Ingestion of Tyrosine: Effects on Endurance, Muscle Strength, and Anaerobic Performance

Erin E. Sutton, M. Regina Coll, and Patricia A. Deuster

Acute tyrosine ingestion is thought to improve aerobic endurance, muscle strength and endurance, and anaerobic power of men undergoing severe physiologic stress. In a double-blind, crossover study, 20 men (32 ± 1 y old) underwent 2 loadcarriage treadmill sessions, 1 after taking tyrosine (150 mg/kg L-crystalline tyrosine) and 1 after taking placebo. Tyrosine dosage was based on subject weight and ingested 30 min before load carriage. A physical performance battery was administered after the load carriage: maximal and submaximal handgrip, pull-ups, and stair stepping with weight. Total time on treadmill was not significantly lengthened with ingestion of tyrosine (118.9 ± 1.4 min) as compared with placebo (119.2 ± 1.2 min). Total power for stair stepping (tyrosine 223 ± 8 watts, placebo 216 ± 9 watts) and muscle strength and endurance (handgrip) was not significantly improved by tyrosine ingestion. The results indicate that acute ingestion of tyrosine by healthy men has no measurable effect on endurance, muscle strength, or anaerobic power.

Key Words: exercise, load carriage, aerobic endurance, power

Tyrosine, a large neutral amino acid normally present in protein foods, is a precursor to the catecholamine (CA) neurotransmitters, dopamine (DA), norepinephrine (NE), and epinephrine (E) (18, 27, 30). Wurtman et al. (29, 30) hypothesized that under stressful conditions, when DA or CA neurons were firing at a high rate, CA depletion might ensue and the availability of tyrosine could be rate-limiting for further CA and DA synthesis. Evidence indicates that dopaminergic neurons projecting to the prefrontal cortex can, under certain circumstances, be readily influenced by the availability of tyrosine (18, 27). Moreover, dopaminergic neurons are more vulnerable to tyrosine depletion than noradrenergic neurons (17). Based on this information, one would postulate that supplemental tyrosine administration should sustain a readily available pool of precursor for neurotransmitter synthesis. When tyrosine is systemically administered in pharmacologic amounts before acute exposure to stressful events, it has been shown to increase brain CA concentrations and turnover (11), and the increases have been associated with improvements in cognitive performance. Oral ingestion of tyrosine by humans has been shown to improve stress-induced cognitive and behavioral deficits, in particular working memory (3, 28), tracking (7, 8), stress-sensitive attentional focus tasks (19, 24, 25).
Given that strenuous or prolonged exercise is associated with central metabolic and neuroendocrine shifts that may relate to central fatigue (20), a role for supplemental tyrosine during exercise seems reasonable. For example, studies have indicated that the dopaminergic system is of utmost importance for motor activation and in central fatigue (20). Aspects of central and peripheral CA synthesis and turnover also have been studied during exercise training (1, 11, 27). Hattori et al. (11) demonstrated that tyrosine hydroxylase (TH) activity in the striatum of rats was elevated after only 7 d of treadmill training, as well as by acute exercise. These findings led them to conclude that both the synthesis and metabolism of DA are closely related to physical activity levels (11). Further, Levenson and Moore (15) hypothesized that long-term physical activity might enhance the ability of the adrenals to synthesize neuropeptide Y (NPY) and CA under conditions of stress. Long-term exercise, however, without the induction of stress, did not alter levels of NPY or TH mRNA. Overall, these studies indicate that tyrosine-dependent pathways are important in exercise, exercise training, and fatigue. Consequently, supplemental tyrosine ingested prior to strenuous/prolonged exercise might ensure an adequate precursor supply for CA and DA synthesis to sustain physical performance and delay the onset of fatigue.

The proposed study was designed to examine the effects of a single dose of tyrosine ingestion on physical performance and catecholamine levels. We hypothesized that oral administration of tyrosine would increase plasma tyrosine levels, which should provide a readily available pool of precursor for maintaining catecholamine synthesis and minimize physical fatigue, which should improve the performance of specific physical tasks of men undergoing severe exertional stress. The specific questions to be addressed included the following: 1) Does supplemental tyrosine extend aerobic endurance? 2) Does tyrosine improve muscle strength and endurance? 3) Does tyrosine increase anaerobic power? and 4) Does supplemental tyrosine alter plasma CA levels? It was believed that the knowledge gained from this work would be fundamental to our understanding the biologic and pharmacologic consequences of tyrosine use in humans and its potential as a performance enhancer.

