Effects of Exercise Training and Amino-Acid Supplementation on Body Composition and Physical Performance in Untrained Women

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The purpose of this study was to determine the effects of 6 wk of essential amino acid (EAA) supplementation on body composition and exercise performance in untrained women ($n = 21$). Subjects were randomly assigned to a placebo (cellulose) or an EAA (average daily dose of 18.3 g of EAAs in pill form) group. Each subject participated in aerobic and heavy-resistance training three times per week. Body composition was assessed via dual x-ray absorptiometry analysis. Muscular endurance was determined via treadmill time to exhaustion, and strength was assessed by the total amount of weight lifted for one set to exhaustion at an estimated 12 repetitions maximum. No changes occurred in either group for body weight, lean body mass, fat mass, or bone mineral content. Treadmill time to exhaustion (TTE) improved significantly ($P < 0.05$) in the EAA group (mean $\pm SD$; pre-TTE = 13.15 $\pm$ 3.67 min, post-TTE = 14.73 $\pm$ 4.26 min), whereas the placebo group did not change significantly. The total weight lifted at the subject’s maximum 12 repetitions did not significantly change in either group. In previously untrained individuals, the ingestion of EAAs combined with aerobic and heavy-resistance training for 6 wk did not have a significant effect on body composition or muscular strength; however, aerobic muscular endurance increased significantly. Nutrition 2000;16:1043–1046. ©Elsevier Science Inc. 2000

Key words: ergogenic aid, nutrition, sports, exercise, exertion, branched-chain amino acids

INTRODUCTION

Bodybuilders and other athletes use various ergogenic aids in the hopes of increasing skeletal-muscle mass and improving performance. One of these dietary ergogenic aids, amino acids, has been shown to have positive effects on muscle-protein metabolism. For instance, Rasmussen et al.\(^1\) demonstrated that 6 g of essential amino acids (EAAs) combined with 35 g of sucrose promotes an acute rise in muscle-protein synthesis 1 and 3 h after a bout of resistance exercises. Furthermore, a 40-g solution of EAAs was as effective as a 40-g solution of mixed amino acids (EAAs and non-EAAs) with regard to improving net muscle-protein balance (i.e., anabolic effect).\(^2\) Thus, it may not be necessary to consume the non-EAAs to elicit an anabolic effect. However, these studies were acute in nature and did not examine whether prolonged consumption of amino acids could result in changes in lean body mass or body composition.

In addition to a potential anabolic effect, the provision of amino acids, in particular the branched-chain amino acids (BCAAs; i.e., valine, leucine, isoleucine), may positively affect body composition and muscular power. Sixteen subjects who participated in a trek at altitude (3255 m) received BCAAs (11.5 g) or placebo daily for the 21-d study duration.\(^3\) Both groups lost similar amounts of fat; however, the BCAA group had improved lean body mass (+1.5%), whereas the placebo group showed no change. In addition, the BCAA group had a smaller decrease in lower-limb maximal power than did the placebo group. Further, 30 d of oral consumption of 14 g of BCAAs resulted in a significant increase in fat-free mass and grip strength in sedentary male subjects.\(^4\) Thus, BCAA supplementation may have a slight anabolic effect and performance-enhancing benefits. However, it is not known whether daily supplementation with EAAs has an ergogenic effect.

Thus, the purpose of this investigation was to determine whether daily EAA consumption improves body composition and exercise performance in previously untrained individuals.

METHODS

Subjects

Healthy untrained women were recruited from the university population through e-mail advertisements. To participate in the study, subjects had to meet the following inclusion criteria: 1) female and 18 to 35 y old, 2) in good health (free from diabetes, cancer, or heart disease as determined by personal disclosure), and 3) not currently taking a dietary supplement that contained protein or amino acids. Informed consent was obtained from each subject, and the institutional review board of the University of Nebraska at Kearney approved the experimental procedures. Subjects were compensated financially for completing the study.

Dietary Supplement

In a double-blind, placebo-controlled study, subjects were randomly assigned to an EAA or a placebo group. The EAA group orally ingested pills that contained EAAs (Table I). The supplement and placebo were provided by Chem International, Inc.
ceeded the number of repetitions required for the three sets of an
machines made by Hammer and Universal. When a subject ex-
cluded free weights and dynamic, constant external resistance
RM, repetitions maximum

* The leg press machine was made by Hammer; all other machines were
made by Universal.

