: A Pragmatic Single Arm Study

*Original Research*

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Chad M. Cook[1], Robert Missman[2], Kristin L. Morris[2]

[1]*Biofortis, Inc., Addison, IL, USA*
[2]*Amway, Ada, MI, USA*

## Abstract

**Introduction**: Essential amino acid (EAA) supplements are popular for increasing muscle mass and improving performance.
**Methods:** This pragmatic single arm study enrolled 30 participants (17F/13M) to consume a commercially available supplement providing 3.6 g/d EAA + arginine and complete supervised strength training (two, upper-body days, two, lower body days/week) over a 10-week period. DXA body composition, muscular strength (1 repetition max [1RM]) muscular endurance (number of repetitions to failure), and the Acute Recovery and Stress Scale (ARSS) were assessed at baseline and week 10.
**Results**: Participants (n=27 completers [15F/12M]; mean ± SD age 38.7 ± 8.6 y and BMI 29.4 ± 3.6 kg/m$^2$) experienced statistically significant ($p<0.05$) reductions in total fat mass (-0.9 [-1.8, -0.1] kg) and visceral fat (-96 [-165, -26] g), with concurrent increases in total lean body mass (1.1 [0.4, 1.8] kg), upper body strength (~18% increase in bench press 1-RM), lower body strength (~40% increase in angled leg-press 1-RM), and muscular endurance (~75% increased repetitions to failure for both exercises). Additionally, participants demonstrated improvements in all stress and recovery outcomes within the ARSS.
**Conclusions**: These results demonstrate the potential value of EAA supplementation as part of a comprehensive approach to support physical performance and body composition in previously untrained or recreationally trained adults.

***Key Words***: lean body mass, muscular strength, protein

Corresponding author: Chad M. Cook, PhD, chad.cook@mxns.com

## Introduction

Resistance training has well-established beneficial effects on body composition and skeletal muscle function, leading to reductions in the risk of numerous diseases and overall mortality while improving quality of life [1]. Training volume (load × sets × repetitions), frequency (sessions per week), training status (sedentary vs. trained), and adequate protein intake are important variables that affect the response to resistance training. Of these, protein intake is the primary dietary determinant to support increases in muscle protein synthesis to optimize the benefits of resistance training [2].

The influence of dietary protein intake on muscle protein synthesis appears to be due almost exclusively to essential amino acids (EAA) [3-5]. The EAA represents a class of amino acids that are not synthesized in humans to meet the demands of metabolic processes and thus must be obtained through the diet. [6] While technically all plant and animal foods contain EAA primarily as intact proteins, the quantity of EAA varies greatly between foods. The Recommended Daily Allowance (RDA) for EAA consumption in healthy adults (mg/kg/d) has been established in the Dietary Reference Intakes [7]. Based on adult body weights from the 2018 NHANES dataset [8], the average adult female (77.5 kg) and male (90.6 kg) in the United States requires approximately 16 to 20 g/d of EAA to meet these requirements. The most common sources of a full complement of EAA are from animal products, which are typically rich in leucine and lysine, such as meet (beef, pork, lamb), poultry (chicken, turkey), fish and seafood, eggs, and dairy products (milk, yogurt, cheese) [9]. There are also some plant-based foods, such as legumes (beans, lentils, chickpeas), nuts and seeds, quinoa, buckwheat, and some soy products (tofu, tempeh, edamame, soy milk) that also contain EAA, but generally do not provide the same quantity and quality of amino acids as animal products.

Although it is feasible for physically active individuals to meet their daily protein needs by consuming whole foods, supplementation serves as a pragmatic approach to ensuring sufficient intake of necessary EAA while keeping excess caloric intake to a minimum. Given that maintenance and building of muscle mass and improvements in muscular strength require higher overall daily protein intakes on the order of 1.6 to 2.0 g/kg/d (greater than the RDA, which currently stands at 0.8 g/kg/d) many individuals utilize supplemental forms to meet these additional requirements; however, there are many commercially available products with differing amounts of EAA that require study to quantify beneficial effects on lean mass and physical performance outcomes. Therefore, the objective of this study was to investigate the effects of a commercially available dietary supplement containing 3.6 g of EAA and arginine on changes in body composition, specifically lean mass, along with muscular strength and muscular endurance over a 10-week period of resistance training in previously untrained or recreationally trained adults.