Methods

Subjects

The Institutional Review Board of the Uniformed Services University of the Health Sciences approved the study and all subjects signed an informed consent document prior to participation. Subjects were carefully screened (medical history, physical exam) by a physician prior to participation in any procedures. Healthy, moderately to highly physically fit males \( (n = 20) \) participated and refrained from prescription medications and vitamin-mineral supplements over the course of the study; all were nonsmokers. Body weight and height were measured, and skinfold thickness was determined at abdominal, midaxillary, and thigh sites to 0.1 mm accuracy using a Lange SKF caliper (Cambridge Scientific Industries, Cambridge, MD). The 3 skinfold thicknesses were summed to calculate percent body fat according to Jackson and Pollack (13). Table 1 presents the general characteristics of the subjects.
The study was a randomized, counterbalanced, double-blind, placebo-controlled, repeated-measures design. Initially, the order of testing was randomized, but to ensure no order effects, the order was subsequently counterbalanced. Subjects (n = 20) underwent a maximal exercise treadmill test to determine maximal oxygen uptake (VO$_{2\text{max}}$), after which they practiced selected physical performance tasks. Subsequently, they underwent 2 exercise tests: a tyrosine load carriage exercise test, and a placebo load carriage exercise test. All testing was conducted in the Human Performance Laboratory (HPL) at the Uniformed Services University of the Health Sciences in the morning on 3 separate days with each test separated by at least 1 wk to allow for physical recovery.

**Exercise Testing**

**Maximal Exercise Test.** The maximal exercise test was conducted on a motorized treadmill (Quinton Medtrack ST65, Quinton Instruments, Bothell, WA). Thirty minutes prior to beginning the test, a peripheral catheter (20 gauge) was inserted in the antecubital fossa of a forearm for blood sampling; the catheter was kept patent with a heparin lock. The test began with a 5-min walk at 3.0 mph and 2% grade, after which the speed was increased to between 5.0 and 8.0 mph, depending on the subject’s heart rate at the end of the warm-up. Thereafter, the grade, which was initially set to 0% incline, was increased by 2.5% every 3 min until volitional exhaustion (13). Oxygen uptake and CO$_2$ production during all exercise tests were determined by a metabolic measurement cart, either the SensorMedics model 2900c (SensorMedics, Yorba Linda, CA) or the CosMed K4b$^2$ (CosMed, Rome, Italy). All subjects met the criteria set forth in our laboratory for achieving VO$_{2\text{max}}$ as described by Petrides et al. (22).

**Load Carriage Test.** The load carriage exercise tests required the subject to wear a backpack weighted to 30% of his body weight (up to a maximum pack weight of 37.7 kg). Heart rate was measured by a Polar Accurex Plus (Polar Electro, Inc., Lake Success, NY); rectal temperature was taken by a rectal probe (YSI, Inc.,

### Table 1 General Characteristics of Subjects

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean (± SEM)</th>
<th>Range</th>
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<tbody>
<tr>
<td>Age (y)</td>
<td>32.0 ± 1.1</td>
<td>22–40</td>
</tr>
<tr>
<td>VO$_{2\text{max}}$ (mL · kg$^{-1}$ · min$^{-1}$)</td>
<td>51.7 ± 2.1</td>
<td>34.0–77.1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>81.1 ± 2.4</td>
<td>65–102</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177.6 ± 2.0</td>
<td>152–196</td>
</tr>
<tr>
<td>Body fat (%)*</td>
<td>10.9 ± 1.7</td>
<td>5.2–18.8</td>
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*Note. SEM = standard error of the mean.