RM, repetitions maximum

(Philadelphia, NJ, USA). On the 3rd day of exercise training, subjects
were instructed to consume 10 pills 20 min before training and 10 pills
within 20 min after training. On non-workout days (4 days/week),
subjects consumed 10 pills in the morning. The manufacturer
recommended this protocol. Thus, the total consumption of pills
per week was 100, with an average of 128 g of amino acids per
week, or 18.3 g daily. Subjects in the placebo group ingested an
equal number of identical-looking pills that contained cellulose.
All subjects were instructed not to change their dietary habits.
Twenty-four-hour dietary recalls were obtained from all subjects
on a random day at baseline and then once a week for 6 weeks (total
of 7 recalls). The average energy and macronutrient intake for each
subject was determined from seven diet recalls via computer analy-

Training Program

All subjects performed a split routine, multiple-set weight-training
regimen three times per week. Subjects were instructed by graduate
assistants in exercise science on proper technique for lifting
weights. The resistance-training protocol was a modified periodiza-
tion scheme (Table II).5 The type of resistance-training devices
used included free weights and dynamic, constant external resistance
machines made by Hammer and Universal. When a subject ex-
ceeded the number of repetitions required for the three sets of an
exercise, the weight was increased slightly (~2 kg) to ensure a
progressive increase in overload. Subjects were supervised by
exercise science graduate assistants to ensure compliance. In ad-


**TABLE I.**

<table>
<thead>
<tr>
<th>COMPOSITION OF ESSENTIAL AMINO ACIDS</th>
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<tbody>
<tr>
<td>10 g provide</td>
</tr>
<tr>
<td>L-isoleucine 1.483 g</td>
</tr>
<tr>
<td>L-leucine 1.964 g</td>
</tr>
<tr>
<td>L-valine 1.657 g</td>
</tr>
<tr>
<td>L-lysine 1.429 g</td>
</tr>
<tr>
<td>L-methionine 0.699 g</td>
</tr>
<tr>
<td>L-phenylalanine 1.289 g</td>
</tr>
<tr>
<td>L-threonine 1.111 g</td>
</tr>
<tr>
<td>L-tryptophan 0.368 g</td>
</tr>
</tbody>
</table>

**RESULTS**

Twenty-one women volunteered for the study. Two women dropped
out from the study due to personal reasons. There were no significant

**Performance Measures Strength/Muscular Endurance**

After three warm-up sets, subjects were instructed to perform the
maximal number of full repetitions for the supine free-weight
bench press at each subject's estimated 12-repetition maximum
(12-RM). A 12-RM test was chosen based on our personal expe-
rience with testing untrained subjects. It is difficult for untrained
subjects to perform a 1-RM and the chances of injury outweigh the
possible benefits of performing such a test. The assistant strength-
and-conditioning coach performed all strength testing. The esti-
imated 12-RM was determined by the strength and conditioning
coach based on how well each subject performed the warm-up sets.
During the test, subjects had their feet fully planted on the floor,
their hips and scapula maintained contact with the bench at all
times, and a slight lumbar lordosis allowed. Repetitions were
performed such that the concentric phase was performed as
quickly as possible and the eccentric phase was performed with a
controlled descent. Hand position was slightly greater than shoul-
der width. The test was terminated when the subject could no
longer complete a full repetition. The same weight used for the
initial 12-RM determination was used for the posttest. The product
of the weight lifted and the number of repetitions performed was
determined (i.e., total weight lifted).

**Aerobic Endurance**

Treadmill time to exhaustion was ascertained. All subjects were
given precise instructions on the nature of the test. After a 5-min
warm-up of easy walking, the test was commenced with each
subject walking at 4.2 miles per hour at 0% grade. Each stage
lasted 3 min. Speed remained constant; however, grade increased
2.5% every 3 min. Subjects were asked to walk or run on the
treadmill until volitional exhaustion. In general, most subjects
walked during the initial stages of the test. During the latter stages,
subjects often found it necessary to jog slowly or run. Time to
volitional exhaustion was recorded.

**Body Composition**

Body composition was assessed via whole-body scans using dual-
energy x-ray absorptiometry (Lunar DPX-IQ, Madison, WI, USA).
To ensure quality control, the dual-energy x-ray absorptiometer unit
was calibrated daily using the standard calibration block provided by
the manufacturer. Bioelectrical impedance analysis was used to esti-
mate total body water (Model 3.10, Body Density, Seattle, WA, USA).
Subjects were instructed to do the following before body-composition
and total-body water testing: no eating or drinking within 4 hours of
the test, no exercise within 12 hours of the test, no alcohol consumption within
2 days of the test, urinate within 30 minutes of the test, and no diuretic
medications within the week of the test.