## Methods

*Participants*

Men and women, age 18 to 50 years, from the greater Chicagoland area were recruited for this study. Screening procedures ensured that all eligible participants were generally healthy, had a BMI of at least 18.5 kg/m$^2$, and participated in resistance training 0-3 times per week for at least two months prior to the onset of the study. Additionally, enrollment required at least 10% of the study population was of Hispanic ethnicity. Prior to initiating this study, the protocol was reviewed and approved by the Sterling Institutional Review Board (IRB; Atlanta, GA) and was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice. Participants provided written informed consent and completed a medical history form.

*Study Design*

This was a single-arm trial with one screening visit and two study visits (week 0 and week 10; Figure 1). At each baseline and end of study clinic visits, participants reported in a fasted state (≥10 hours water only) where they completed the following assessments: (a) In-clinic urine pregnancy test for all female participants; (b) vital signs; (c) body weight; (d) body composition using dual-energy X-ray absorptiometry (DXA) (General Electric Lunar Prodigy; Madison, WI, USA); (e) 3-day diet record review.

*Resistance Training Program*

All participants completed the exercise training under supervision at the Addison, IL park district fitness facility (https://addisonparks.org/club-fitness/). The resistance training program consisted of approximately 60–90 minutes/day of training 4 days/week, split into two upper-body and two lower-body workouts each week, for a total of 10 weeks modeled after similar routines used in previous studies [10,11]. Upper-body and lower-body muscular strength and endurance were determined using the National Strength and Conditioning Association guide to tests and assessments [12].

*Exercise Testing*

Participants performed muscle strength and endurance tests on the free-weight bench press and angled leg press at the beginning of the resistance training program (prior to the first dose of supplement) and after 10 weeks of supplementation under the supervision of trained study staff. Each exercise testing session started with muscle strength assessment (bench press followed by angle leg press) followed by muscle endurance assessment (bench press followed by angle leg press).

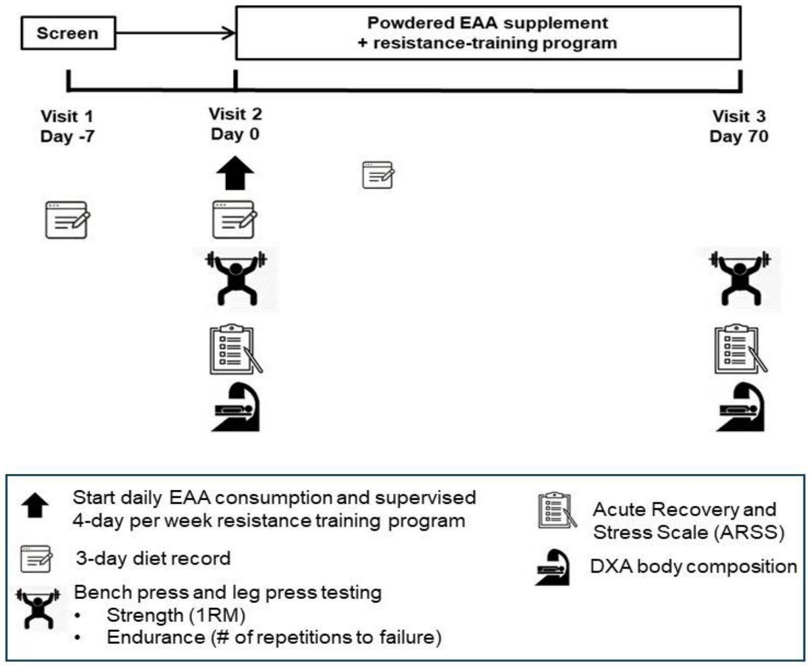


**Figure 1.** Study design.

Muscle strength was assessed by one repetition maximum (1RM) tests on the free-weight bench press and angled leg press exercises. Participants warmed up for each exercise by completing 10 repetitions at 50% of their total body mass from the morning of the visit measured using DXA and rounded down to the nearest weight. Participants then rested for 2 min, followed by completing 3-5 repetitions at 75% of their body mass. The weight was then increased conservatively, and the participant attempted to lift the weight. If the lift was successful, the participant rested for two minutes before attempting another weight increment. This procedure continued until the participant failed to complete a full repetition.