*Determined from chest, abdomen, and thigh skinfold.
Yellow Springs, OH) continuously throughout the test. After a 5-min warm-up at 50% VO\textsubscript{2max} and a 3% grade, the grade was increased to 5% and the speed was adjusted to achieve 70% of each subject’s VO\textsubscript{2max}. The speed (3.7 mph ± 0.02) and grade were maintained for 120 min or until volitional exhaustion. If a subject was able to continue for more than 120 min, he was exercised to exhaustion by increasing the grade and speed to achieve a power output approximating 90% of maximal capacity. Upon exhaustion, the subject rated his perceived exertion (RPE) using the Borg scale, had the backpack removed, and then walked at 3.5 mph at a 2.5% grade for 5 min to cool down. Metabolic data, blood samples, and subject responses to Subjective Exercise Experience Scales (SEES) (16) and 100 mm Visual Analog Scale (VAS) (10) were obtained before, during, and after exercise. Blood draws for the load carriage test sessions were taken 35 min before starting exercise (Pre-Ex), 60 min after starting exercise (60), immediately after completing the load carriage task at 120 (111 to 129 min: Post-Ex), after completing the physical tasks at approximately 150 min (Post-Tasks), and again at 180 min (End). Samples for measurement of plasma tyrosine were obtained 35 min before starting exercise, immediately after completing load carriage (Post-Ex) and again at 180 min (End). Figure 1 presents a chronological overview of the experimental procedures for the load carriage sessions.

**Physical Performance Battery**

Subjects underwent practice sessions to attain proficiency on a physical performance battery designed to measure handgrip strength and endurance, lower body strength and coordination, and upper body strength and endurance. The specific physical tasks included 1) three maximal voluntary contractions (MVC) (30 s of

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**Figure 1 — Timeline for the experimental sessions.**
rest between) with a handgrip dynamometer followed by a 1 min rest and then maintenance of an isometric contraction equivalent to 30% of the means MVC for as long as possible; 2) maximum number of stairs (height = 0.25 m) stepped up and down in 1 min while wearing a 20 kg weight belt; and 3) as many pull-ups as possible with palms forward and chin touching the pole. All tests were conducted in a standardized manner as described by Hyde et al. (12). The tests, a subset of a performance test battery developed by the Naval Medical Research Institute, Bethesda, MD (12), were administered after completing the load carriage test. Power (watts) for the step test was calculated as body weight (kg) × 9.8 × 0.25 (step height) × steps/60.

**Ingestion of Tyrosine or Placebo**

Tyrosine (150 mg/kg 1-crystalline tyrosine in 70 g of apple sauce) and placebo (7 g microcrystalline cellulose in 70 g of apple sauce) were prepared and coded by a local pharmacy (Pathways, Bethesda, MD). The pharmacist kept the code until data collection was completed to maintain the double-blind status of the study. The tyrosine or placebo mixture was prepared in the HPL by mixing the set volume of apple sauce with the coded supplement. The mass of the supplement added was calculated based on the subject’s weight on the date of their VO\textsubscript{2max} test. The treatment was administered 30 min prior to starting exercise based on the literature indicating beneficial effects on cognitive performance (3, 6, 7, 25).

**Dietary Control**

A list of tyrosine-rich foods to avoid 24 h prior to testing was provided to each subject. The list included bananas, meats, pickled foods, cheeses (with the exception of cottage and cream cheeses), chocolate, any whole wheat products, and dairy products. In addition, subjects were asked to refrain from consumption of caffeine and alcoholic beverages for 24 h prior to testing. Subjects were encouraged to eat carbohydrate-dense foods, such as bagels, potatoes, and pasta with red sauce the night before testing. All subjects recorded their dietary intake on the day preceding the first load carriage test and were asked to duplicate the intake for the second test. Subjects were requested to refrain from eating or drinking after 10:00 PM the night before the load tests.

**Subjective Measures**

The Subjective Exercise Experiences Scale (SEES) is a 12-item scale that assesses 3 general categories of subjective responses to exercise stimuli: positive well-being, psychological distress, and fatigue. The subjects rated each item on a 7-point Likert scale (ranging from 1, “Not at all,” to 7, “Very much so”) describing how strongly they were experiencing each feeling (16), so that the highest score for each category was 28. In addition, two 100 mm, standardized Visual Analog Scales were used to assess anxiety and gastrointestinal (GI) discomfort before and after exercise. Subjects rated their GI discomfort and anxiety at the pre- and post-exercise time points, with the qualifiers ranging from none (0 mm) to extreme (100 mm) for both the GI and anxiety scale (10).
Biochemical Assays