**Statistical Analyses**

Data were analyzed by analysis of variance for repeated measures
(treatment group × time). A Student-Neuman-Keuls post hoc test
was used to determine which pairs differed. Statistical significance
was set at P < 0.05. Data are shown as means ± standard deviation.
Data were analyzed using SigmaStat (SPSS Inc., Chicago, IL, USA).

**TABLE II.**

<table>
<thead>
<tr>
<th>RESISTANCE TRAINING PROGRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weeks 1, 2 (3 sets of 10–12 RM)</td>
</tr>
<tr>
<td>Weeks 3, 4 (3 sets of 8–10 RM)</td>
</tr>
<tr>
<td>Weeks 5, 6 (3 sets of 6–8 RM)</td>
</tr>
<tr>
<td>Monday</td>
</tr>
<tr>
<td>Leg press*</td>
</tr>
<tr>
<td>Leg curl</td>
</tr>
<tr>
<td>Lat pull-down</td>
</tr>
<tr>
<td>Bent-over row</td>
</tr>
<tr>
<td>Preacher curl</td>
</tr>
<tr>
<td>Abdominal circuit</td>
</tr>
</tbody>
</table>

* The leg press machine was made by Hammer; all other machines were
made by Universal.
baseline differences between groups for age (mean ± SD: EAA group, 26.9 ± 6.1 y; placebo group, 27.4 ± 7.4 y) or height (EAA group, 167.4 ± 6.9 cm; placebo group, 169.9 ± 4.9 cm). There were no baseline or before-and-after differences in body weight, total body water, total bone-free lean body mass, total fat mass, bone mineral content, and percentage of fat for either group (Table III). Total weight lifted (weight × number of repetitions) did not change significantly before versus after for either group; however, treadmill time to exhaustion improved significantly (P < 0.05) in the EAA group but not in the placebo group (Table IV). There were no significant differences in fat or protein intake; however, the placebo group consumed on average more total kilocalories and carbohydrates (P < 0.05) than the EAA group (Table V).

**DISCUSSION**

The acute ingestion of EAAs has been shown to augment muscle-protein synthesis in healthy human subjects.1,2 Tipton et al.2 examined the effects of resistance exercise followed by the consumption of a 40-g solution of mixed amino acids (EAAs and non-EAAs), a 40-g solution of EAAs, or a placebo on net muscle-protein synthesis in six healthy adults (three men, three women). These investigators found that the acute ingestion of a solution of EAAs was as effective as mixed amino acids in promoting a net gain in skeletal–muscle-protein synthesis 270 min after exercise. Work from the same laboratory showed that a 13.4-g solution of EAAs and 35 g of sucrose also effectively stimulated muscle-protein anabolism at rest.1 Although the acute ingestion of EAAs can augment muscle-protein synthesis, it is not known whether chronic supplementation with EAAs can increase total lean body mass. To our knowledge, our investigation is the first that has examined the effects of EAA supplementation on body composition and exercise performance.

In the current study, 6 wk of EAA supplementation plus aerobic and resistance training did not produce changes in body composition. We surmise that 6 wk of exercise training may not be an adequate stimulus for increasing lean body mass or decreasing fat mass, even though our subjects trained under the supervision of an athletic trainer or strength-and-conditioning specialist. This has been shown by other investigators in that 6 wk of circuit weight training without substantial caloric restriction did not alter body composition in overweight (body mass index ≥ 25) adults.5,7 A decrease in caloric intake or a further increase in energy expenditure may be necessary for weight loss. It has been reported that weight loss through increased energy expenditure does not readily occur in women unless it is accompanied by a decrease in caloric intake.8 In contrast, men tend to lose weight more readily with exercise alone.8 The lack of body-composition changes in the subjects of our study may be due to the fact that our subjects were women.