The 1RM was recorded as the maximum weight that the participant could lift for one repetition. For the bench press, a requirement for a successful attempt included the bar lightly touching the chest during bar descent. For the angled leg press, range of motion (ROM) was set at 90° for each participant to ensure this ROM was reached on each attempt. After a 5-minute rest period following completion of the leg press 1RM test, muscle endurance was assessed using the free-weight bench press and angled leg press exercises by having participants perform as many repetitions as possible, while retaining proper form, with 75% of their previously established 1RM for each exercise.

*Supplementation*

The study product was a commercially available powdered, wild berry flavored EAA dietary supplement, XS™ Muscle Multiplier* Essential Amino Acid Supplement providing a proprietary mixture of 3.6 g EAA. Participants were instructed to mix one stick pack in a blender bottle containing 237-296 mL (8-10 fl. oz.) cold or room temperature water and shake until well combined (~15-30 seconds of shaking). On days when participants engaged in resistance training, they consumed the EAA supplement within 30 minutes following the conclusion of the resistance exercise training. On days when the participant did not engage in resistance training, the EAA supplement was consumed at least four hours prior to bedtime.

*Body Composition Testing*

DXA scans (GE Lunar Prodigy, enCORE software version 16, Madison, WI) were performed at weeks 0 and 10 to assess body composition. The DXA scan provided estimates of total and regional fat mass and lean mass, in addition to visceral fat mass and volume.

*Acute Recovery and Stress Scale*

The ARSS was completed immediately before the fifth exercise session (i.e., immediately before the first exercise session of the second week, after completion of the first four exercise sessions during the first week) and again at the end of week 10. The ARSS is a 32-item adjective list (e.g., "rested," "tired") that is rated from 0 ("does not apply at all") to 6 ("fully applies") (Kellmann & Kölling, 2019). Eight scales were generated by summarizing four items which cover the Recovery dimension (Physical Performance Capability, Mental Performance Capability, Emotional Balance, Overall Recovery) and the Stress dimension (Muscular Stress, Lack of Activation, Negative Emotional State, Overall Stress).

*3-Day Diet Record*

Participants were dispensed a 3-day Diet Record with instructions to record all foods and beverages consumed for one weekend day and two weekdays immediately prior to baseline and end of study.

*Statistical Analysis*

No formal sample size calculation was performed as this was a single arm study with the purpose of gathering real world effectiveness data. A sample size of n = 30 enrolled and n = 20 evaluable was estimated based on sample sizes of similar studies in the published literature. No participants were replaced in the event of early terminations.

SAS (version 9.4) was used for statistical analyses. All analyses were conducted according to a statistical analysis plan (SAP) developed prior to any data analysis. The change from baseline to the end of study was calculated for each outcome variable and summarized descriptively (mean, standard deviation, median, interquartile limits, and range limits, 95% confidence interval). The change scores were analyzed using a paired t-test. To further explore the relationship between the change score and other possible covariates, a linear model was fit adjusting the change from baseline score for the baseline measurement and sex. The model derived adjusted means along with the corresponding 95% confidence interval was estimated. Additionally, protocol compliance regarding the maintenance of habitual diet and exercise attendance was evaluated descriptively. Diet was assessed with the average total calories and macronutrients [i.e., carbohydrate (g), fat (g), protein (g), and dietary fiber (g)] over the reported 3-day Diet Record. The change from baseline to the end of study measure was summarized with descriptive statistics and evaluated with the Wilcoxon signed rank test. Exercise attendance compliance was defined as the number of days of documented attendance at the fitness center divided by the total number of expected days of attendance multiplied by 100, and descriptive statistics were provided (mean, standard deviation). Compliance to EAA supplementation was similarly analyzed.

## Results

*Compliance and Baseline Characteristics*

Thirty participants were enrolled, with 27 completing all study requirements (Figure 2). With only two study time points (baseline and end of study), the intent-to-treat (ITT) population with the missing data (from early terminations) and the per protocol population were the same. Therefore, only one study population was analyzed using only observed data from the 27 participants who completed the study. Of those participants who completed the study, mean product compliance was 98.6% ± 6.2% and had a gym attendance (based on card scanning) compliance of 73% ± 15% while participant self-reported daily exercise logs indicated exercise compliance of 92% ± 9%.