Whole blood (1.0 mL) was collected in EDTA tubes for measuring hemoglobin and hematocrit by Baker Cell Counter (system 9000, ABX Diagnostics, Irvine, CA). Hemoglobin and hematocrit were used to exclude subjects who were anemic. Blood samples (1.5 mL) for measuring lactate and glucose were collected in tubes containing sodium fluoride; samples were centrifuged and the plasma was kept refrigerated at 4 to 6 °C until measured within 24 h by a YSI analyzer (model 2700, YSI, Inc.). Blood samples were collected in chilled EDTA tubes at 5 time points (−35, 60, 120, 150, and 180), centrifuged and stored at −80 °C for later analysis of cortisol, ACTH, epinephrine, and norepinephrine. Plasma cortisol (Diagnostics Products Corp., Los Angeles, CA) and ACTH (Nichols Institute Diagnostics, San Juan Capistrano, CA) were analyzed by standard radioimmunoassay (22, 23). Detection limits for cortisol and ACTH were 8.3 nmol/L and 0.22 pmol/L, respectively. Intra-assay coefficients of variation (CV) were less than 6%, and 8%, and interassay CVs were less than 10% and 15% for cortisol and ACTH, respectively. Plasma catecholamines were measured (time −35, 120, and 180) by liquid chromatography and electrochemical detection as described by Eisenhofer et al. (9). The detection limits of the assays were 1 to 2 pg/mL. Blood for plasma tyrosine (1.0 mL) was collected in chilled sodium heparin tubes at 3 periods during the load carriage test: −35, Post-Exercise, and Post-Cognitive. Plasma tyrosine concentrations were measured by high pressure liquid chromatography at Massachusetts Institute of Technology, Clinical Research Center, Cambridge, MA.

Statistical Analysis

The study was a multivariate factorial design consisting of within-subject factors of treatment (tyrosine vs. placebo) and time (repeated measures). Statistical Analysis System (SAS Institute Inc., Cary, NC) software was used for all statistics. Data are presented as mean ± standard error of the mean. Dependent measures included the performance tasks and repeated measure parameters included tyrosine, lactate, ACTH, and cortisol. The level of significance was set at $P < 0.05$. Sample size calculations were based on 1-tail tests using power = 0.80, the known intra-subject variability of the individual tasks, and an expectation that physical performance would improve at least 10% for each task. Specifically, overall improvements of 10%, 12%, 18%, 10%, and 10% were expected for the load carriage, maximal handgrip strength, grip endurance, pull-ups, and stair stepping, respectively, based on the within-subject CV for each task.

Results

Biochemical Measures

Tyrosine ingestion significantly ($P < 0.05$) raised plasma tyrosine after 120 min from baseline values of $65 \pm 3$ to $213 \pm 15$ μM. In contrast, plasma tyrosine post-exercise was not different from baseline under placebo conditions (Figure 2). Although neither plasma lactate nor glucose concentrations differed significantly as a function of tyrosine ingestion, both increased with exercise. Baseline lactate
values were $1.1 \pm 0.1$ mM and peak plasma lactate were $2.9 \pm 0.4$ and $3.9 \pm 0.5$ mM at the end of load carriage and $13.5 \pm 0.8$ and $12.8 \pm 0.7$ mM after pull-ups for tyrosine and placebo, respectively. Glucose levels increased from baseline values of $5.5$ mM to $5.7 \pm 0.2$ and $6.0 \pm 0.2$ mM after exercise under tyrosine and placebo, respectively.

Patterns of change in plasma ACTH and cortisol are shown in Figure 3. Although exercise induced marked increases in both ACTH and cortisol, responses under tyrosine and placebo were not significantly different for any time point.

Figure 2 — Mean plasma tyrosine concentrations for tyrosine (closed circles) and placebo (open circles) load carriage test sessions. Plasma tyrosine concentrations were measured before (Pre–Ex) and after (Post-Ex) load carriage, and at 180 min (End).

Figure 3 — Mean plasma ACTH (left panel) and cortisol (right panel) concentrations for tyrosine (closed circles) and placebo (open circles) treatments. Concentrations were measured before (~35), during (+60), and after (+120) load carriage, additionally after (+150) physical battery and cognitive battery (+180).
Similarly, tyrosine ingestion had no effect on plasma E or NE concentrations, although, as expected, the load carriage task significantly increased both E and NE (Figure 4).