We advised our subjects not to change their dietary habits for the duration of the study. Because there were no temporal changes in dietary intake, it is reasonable to assume that subjects did in fact maintain the same eating habits throughout the study. Although the EAA group consumed fewer calories and carbohydrates than the placebo group, this did not translate into a loss of body weight or fat. There were no differences in non-supplemented protein intake between groups; however, the additional 18 g of amino acids per day (in the supplemented group) would result in an approximately 30% greater amino-acid (i.e., protein) consumption than in the placebo group, but this did not influence lean body mass. The protein consumption for placebo group was approximately 0.9 g of protein per kilogram of body weight daily. However, the protein consumption of the EAA group was approximately 1.2 g of protein per kilogram of body weight daily (this includes the ~18 g of EAAs consumed daily). It is possible that the level of protein

**TABLE III.**

**BODY COMPOSITION***

<table>
<thead>
<tr>
<th></th>
<th>BW (kg)</th>
<th>TBW (L)</th>
<th>LBM (kg)</th>
<th>TFM (kg)</th>
<th>BMC (g)</th>
<th>% Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amino acid (n = 10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>68.9 ± 15.2</td>
<td>33.9 ± 4.9</td>
<td>42.6 ± 4.8</td>
<td>24.1 ± 1.1</td>
<td>2698 ± 322</td>
<td>33.1 ± 9.0</td>
</tr>
<tr>
<td>Post</td>
<td>69.6 ± 16.0</td>
<td>34.0 ± 5.1</td>
<td>42.8 ± 5.0</td>
<td>23.9 ± 1.2</td>
<td>2707 ± 318</td>
<td>32.7 ± 9.3</td>
</tr>
<tr>
<td>Placebo (n = 9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>74.0 ± 12.8</td>
<td>34.5 ± 3.9</td>
<td>44.5 ± 5.1</td>
<td>26.8 ± 8.9</td>
<td>2693 ± 379</td>
<td>35.4 ± 6.5</td>
</tr>
<tr>
<td>Post</td>
<td>74.7 ± 13.2</td>
<td>35.2 ± 4.8</td>
<td>44.2 ± 4.8</td>
<td>27.3 ± 9.3</td>
<td>2733 ± 395</td>
<td>35.9 ± 7.0</td>
</tr>
</tbody>
</table>

* Data are means ± standard deviations. Dual-energy x-ray absorptiometric scans were used to determine body composition. There were no within- or between-group differences for any of the parameters measured.

BM, bone mineral content; BW, body weight; LBM, bone-free lean body mass; TBW, total body water; TFM, total fat mass.

**TABLE IV.**

**EXERCISE PERFORMANCE***

<table>
<thead>
<tr>
<th></th>
<th>TTE (min)</th>
<th>TWL (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amino-acid group (n = 10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>13.15 ± 3.67</td>
<td>291.8 ± 88.9</td>
</tr>
<tr>
<td>Post</td>
<td>14.73 ± 4.26†</td>
<td>349.1 ± 96.7</td>
</tr>
<tr>
<td>Placebo group (n = 9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>11.48 ± 3.40</td>
<td>354.3 ± 122.2</td>
</tr>
<tr>
<td>Post</td>
<td>11.92 ± 3.04</td>
<td>331.5 ± 118.9</td>
</tr>
</tbody>
</table>

* Data are means ± standard deviations.
† P < 0.05, pre versus post.

TTE, treadmill time to exhaustion; TWL, total weight lifted (weight × repetitions).

**TABLE V.**

**DIETARY INTAKE***

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>Placebo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kcal‡</td>
<td>1544 ± 335‡</td>
</tr>
<tr>
<td>CHO (g)</td>
<td>203 ± 78‡</td>
</tr>
<tr>
<td>PRO (g)</td>
<td>68 ± 29</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>59 ± 15</td>
</tr>
</tbody>
</table>

* Data are means ± standard deviations.
‡ Indicates significant differences (P < 0.05) between groups.
CHO, carbohydrates; PRO, protein.
consumed by either group was inadequate for promoting gains in lean body mass. According to Lemon, an intake of 1.2 to 1.4 and of 1.6 to 1.7 g of protein per kilogram of body weight daily is needed for endurance and strength training individuals. Because our subjects performed both aerobic and resistance training, it would be reasonable to assume that their protein needs would fall somewhere in the middle of that range (~1.45 g per kilogram of body weight daily) of protein requirements. However, our subjects did not meet that requirement.

Furthermore, the training status of our subjects may have masked any potential gains in lean body mass that could be realized from resistance training. Because our subjects were initially untrained, any changes seen in strength are most likely due to neural adaptation rather than to skeletal-muscle hypertrophy. Subjects in the EAA group had an average increase of 23% in total weight lifted (maximal repetitions at the subjects’ estimated 12-RM), although it was not statistically significant. In contrast, the placebo group actually had a slight decrease in total weight lifted. We posit that both groups should have experienced significant gains in total work performed because they were initially untrained. Thus, it is unexpected that neither group improved in this measure. Also, it is possible that our subjects did not exert maximal effort during their 12-RM despite the motivation provided by the strength-and-conditioning coach.