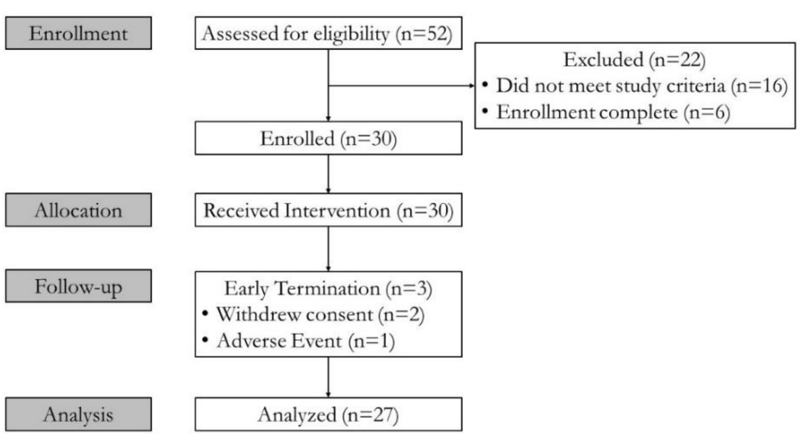


**Figure 2.** Participant disposition.

As shown in Table 1, the analysis population of completers was majority female, not Hispanic/Latino ethnicity, White race, with a mean age and BMI of 38 years and 29.3 kg/m$^2$, respectively.

**Table 1.** Participant (n = 30 enrolled) characteristics at the start of the study

| | **n (%)** |
|---|---|
| Sex | |
| Male | 17 (56.7) |
| Female | 13 (43.3) |
| Race | |
| White | 19 (63.3) |
| Black-African American | 6 (20.0) |
| Asian | 5 (16.7) |
| Ethnicity | |
| Not Hispanic/Latino | 23 (76.7) |
| Hispanic/Latino | 7 (23.3) |

| | **Mean ± SD** |
|---|---|
| Age (years) | 38.1 ± 8.8 |
| Body Mass Index (BMI) (kg/m$^2$) | 29.3 ± 3.6 |
| Weight (kg) | 82.5 ± 12.7 |
| Diastolic blood pressure (mm Hg) | 74.0 ± 8.0 |
| Systolic blood pressure (mm Hg) | 117.0 ± 10.0 |

*Body Composition - Total Body Mass, Lean Body Mass, and Fat Mass*

A statistically significant ($p<0.05$) change from baseline to the end of study was observed for total fat mass and total lean mass whereby, on average, total fat mass decreased, and total lean mass increased by approximately 1 kg each, with no change detected in total body mass (Figure 3). A statistically significant change from baseline to the end of study was observed for all lean body mass measures ($p<0.05$), whereby lean mass measures generally increased. However, no significant change was detected for appendicular lean mass percentage. A statistically significant and/or a marginally significant change from baseline to the end of study was observed for all fat mass measures ($p<0.10$), whereby fat mass measures generally decreased. However, no significant change was detected for the appendicular fat mass percentage and legs fat mass. Regional measures that reached statistical significance ($p<0.05$) included visceral fat mass, visceral fat volume, arm fat, and trunk fat mass. Regional measures that suggested a trend/marginally significant ($0.05 < p < 0.10$) included android fat mass, appendicular fat mass and gynoid fat. All results from the statistical model adjusted for sex and baseline were consistent with the paired t-test.

*Muscular Strength and Endurance*

Strength as measured by the 1RM free weight bench press and 1RM angled leg press was statistically significant ($p<0.001$), whereby strength measures increased from baseline to end of study (Figure 4). The change in muscular endurance for the free-weight bench press and angled leg press was statistically significant ($p<0.001$), whereby endurance measures increased from baseline to the end of study. Results from the model adjusted for sex and baseline were consistent with the paired t-test.

