

The Effects of Chronic Branched-Chain Amino Acid Supplementation on Running Kinematics: Single Case Research

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The Effects of Chronic Branched-Chain Amino Acid Supplementation on Running Kinematics:
Single Case Research

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Abstract

Purpose: To monitor the effects of chronic branched-chain amino acid (BCAA) supplementation on running kinematics in a trained ultra-endurance runner. **Methods:** One well-trained ultra-endurance runner followed three 10-day cycles of an AB design consuming a BCAA drink (SUP) or placebo (PLA) surrounding daily key workouts leading up to a 50-mile race (dosage = 0.08g/kg/day = 3.52g BCAA/day and 10.32g AA/day). During each 10-day cycle, the athlete completed a 5km run on an outdoor track at 6:30min/mile pace. A 10-meter capture zone was measured and marked with two orange cones for video recording and analysis. Kinovea open-source software (Version 0.8.15) was used to measure running kinematic variables: ground contact time (GCT), flight time (FT), and vertical oscillation (VO). **Results:** Vertical oscillation (VO) during a constant-pace run was significantly reduced from 88mm to 76mm when athlete was on SUP vs PLA condition ($p = 0.00$, $\text{Tau-U} = 0.40$). Statistical significance was not achieved for differences in GCT and FT between SUP and PLA ($p = 0.06$, $\text{Tau-U} = 0.17$ and $p = 0.28$, $\text{Tau-U} = 0.10$ for GCT and FT, respectively). Weighted Tau-U results suggest that the BCAA supplement was overall 11% effective in improving combined measures of running kinematics ($p = 0.04$, $\text{Tau-U} = 0.11$). **Discussion:** A decrease in VO can indicate less overall muscle support requirements during stance phase and a reduced aerobic demand for a given task. We observed decreased VO during the 5km running tests on SUP indicating a reduction in wasteful vertical motion. Possible explanations for this could relate to improvement in muscle recovery characteristics from increased availability of BCAs resulting in less chronic fatigue. Less fatigue can allow greater coactivation between two-joint muscles of the leg during stance resulting in more efficient joint rotations that are transferred into desired external forces, promoting more efficient movement and a more economical runner.

Introduction

Activities (such as running) that include an eccentric contraction component result in exercise-induced muscle damage with a subsequent inflammatory response (Peake, Nosaka, & Suzuki, 2005). This inflammatory response is responsible for initiating tissue repair and remodeling (Hyldahl & Hubal, 2014; Peake et al., 2005). Specifically, satellite cells, inflammatory cells, vascular cells, and stromal cells all interact with each other within the extracellular matrix of skeletal muscle and the time course of each is dependent on the magnitude of recovery necessary from muscular damage (Hyldahl & Hubal, 2014; Peake et al., 2005). Exercise-induced muscle damage from eccentric contraction components cause sarcomere damage as evidenced by Z-disk streaming and likely directly reduce force production characteristics (Peake et al., 2005). Sarcomere damage is not a single event, but may cause opening of stretch-activated channels, membrane disruption, and excitation-contraction coupling dysfunction resulting in a prolonged loss of muscle strength (Hyldahl & Hubal, 2014; Peake et al., 2005).

In addition to loss of muscle strength and power, other symptoms include delayed onset muscle soreness (DOMS), swelling, reduced range of motion of the affected body part, an efflux of inflammatory enzymes, or a combination of these (Hyldahl & Hubal, 2014). These symptoms often peak around 1-3 days after exercise (Hayashi et al., 2017) and are a normal part of an athlete's recovery adaptation process. Some research has shown a reduction in symptoms of exercise-induced muscle damage and fatigue with BCAA supplementation (Beelen et al., 2010; E. Blomstrand et al., 1996; Kim, Kim, Jeong, & Lee, 2013b; K. Matsumoto et al., 2009b; Sharp & Pearson, 2010). In addition, a review of the literature by (9) suggested that BCAA supplementation can be effective on reducing outcomes of exercise-induced muscle damage, as

long as the extent of muscle damage was low-to-moderate, the supplementation strategy combined a high daily BCAA intake (>200 mg/kg/day) greater than 10 days, and was especially effective if taken prior to the damaging exercise.