The average daily intake of EAA's in our study was 18.3 g/d. In contrast, other investigators have shown that consuming 6 or 13.5 g of EAA's with 35 g of sucrose causes an acute rise in muscle-protein synthesis. Thus, the lack of change in body composition is probably not due to an insufficient amount of amino-acid supplementation; however, total protein or amino acid intake may have been insufficient to elicit an anabolic response. Also, our subjects were instructed to ingest the EAA's with water. It may be necessary to consume sucrose or carbohydrate with the EAA's to elicit an anabolic effect. The combination of carbohydrate and EAA's would serve to augment plasma-insulin concentrations. In turn, the increase in plasma insulin concentration would stimulate muscle-protein synthesis via uptake of plasma amino acids. Future work should examine whether supplementation with the combination of sucrose and EAA's can positively affect body composition.

Treadmill time to exhaustion improved significantly in the EAA group but not in the placebo group. In fact, the EAA group’s improvement in treadmill time to exhaustion was more than twice that of the placebo group. There are no studies that have examined the influence of chronic EAA supplementation on exercise performance; however, other investigators have examined whether BCAAs have a performance-enhancing effect. This is important because 51% of the EAA consumed in this study was composed of BCAAs (i.e., leucine, isoleucine, valine). This corresponded to a daily dose of 3.59, 2.71, and 3.03 g of leucine, isoleucine, and valine, respectively (average total daily dose of 9.33 g of BCAAs).

BCAA ingestion has been shown to have an ergogenic effect. In 16 subjects who participated in a 21-d trek at altitude (3255 m), those who received BCAAs (5.76, 2.88, 2.88 g of leucine, isoleucine, and valine, respectively; total dose of 11.5 g) during the treatment period had less of a decrement in lower-limb maximal power than did the placebo group. Bigard et al. examined the effects of BCAA supplementation (7.8, 3.4, 11.2 g of leucine, isoleucine, and valine, respectively; total dose 22.4 g) in 24 highly trained subjects who participated in six consecutive sessions of ski mountaineering (6 to 8 h per session, 2500 to 4100 m in altitude). BCAA supplementation prevented the weight loss seen in the placebo group; furthermore, peak power measured during incremental bicycle exercise did not change in the BCAA group but decreased in the placebo group. In these studies, BCAA supplementation at a daily dose of 11.5 and 22.4 g for 3 to 4 wk did not actually improve performance per se, but rather prevented the performance decrement observed in the placebo group. In contrast, our investigation showed that EAA supplementation actually improved performance when compared with the placebo.

The performance enhancement seen in the EAA group could be due to the provision of an added fuel source during exercise. Blomstrand et al. found that the provision of BCAAs during sustained exhaustive exercise in male endurance-trained cyclists had a muscle glycogen-sparing effect. However, Varrniet et al. found no effect of BCAA infusion on total work performed during incremental exercise in muscle glycogen-depleted subjects. Also, our test of muscular endurance did not last long enough for glycogen depletion to play a role. It is therefore unlikely that BCAA could have played a substantial role as a fuel for exercise. Another intriguing possibility is whether BCAA ingestion can improve performance based on its effect on the ratio of free tryptophan to BCAAs in plasma. During sustained exercise, the ratio of free tryptophan to BCAAs increases due to the oxidation of BCAAs. Tryptophan and BCAAs compete for the same transport molecules for entry into the brain. If the ratio of tryptophan to BCAA favors tryptophan, the increased concentration of tryptophan in the brain will result in the formation of 5-hydroxytryptamine or serotonin. The increased synthesis of serotonin may suppress motor-neuron excitability, induce sleep, and contribute to fatigue. We did not measure plasma BCAA or tryptophan concentration; thus, it is unknown whether this mechanism explains the performance enhancement seen in our subjects. In addition, the subjects did not consume the EAAs on the day of exercise testing. Therefore, it is unlikely that an altered ratio of tryptophan to BCAA could explain the improved running performance.

Thus, the current study suggests that daily consumption of approximately 18 g of EAAs for 6 wk can improve aerobic muscular endurance without a change in body composition or total weight lifted. We speculate that an extended treatment period could provide further improvement in physical performance and body composition.

REFERENCES