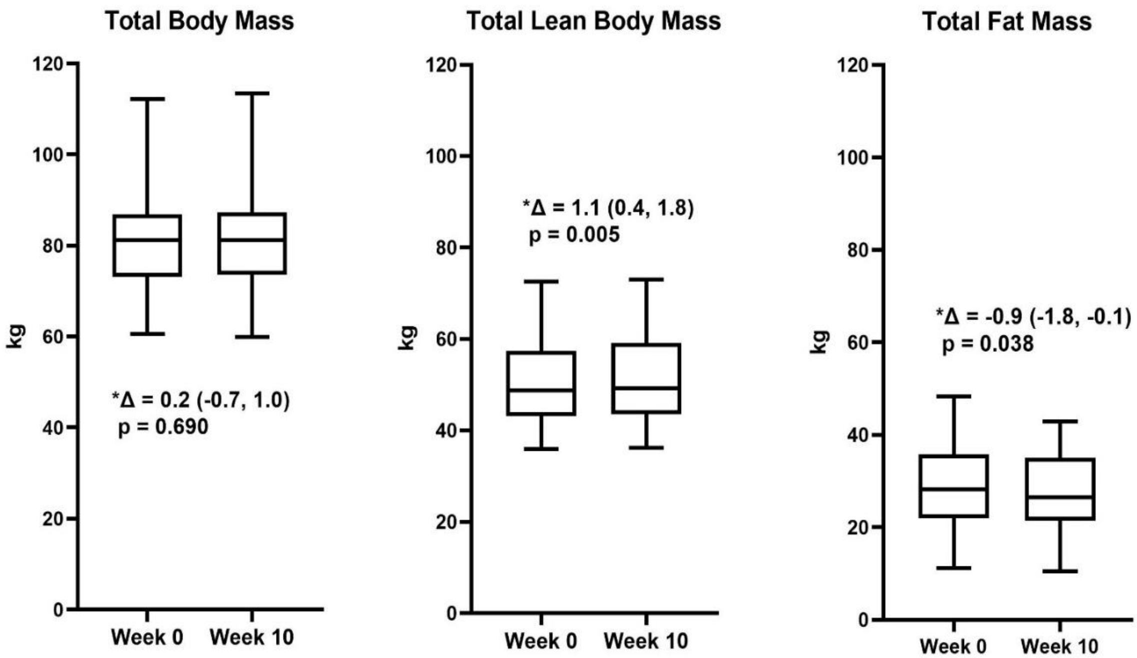


**Figure 3.** Body composition at baseline (week 0) and week 10 (end of study). Box and whisper plots = median (line) with interquartile range box (25th and 75th percentiles) and minimum and maximum whiskers. The change (Δ) from week 0 to week 10 reflects the mean and 95% confidence interval adjusted for baseline measure and sex.

*ARSS*

Results from the ARSS are shown in Table 2. Emotional balance, mental performance capability, overall recovery, and physical performance capability significantly ($p<0.01$) changed from baseline to end of study, where scores were higher at the end of study. Lack of activation, muscular stress, negative emotional state, and overall stress significantly ($p<0.02$) changed from baseline to end of study where scores, where lower at the end of study. Results from the model adjusted for sex and baseline were consistent with the paired t-test.

**Table 2.** Responses to the Acute Recovery and Stress Scale (ARSS) questionnaire.

| ARSS Item | Baseline (n = 27) | Week 10 (n = 27) | Δ[1] (n = 27) | P-value |
|---|---|---|---|---|
| Emotional Balance | 4.4 ± 1.1 | 5.3 ± 0.7 | 0.9 (0.6, 1.1) | 0.001 |
| Mental Performance Capability | 4.5 (1.0) | 5.1 (0.8) | 0.6 (0.3, 0.9) | <0.001 |
| Physical Performance Capability | 4.1 (1.0) | 5.1 (0.7) | 1.0 (0.7, 1.3) | <0.001 |
| **Overall Recovery** | 3.3 (1.3) | 4.6 (1.0) | 1.3 (0.9, 1.7) | <0.001 |
| Lack of Activation | 1.4 (0.9) | 0.9 (0.9) | -0.4 (-0.7, -0.1) | 0.007 |
| Muscular Stress | 3.3 (1.3) | 1.3 (1.3) | -2.0 (-2.5, -1.5) | <0.001 |
| Negative Emotional State | 0.8 (0.7) | 0.5 (0.6) | -0.3 (-0.5, -0.1) | 0.016 |
| **Overall Stress** | 2.1 (1.3) | 1.2 (1.1) | -0.9 (-1.3, -0.4) | 0.006 |

Values at baseline (after the first week of resistance training) and week 10 (end of study) = mean ± SD.
[1] Change in ARSS items over time = mean (95% CI), adjusted for baseline measure and sex.

*3-Day Diet Records*

Results from the 3-day diet records are shown in Table 3. There were no statistically significant changes in total kcal/d, macronutrients, or dietary fiber intakes from baseline to end of study.