Physical Tasks

Despite significant elevations in plasma tyrosine, no significant differences were noted for any physical task. Ingestion of tyrosine did not significantly lengthen total time on the treadmill: 118.9 ± 1.4 min for tyrosine as compared to 119.2 ± 1.2 min for placebo treatment. Four subjects failed to complete the 120 min load carriage task for both treatments and 3 persons failed to complete 1 test: there were 2 incompletes for placebo and 1 for tyrosine. Those who were unable to finish had VO\textsubscript{2\max} values of 52.9 ± 4.2 mL · kg\textsuperscript{-1} · min\textsuperscript{-1} as compared to 51.2 ± 1.3 mL · kg\textsuperscript{-1} · min\textsuperscript{-1} for those who complete both tests. All subjects completed the physical performance battery. Table 2 presents the results of the physical performance battery tasks under each treatment condition. As shown, anaerobic power for the stair step (tyrosine: 223 ± 8 watts and placebo: 216 ± 9 watts) and muscle strength and endurance (handgrip) were not significantly improved by tyrosine ingestion.

Physiologic Measures

Temperature and heart rate measurements followed the same trends for both treatment conditions: no significant differences were noted. Peak core temperature averaged 38.1 °C for both tyrosine and placebo during the load carriage tasks. Likewise, peak heart rates during load carriage averaged 159 ± 6.0 and 161 ± 3.2 bpm for tyrosine and placebo, respectively.
**Subjective Measures**

State anxiety and gastrointestinal (GI) symptoms of the subjects were quantified before and after each load session by using the 2 VAS scales. No significant differences in GI or anxiety scores were noted as a function of treatment (data not shown). The load carriage paradigm per se markedly increased GI distress and anxiety, however. Baseline scores averaged 1.5 ± 1.5 and 10 ± 2.7 and at the end of the load carriage averaged 8.0 ± 3.8 and 19.3 ± 5.1, for GI distress and anxiety, respectively. Perceived exertion following the load carriage did not differ significantly as a function of treatment with tyrosine (tyrosine: 13.9 ± 0.9 vs. placebo: 14.6 ± 0.5). The SEES scores illustrate a strenuous work effort for both treatments, but the scores did not differ significantly with regard to treatment (Table 3). Although the percent change in perception of fatigue increased to a greater extent with placebo (112.4% ± 23.9) as compared to tyrosine (103.2% ± 27.8), the intra- and inter-subject variability was great. As such, the changes did not differ significantly as a function of treatment.

**Discussion**

The purpose of this study was to determine if acute ingestion of tyrosine would enhance aerobic endurance, muscle strength and endurance, or anaerobic power. To date, minimal work has been conducted to examine this question, and most of the work has been carried out in animals. Acute exposure to stressful events, such

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**Table 2  Mean Scores on Physical Battery Tasks**

<table>
<thead>
<tr>
<th>Task</th>
<th>Tyrosine</th>
<th>Placebo</th>
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<tbody>
<tr>
<td>Hand grip max (lbs)</td>
<td>105.1 ± 5.7</td>
<td>116.5 ± 6.1</td>
</tr>
<tr>
<td>Grip time (s)</td>
<td>150.0 ± 10.0</td>
<td>145.3 ± 12.5</td>
</tr>
<tr>
<td>Stair steps (number/min)</td>
<td>56.5 ± 1.8</td>
<td>54.5 ± 2.0</td>
</tr>
<tr>
<td>Pull-ups (number completed)</td>
<td>12.4 ± 1.0</td>
<td>12.0 ± 1.2</td>
</tr>
</tbody>
</table>

*Note.* Values are means ± standard error of the mean.

**Table 3  Mean Scores of Subjects on Subjective Exercise Experiences Scale**

<table>
<thead>
<tr>
<th>Response</th>
<th>Tyrosine</th>
<th>Placebo</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Positive feelings</td>
<td>24.7 ± 0.7</td>
<td>20.1 ± 1.2</td>
</tr>
<tr>
<td>Negative feelings</td>
<td>4.6 ± 0.2</td>
<td>7.1 ± 0.7</td>
</tr>
<tr>
<td>Fatigue feelings</td>
<td>6.0 ± 0.6</td>
<td>15.5 ± 1.4</td>
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*Note.* Values are means ± standard error of the mean.
as cold, sleep deprivation, and starvation, is associated with neurochemical, behavioral, and cognitive changes (1, 5, 6, 7, 21, 24, 25, 28). Administration of tyrosine has been shown to attenuate many of the stress-induced cognitive deficits (3, 7-9, 19), as well as to decrease systolic blood pressure (6, 7). In contrast to tyrosine’s beneficial effects on cognition, ingestion of tyrosine in the present study did not improve physical performance, either by extending the time to fatigue during a strenuous load carriage task or by improving performance on various anaerobic physical tasks. Thus, tyrosine does not appear to be justified as a performance-enhancing agent.

