

# 行政院國家科學委員會專題研究計畫 成果報告

## 補充精胺酸與支鏈胺基酸對運動表現的影響 研究成果報告(精簡版)

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執行期間：97年08月01日至98年07月31日  
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計畫主持人：張振崗  
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行政院國家科學委員會補助專題研究計畫  成果報告  
 期中進度報告

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成果報告類型(依經費核定清單規定繳交)： 精簡報告  完整報告

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執行單位：國立臺灣體育學院

中華民國 98 年 10 月 29 日

## Abstract

Nitric oxide (NO) is a potent endothelium-derived vasodilator synthesized by nitric oxide synthase (NOS) using arginine as the precursor. Exercise-induced NO production could result in improved endothelium-dependent vasodilation. The accumulations of lactate and ammonia have been shown to be involved in the development of muscular fatigue due to the increased muscular acidity. The acute oral supplementation of arginine could also decrease exercise-induced ammonia. The purpose of this study was to investigate effect of arginine and BCAA supplementations during recovery period on subsequent exercise bouts after high-intensity intermittent exercise in Taekwondo athletes. The substrate utilization during the period was also examined. This study uses a randomized and cross-over design. Each subject underwent 3 trials, separated by a 2-week wash-out period. Each trial contained 3 exercise tests with a 2-hr recovery period between each exercise test. Eight male Taekwondo athletes were recruited. In each of the 2 recovery periods, the subjects consumed 1 g/kg body weight carbohydrate (CHO trial), 1 g/kg carbohydrate plus 0.1 g/kg arginine and 0.1 g/kg BCAA (leucine:isoleucine:valine = 2:1:1) (CHO+AA trial), or 1.2 g/kg carbohydrate (CHO+CHO trial, isocaloric to CHO+AA trial). CHO+AA trial showed significantly higher accumulated work during the 3 test periods than the other 2 trials. CHO+CHO trial also had significantly higher accumulated work than CHO trial. The area under the curve (AUC) of plasma glucose during the entire study period was significantly lower in CHO+AA trial, compared to the other 2 trials. CHO+AA trial also showed significantly higher AUC of plasma insulin during the entire period than the other 2 trials. The results of this study suggested that supplementation of arginine and BCAA, in combination with glucose, could improve intermittent high-intensity exercise performance. One of the potential mechanism is better glucose recovery as CHO+AA trial had higher insulin response and lower plasma glucose during the entire study period.

## 摘要

Nitric oxide (NO)可促進血管舒張，前驅物為精胺酸，運動期間增加的NO合成可促進運動期間的血管擴張。乳酸與氨的累積是造成疲勞的原因之一，補充精胺酸可能可以減少運動期間氨的堆積。本研究目的為探討於休息期間補充精胺酸與支鏈胺機酸對後續跆拳道運動表現的影響，並探討測試期間受質利用的改變。本研究採用交叉實驗設計，每位受測者進行3次測試，共8名男性跆拳道選手，在2次休息期間，分別攝取醣類 1 g/kg (CHO trial)、醣類 1 g/kg、0.1 g/kg arginine and 0.1 g/kg BCAA (leucine:isoleucine:valine = 2:1:1) (CHO+AA trial)、醣類 1.2 g/kg (CHO+CHO trial)。CHO+AA trial 在3次運動測試期間總做功顯著高於其他2 trials，CHO+CHO trial 的總做功亦高於CHO trial。CHO+AA trial 血糖曲線下面積顯著低於其他2 trials，胰島素濃度曲線下面積則顯著高於其他2 trials。本研究顯示，補充精胺酸與支鏈胺機酸可增加對後續跆拳道運動的表現，可能機轉為精胺酸與支鏈胺機酸增加胰島素反應，增加肝醣恢復。

## Introduction

NO is a potent endothelium-derived vasodilator synthesized by nitric oxide synthase (NOS) using arginine as the precursor. Regular exercise training has been shown to increase basal NO production via increased Shear stress in vascular endothelial cells (1). Shear stress may increase the availability of intracellular arginine by stimulating the high-affinity/low-capacity transport system (2). Shear stress also markedly increases endothelial NOS (eNOS) activity (3) by phosphorylation via a phosphatidyl-inositol-3-kinase and serine/threonine kinase Akt pathway (4). Exercise-induced NO production could result in improved endothelium-dependent vasodilation in animal aorta (5-8) and human forearms (9). This mechanism has also been suggested to be one of the reasons responsible for the cardiovascular protective effect of regular exercise (1).