**Table 3.** Diet record results at baseline and end of study.

| | Baseline (n = 27) | Week 10 (n = 27) | Δ (n = 27) | P-value[1] |
|---|---|---|---|---|
| Calories (kcal/d) | 1888 (1196, 3502) | 1889 (977, 4364) | -79 (-1810, 1148) | 0.66 |
| Carbohydrates (g/d) | 223 (113, 463) | 220 (104, 473) | -9 (-174, 116) | 0.85 |
| Dietary Fiber (g/d) | 11 (0.3, 27) | 10 (3.0, 24) | 0.8 (-18, 17) | 0.71 |
| Fat (g/d) | 87 (44, 166) | 76 (41, 171) | -5 (-95, 47) | 0.30 |
| Protein g/d) | 81 (40, 174) | 84 (43, 225) | 6 (-75, 144) | 0.41 |

[1] Wilcoxon signed rank test. Values = median (interquartile range).

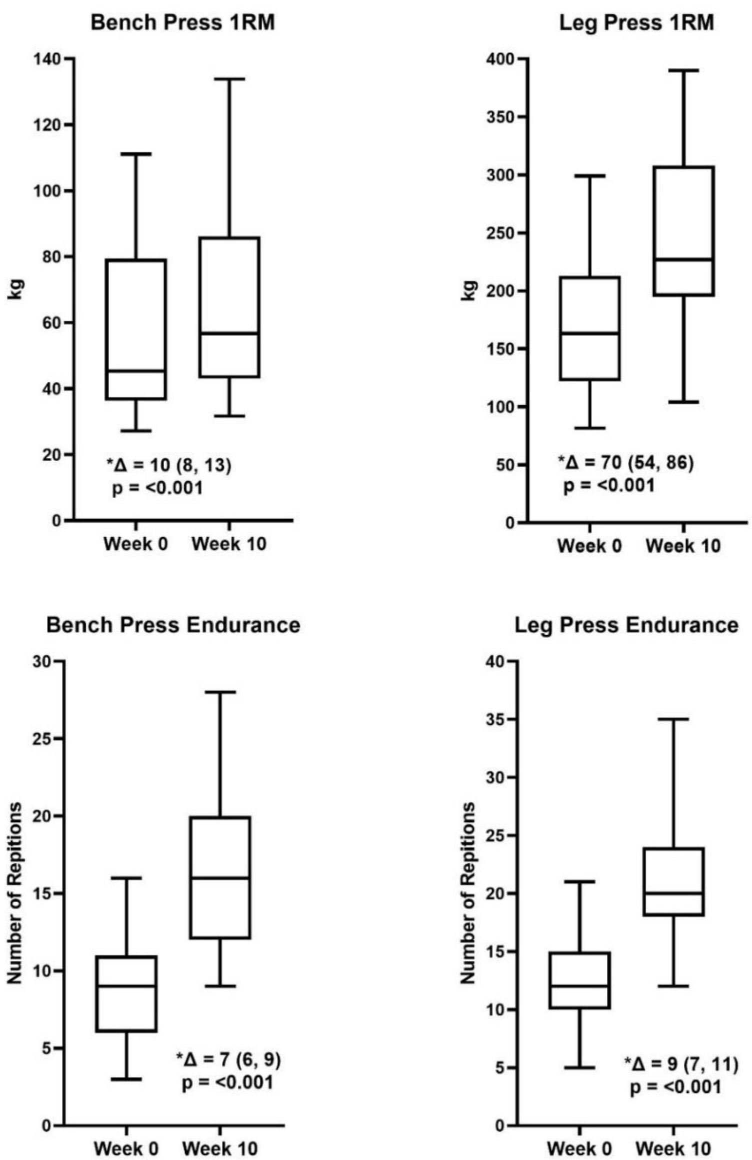


**Figure 4.** Muscular strength and endurance at baseline (week 0) and week 10 (end of study). Box and whisper plots = median (line) with interquartile range box (25th and 75th percentiles) and minimum and maximum whiskers. The change (Δ) from week 0 to week 10 reflects the mean and 95% CI adjusted for baseline measure and sex.

**Discussion**

In this pragmatic study, daily consumption of a dietary supplement containing a mixture of 3.6 g EAA and arginine, in combination with resistance training four times per week in free-living conditions over a 10-week period, resulted in increased lean body mass and muscular strength/endurance with corresponding beneficial changes in subjective ratings of stress and exercise recovery in previously sedentary or minimally trained adults. These changes occurred without significant changes in other dietary intake parameters assessed by 3-day diet records.