Protein and BCAA supplementation practices surrounding training sessions has a culture that is deep-rooted in the strength training community with a wealth of research that supports the harmonious relationship between increased protein availability and enhanced postexercise muscle protein synthesis (MPS) for muscle remodeling and repair (10). In contrast, the use of dietary protein supplements in the endurance training community is relatively recent (11). Endurance athletes who undertake prolonged (i.e. >1 h) training bouts or who train multiple times a day (but not always in a glycogen-depleted state) subject their muscles to prolonged periods of net catabolism that may impact enhancement of MPS and whole body muscle protein balance in the postexercise recovery period (11). Further, the mechanical events associated with continuous endurance training undoubtedly result in skeletal muscle structural and protein damage that requires nutritional intervention (12–14).

While the repair and remodeling of damaged muscle proteins is still a primary goal for endurance athletes who consume protein/BCAA supplements, benefits also include synthesizing new proteins that directly influence aerobic training adaptations (including myofibrillar, mitochondrial, and associated enzyme complexes) (11). This repair, remodeling, and synthesis of proteins underpins many of the training-induced adaptations that athletes seek and are ultimately related directly to the quality of muscle (i.e. mitochondrial density and/or cross-sectional area) responsible for improved sport performance (i.e. improved running economy) (11,15). Many endurance events provide athletes with a carbohydrate only option post-race, (e.g. bananas), however, the most important nutritional factor in enhancing postexercise MPS is the ingestion of

dietary protein (11,16–18). While carbohydrate ingestion alone can halt further protein breakdown, it has little effect on MPS and does not further the dietary amino acid induced stimulation of MPS after exercise (16, 17, and 19).

Amino acid oxidation can provide up to 10% of total energy during endurance exercise (20). This enhanced oxidation arises from the breakdown of muscle proteins into amino acids which are released from the muscle for hepatic gluconeogenesis and/or deaminated and oxidized within muscle mitochondria as a direct source of fuel (19–22). Further oxidation of endogenous amino acids supports muscle contraction and can be enhanced by several factors such as exercise intensity and/or duration and low muscle glycogen availability (19–21, 23). This in turn leads to decreased substrate availability that may limit or prolong postexercise muscle protein repair and synthesis (19).

Whole-body rates of amino acid oxidation still remain elevated above rest with an estimated 1.2g of total body leucine loss over 2 hours of moderate intensity endurance exercise (~60% VO_{2max}) (24). When amino acids are oxidized during exercise they are lost from the body and unable to contribute to the increased MPS observed during recovery therefore necessitating dietary replacement (21, 24). Several studies have shown that an increased supply of BCAAs prior to exercise may have a sparing effect on muscle glycogen degradation during exercise as well as a decreased rate of release of essential amino acids from exercising muscle and therefore a decreased rate of protein degradation (19,22,25). Where fatigue symptoms from training are a major factor influencing running economy, we chose various running kinematics to observe as fatigue indices during a constant-paced 5km training run between chronic conditions of SUP or a PLA (15). Theoretically, the BCAA may promote a greater MPS and recovery from day to day training resulting in a decreased fatigue state, improved running mechanics, and

therefore a greater running economy than when on a PLA. Therefore, the purpose of this study was to investigate the influence of BCAA supplementation on various running kinematics during constant-paced 5km training runs in a trained ultra-endurance runner.

Methods

Subject

One well-trained, experienced ultra-endurance runner was monitored during one macrocycle leading up to a 50-mile running competition. Inclusion criteria were determined by training status and experience level and were met by the criteria of 1.) had to be currently training for an ultra-endurance event, and 2.) had previously competed in an ultra-endurance event. This athlete was consistently a top 20 placement finisher in all lifetime races. Prior to participation, the athlete read and signed a written informed consent document that was approved by the East Tennessee State University Institutional Review Board.

Laboratory testing

Prior to beginning the study, the athlete underwent two lab testing sessions for assessment of fitness and determination of training paces to be incorporated into his training program. Each laboratory testing session included a velocity at VO₂max (vVO₂max) test (26, 27). The vVO₂max testing sessions took place on a laboratory treadmill (Tuff Tread Model RL35023-N5-1K, Willis, TX) using a metabolic cart (ParvoMedics TrueOne 2400 Metabolic Measurement System, Sandy, UT) to measure gas exchange. Testing sessions were separated by one week to eliminate the influence of fatigue on performance and results were averaged. Prior to each testing session, the athlete consumed the same self-selected breakfast meal. Collected variables during the vVO₂max test were VO₂max and peak treadmill running velocity, as the latter has been shown to predict performance in 10km-90km running specialist (27). In addition,

aerobic and anaerobic ventilatory thresholds (VT1 & VT2) were obtained using the ventilatory equivalents method and visual inspection. Training paces for programming were calculated from a percentage of the athlete's VO₂max and corresponding treadmill running velocities to correspond with zones established by running coach Dr. Jack Daniels (E, M, T, I, & R, or - easy, marathon, threshold, tempo, interval, and repetition, respectively).