Plasma ammonia concentration increases during intensive exercise due to a combined effect of purine nucleotide deamination and amino acid catabolism within the active muscle (10, 11). The accumulations of lactate and ammonia have been shown to be involved in the development of muscular fatigue due to the increased muscular acidity (12-14). The acute oral supplementation of arginine could also decrease exercise-induced ammonia. Eto et al. suggested that the intake of 20 g arginine 30 min prior to the exercise at 75-80%  $\dot{V}O_{2max}$  for 30 minutes could diminish the elevation in blood ammonia (15). The chronic oral arginine supplementations also showed similar effects on exercise. After supplemented with arginine aspartate for 10 days, the increase of blood ammonia was significantly lower than the placebo group after exercising at 80%  $\dot{V}O_{2max}$  for 15 minutes (16).

Muscle glycogen is the most important energy source during high-intensity intermittent exercise such as Taekwondo. Taekwondo tournaments usually finish in one day, containing multiple contests with 1-2 hours of rest in between. The insufficient recovery of muscle glycogen after previous contests may affect the performance in the subsequent contest. Therefore, it is essential to establish the optimal post-exercise muscle glycogen recovery protocol following high-intensity intermittent exercise.

Fallowfield et al. suggested that during the 4 hr recovery period after running for 90 min at 70%  $\dot{V}O_{2max}$ , carbohydrate supplementation could increase the time to exhaustion in the subsequent exercise (17). The consumption of carbohydrate-protein drink after glycogen-depleting exercise also increased the time to exhaustion by 55% in the subsequently cycling exercise at 85%  $\dot{V}O_{2max}$ , compared to carbohydrate alone (18). Betts et al. revealed that carbohydrate-protein supplementation during the 4-hr post-exercise recovery period significantly increased time to exhaustion in the subsequent running exercise at 70%  $\dot{V}O_{2max}$  compared to carbohydrate alone (19). However, the carbohydrate-protein supplementation did not show any additional effect compared to isocaloric carbohydrate (19). On the other hand, several studies have failed to observe the beneficial effect of carbohydrate-protein supplementation during post-exercise recovery on the performance of subsequently exercise compared to carbohydrate alone (20, 21). The aforementioned studies all focused on endurance exercise. No study has investigated the

effect of recovery regimen on high-intensity intermittent exercise.

The purpose of this study was to investigate effect of arginine and BCAA supplementations during recovery period on subsequent exercise bouts after high-intensity intermittent exercise in Taekwondo athletes. The substrate utilization during the period was also examined.

## Methods

### Subjects

Eight male Taekwondo athletes were recruited from NTCPE. All subjects have been participated in regular Taekwondo training for at least 3 years and have competed in national or international level. All subjects have not taken any protein supplementation for at least 3 months prior to the study. The subjects maintained their regular training schedule and diet habits during the study period.

### Experimental procedure

The procedure of the study is displayed in Fig 1. This study uses a randomized and cross-over design. Each subject underwent 3 trials, separated by a 2-week wash-out period. Each trial contained 3 exercise tests with a 2-hr recovery period between each exercise test. The order of each trial was randomized for each subject. Each subject arrived in the lab at 8:00 am after an overnight fast. After recording nude body mass, a cannula was put in the antecubital vein by licensed personnel for blood sampling. The subjects then ate a standardized breakfast of white bread, jelly, and carbohydrate drink, providing 1.5 g/kg carbohydrate. The exercise started 60 min after the breakfast. In each of the 2 recovery periods, the subjects consumed 1 g/kg body weight carbohydrate (CHO trial), 1 g/kg carbohydrate plus 0.1 g/kg arginine and 0.1 g/kg BCAA (leucine:isoleucine:valine = 2:1:1) (CHO+AA trial), or 1.2 g/kg carbohydrate (CHO+CHO trial, isocaloric to CHO+AA trial), dissolved in 600 ml water, in each of the 2 recovery periods.

### Exercise test

Each trial contained 3 exercise periods with a 2-hr recovery period between each period. Each exercise period was divided into three 2-min bouts with 1 min interval between each bout. The subjects alternated 10-sec all-out exercise and 20-sec rest periods on a Monarch cycle ergometer (894E, Monark, Varberg, Sweden). The load in the exercise period was set at 0.1 kp/kg. The subjects were asked to pedal as fast as possible with vocal encouragement by research personnel. In the rest period the load was set at 0 and the subjects pedaled at 60 rpm. The total work performed in the entire exercise period was calculated.