These results are meaningful because a growing body of evidence has established the need for EAA to support muscle protein synthesis with resistance training. [13] Previous research has suggested leucine is an important EAA stimulus for muscle protein synthesis in response to exercise. [14] Yet, in the absence of a complete set of EAA, leucine appears to be insufficient alone to trigger muscle protein synthesis [15] indicating the need to consume a complete mixture of EAA. On this basis, it was reasonable to expect that regular consumption of 3.6 g of the EAA and arginine mixture would result in beneficial physiological effects coupled with sufficient stimulus invoked by resistance training. Indeed, compared to non-caloric or carbohydrate-only conditions, supplementation with EAA coupled with resistance training has been shown to significantly increase muscle fiber cross-sectional area [16,17], as well as increase lean body mass. [18-21] At rest, an oral EAA dose as small as 1.5 g has been reported to stimulate muscle protein synthesis[22]. Interestingly, supplements containing EAA have even demonstrated a greater ability to stimulate muscle protein synthesis compared to intact protein, whether in its isolated form such as whey[23] or as part of a meal. For example, 3 g of EAA was found to stimulate MPS to a similar degree as 20 g of whey protein isolate containing approximately 10 g of EAA.[24]

EAA supplements (especially those enriched with leucine) have also been shown to aid in muscle recovery and repair. [25] This has the potential to reduce post-workout soreness and fatigue, a potential effect supported by the observed changes in the self-reported Acute Recovery and Stress Scale questionnaire outcomes in the present study. Feeling less sore and fatigued may also contribute to individuals being more likely to stick with their training schedule. These findings lend credence to the hypothesis that EAA supplementation may play a role in improving exercise compliance for some individuals, but should be viewed as one component of a comprehensive approach to training and overall health. It should be acknowledged that it is essential to prioritize proper nutrition coupled with adequate rest, consistent training, and individualized goal setting when aiming for long-term success with any resistance-training program.

This study does have some potential limitations. While the results provide valuable insights into the potential benefits of EAA supplementation alongside resistance training in the sample population studied, it should be acknowledged this study design does not provide an estimate of the effects of either separately. While it is acknowledged that the lack of a control group is a limitation, the study findings do demonstrate feasibility and provide preliminary estimates of effect size to inform the design of future well-controlled trials that could be conducted over a longer time period. Extending the study to 6-12 months could help assess whether the beneficial changes in body composition and muscular strength/endurance are sustained or plateau, or if there are any risks associated with long-term supplementation. Additionally, this study focused on untrained or minimally trained young to middle-aged (18 to 50 y) males and females, and therefore did not include unique populations such as the elderly or athletes. This study was not sufficiently powered to consider subgroup analyses to draw any meaningful inferences with respect to the impact of sex on outcomes of interest. Future research could include diverse populations to examine whether the findings generalize to older adults, highly trained individuals, or those with specific health conditions

It should also be noted that individual variations in dietary intake could have masked some effects, as dietary intake was only assessed using two separate 3-day diet records at the beginning and end of study. However, there were no statistically significant changes in energy or macronutrient intakes, which may infer maintenance of habitual diet over the intervention period (on average). Last, some discrepancies were noted in the different exercise compliance assessments when comparing gym ID card scans (~73%) with participant self-reported exercise log (~92%), which may have introduced some variability in the response to the intervention. While objective measures of exercise compliance, such as the gym ID card scan, likely better represents true compliance compared to subjective self-report, our combined measures still provide evidence that participants were generally consistent with the study protocol resistance training program. As in any clinical trial, adherence to study procedures is one of many sources of variability in the response to an intervention and should be taken into consideration in sample size calculations for future studies. Future studies should consider supervision of all exercise sessions or possible use of wearable activity trackers.

## Conclusions

These study findings support the potential value of 3.6 g/d EAA and arginine supplementation as part of a comprehensive approach to enhance physical performance and body composition in previously untrained or recreationally trained adults.


## Acknowledgements

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## Conflict of Interest

CMC was an employee of Biofortis, Inc., a Contract Research Organization that received funding from the manufacturer (Amway, Ada, MI) of the study product tested. RM and KLM were employees of Amway, the company that funded the study.

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