To date, only a very limited number of human studies have examined the effects of tyrosine ingestion on physical performance. Struder et al. (26) studied 10 male subjects who cycled in 4 trials until exhaustion. For one of the trials, subjects were supplemented with 10 g of tyrosine on 2 occasions: 15 min before cycle exercise and again 60 min into the trial. The investigators were unable to demonstrate any positive effect from the use of supplemental tyrosine during exercise (26). They did, however, conclude that pharmacological augmentation of brain serotonergic activity was associated with a more rapid onset of fatigue. A more recent study by Chinevere et al. (4) also found no beneficial effect of tyrosine administration on physical performance. They studied 9 competitive cyclists during 90 min of cycling exercise at an intensity equivalent to 70% of peak oxygen uptake. Every 30 min, starting 60 min prior to exercise, the subjects ingested either water sweetened with aspartame, 25 mg/kg body weight of L-tyrosine, a 7% glucose polymer solution (GPS) or a combination of tyrosine with GPS and L-tyrosine. Overall, the total amount provided by Chinevere et al. (4) was comparable to that in our study (10.5 g for a male subject weighing 70 kg), whereas Struder et al. (26) provided a total of 20 g and did not account for body weight. Because neither of the dosages conferred any measurable benefit, particularly with respect to endurance performance, one could conclude that a higher dosage is needed. In the present study and in the study by Chinevere et al., however, (4), plasma tyrosine increased three to fivefold, which provided clear evidence that the ingested tyrosine was available. Thus, it is difficult to expect higher blood values to yield a beneficial effect.

Chinevere et al. (4) postulated a threshold dose wherein there would be a marked beneficial response below and a negative one above a certain blood threshold. Although we cannot test the validity of that hypothesis, it is clear that Chinevere’s group achieved blood levels in excess of 350 μM. Based on the available data, it seems that plasma tyrosine levels between 200 and 350 μM have no beneficial effect on physical performance (4, 26) and, furthermore, such levels do not increase plasma catecholamines. Although the timing of administration might also have an effect on the outcome of tyrosine ingestion, the 3 available studies provided tyrosine on 1 (present), 2 (Struder), and 6 (Chinevere) occasions, all with comparable results, so it is unlikely that a different ingestion schedule would have affected the results. Lastly, the form of administration of the supplement may be a factor in the results, but again, the tyrosine was provided as a powder in food, in fluid, and in capsule forms with negative results (4, 26).

Although one could also argue that no benefits were noted because the protocol was not sufficiently stressful, the stressful nature is supported by a number of markers. First, circulating levels of ACTH and cortisol increased significantly.
Second, blood levels of both lactate and glucose were elevated during the protocol: blood lactate increased tenfold by the end of the physical tasks. Third, plasma levels of NE and E increased at least fivefold. Finally, the subjective measures of GI distress, anxiety level, affect, and fatigue clearly indicated the strenuous nature of the tasks. Together, these results demonstrate that the subjects were significantly stressed. Importantly, no improvements in performance were noted when tyrosine was ingested as compared to placebo even though subjects were clearly stressed. Furthermore, plasma tyrosine levels did not decrease significantly as a function of the strenuous exercise, which suggests that tyrosine availability might not be compromised by acute strenuous physical stress. Plasma tyrosine levels in the studies of Chinevere et al. (4) also were maintained.

In summary, this study examined whether acute ingestion of tyrosine could improve aerobic endurance, muscle strength and endurance, or anaerobic power. Despite marked increases in plasma tyrosine and plasma NE and E, physical performance across a number of physical tasks was unaffected by tyrosine ingestion as compared to placebo. Whereas many possible factors could account for no effect (dosage, timing, and mode of administration), careful evaluation indicates that it is unlikely that the amino acid, tyrosine, is an ergogenic agent.

Acknowledgments

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References