### Blood analyses

Plasma NO<sub>x</sub> concentrations will be determined by Griess reaction (22) with slight modifications. Plasma concentrations of glucose, free fatty acid, glycerol, ammonia, and lactate were measured by an automatic analyzer (Hitachi 7020, Tokyo, Japan) using commercial kits. Plasma

concentrations of insulin were measured by electrochemiluminescence (Elecsys 2010, Roche Diagnostics, Basel, Switzerland) with the kits provided by the manufacturers.

### Statistical analysis

The differences in total work of each exercise period, plasma biochemical and hormonal parameters were analyzed by two-way ANOVA for repeated measures (treatment x time). A Tukey test will be used in post hoc analysis to detect differences over time. All analyses will be performed with SPSS for Windows 10.0 (SPSS Inc., Chicago, IL, USA). Data was expressed as mean±SD.

### Results

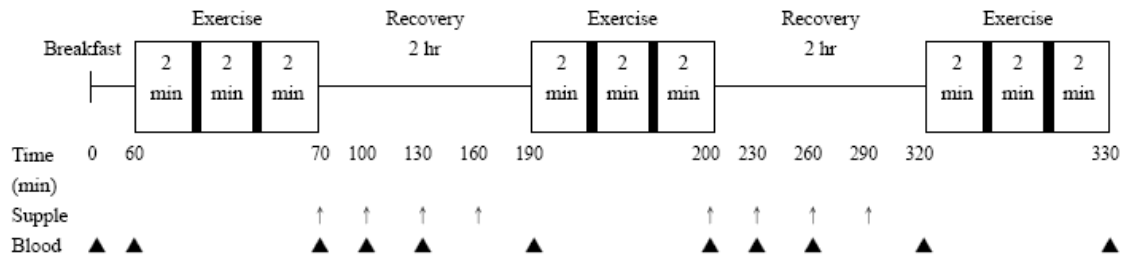
The age of subjects was 21.2±1.2 years, height was 1.75±0.05 m, body weight was 77.5±8.6 kg, VO<sub>2</sub>max was 53.2±6.5 ml/kg/min. CHO+AA trial showed significantly higher accumulated work during the 3 test periods than the other 2 trials. CHO+CHO trial also had significantly higher accumulated work than CHO trial (Figure 2). The area under the curve (AUC) of plasma glucose during the entire study period was significantly lower in CHO+AA trial, compared to the other 2 trials (Figure 3). CHO+AA trial also showed significantly higher AUC of plasma insulin during the entire period than the other 2 trials.

### Discussion

The results of this study suggested that supplementation of arginine and BCAA, in combination with glucose, could improve intermittent high-intensity exercise performance. One of the potential mechanism is better glucose recovery as CHO+AA trial had higher insulin response and lower plasma glucose during the 6-h study period.

The consumption of arginine and leucine along with glucose could result in higher insulin response comparing to glucose alone in healthy subjects at rest (23) and after exercise (24). The supplementation of leucine in combination with carbohydrate resulted in higher post-exercise insulin concentration and greater muscle glycogen recovery comparing to carbohydrate alone in highly trained athletes (25). Other studies also suggested that supplementation of carbohydrate and protein hydrolysates could increase post-exercise muscle glycogen resynthesis compared to isocaloric carbohydrate (26, 27). Several in vitro studies have also confirmed the stimulatory effect of arginine and leucine on insulin secretion in isolated beta-cells (28-30). In addition, it has been suggested that NO may increase the expression and translocation of glucose transporter-4 (GLUT-4) in rat skeletal and heart muscles (31, 32). The vasodilation effect of arginine may increase blood flow and substrate delivery to muscle and increase glycogen recovery. This study also indicated that supplementation of BCAA and arginine could increase insulin response to carbohydrate consumption, which lead to increased glucose deposit to muscle cells. The higher glycogen content lead to higher exercise performance in intermittent high intensity exercise.

Year 1



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Year 1

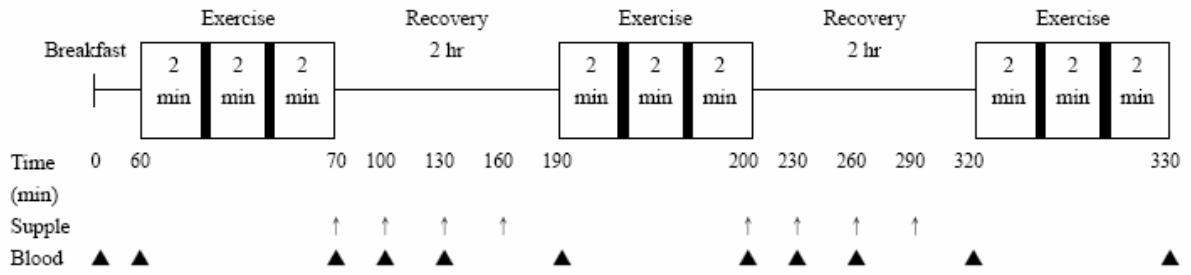


Figure 1. Experimental procedure

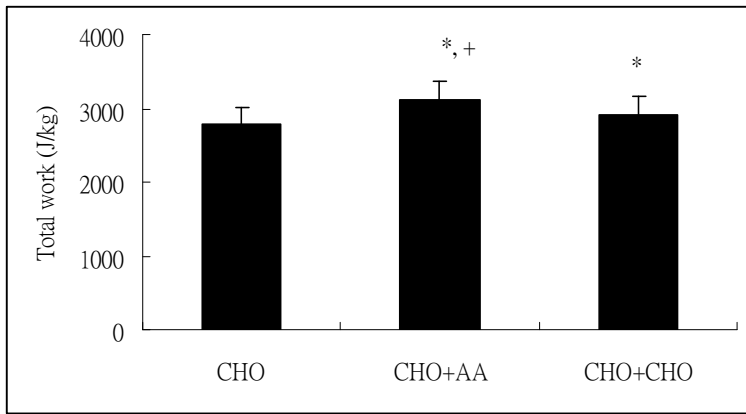


Figure 2. Total work of the 3 exercise tests of the 3 trials. \* $p < 0.05$ , compared to CHO. + $p < 0.05$ , compared to CHO+CHO.

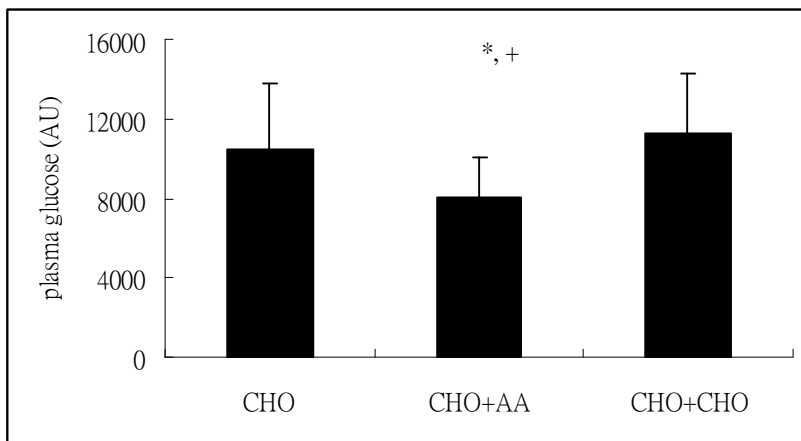


Figure 2. Area under the curve of plasma glucose of the 3 trials. \* $p < 0.05$ , compared to CHO. + $p < 0.05$ , compared to CHO+CHO.

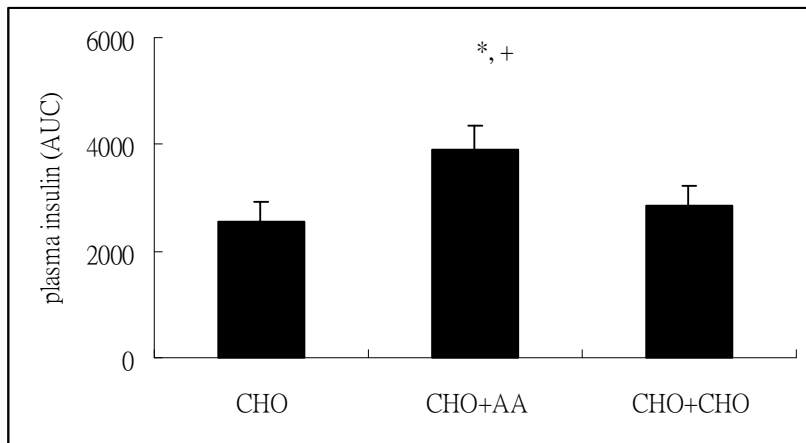


Figure 3. Area under the curve of plasma insulin of the 3 trials. \* $p < 0.05$ , compared to CHO.  
+ $p < 0.05$ , compared to CHO+CHO.