Training

The athlete's training plan was composed of 10-day mesocycles (vs. the traditional 7-day mesocycle that is typical for runners to follow) to allow more recovery time/restoration sessions that are necessary, but often neglected, from the intense training that an ultra-endurance event requires. The running training plan followed a polarized model with Zones 1, 2, & 3 demarcated by ventilatory thresholds 1 & 2. Key workouts in the running plan included: 1.) Back-to-back long runs – one shorter, followed by one longer the next day for 1 set/mesocycle. The shorter long-run was prescribed as 65% of the following day's long run through the special prep phase. The longer runs were built off the percentage of the peak long-run mileage mesocycle which included a training race of 31 miles plus the mileage of the shorter long run of 7 miles to total 38 miles for the back-to-back peak mileage long-run. Thirty-eight miles was 75% of the 50-mile goal. The long runs started at 40% of the 31-mile single-session run which was equal to a 12.5-mile-long run in the first cycle of the training program; 2. Tempo/Threshold Runs occurred once/mesocycle and followed a progressive build up to a 40-minute steady-state; 3. Speed or Hill session – once/alternating mesocycles where speed sessions started at tempo pace (Zone 2) during general preparation and advanced to interval pace (Zone 3) during specific preparation. Hill intervals increased in distance, degree of inclination, and speed to build specific strength for being able to run over mountainous, varying terrain.

In addition to a running training plan, the athlete followed a block-periodized strength training program that incorporated the basic principles of progressive overload and used relative-intensities for training load prescription. Strength sessions were prescribed 3 times/mesocycle (or 3 sessions every 10 days), through the special preparation period, and thereafter decreased to 2 sessions/cycle through the competition and taper phase.

Intervention

Following 4 cycles of an AB single-blind design, the athlete consumed either BCAA drink or placebo before and after every key workout every day through his goal race. The BCAA drink and placebo were isocaloric and flavor matched. Each condition lasted the duration of one mesocycle (10 days) and then was reversed. In addition, conditions were randomized so that the athlete wasn't always on SUP on his heaviest training cycle. The athlete consumed the manufacturer recommended product dosage of 0.08g/kg that was split evenly between a "pre-workout" and "post-workout" supplement so that before the workout 0.04g/kg of product was consumed, and after 0.04g/kg of product was consumed which resulted in a total of 10.32g of total amino acids/day for this athlete (see Table 4.1). Dosages were portioned out, labeled "pre" or "post" in baggies, and given to the athlete at the beginning of each mesocycle to consume before/after workouts.

Table 4. 1. Composition and dosages of pre- and post- workout supplements.

PRE-WORKOUT (0.04g/kg)			
Serving size 5.6g = 1 stick pack			
Amino Acid	Serving (g)	g per 1 g	Athlete's Serving Size (g)
Leucine	0.528	0.094	0.93
Isoleucine	0.424	0.075	0.75
Valine	0.36	0.064	0.64
Total BCAA	1.312	0.239	2.32
Arginine	0.6	0.106	1.06
Glutamine	0.622	0.11	1.10
TOTAL AMINO ACIDS			6.81
 POST-WORKOUT (0.04g/kg)			
Serving size 8.24 = 1 scoop			
Amino Acid	Serving (g)	g per 1 g	Athlete's Serving Size (g)
Leucine	0.438	0.053	0.50
Isoleucine	0.33	0.04	0.38
Valine	0.28	0.034	0.32
Total BCAA	1.047	0.127	1.20
Arginine	0.47	0.057	0.54
Glutamine	0.488	0.059	0.56
TOTAL AMINO ACIDS			3.51

Monitoring

Once per mesocycle and condition, the athlete completed a running field test on an outdoor track. The run was 5km and performed at a 6:30min/mile pace that was associated with the athlete's prescribed marathon pace – the approximate effort at which an ultra endurance race would be performed. Prior to starting the run, the athlete measured a 10-meter capture zone on the same section of track and marked the zone with two orange cones. A video camera (30fps x 1080p) was set up on the side of the track, far enough away so that the entire capture zone and horizon were in view. After a warm-up, the athlete turned the video camera on and proceeded with the 5km run using the Garmin 220 GPS wrist-watch to allow pace monitoring. Video-taped 5km field tests were analyzed using Kinovea open-source software (Version 0.8.15) for running kinematic variables such a ground contact time (GCT), flight time (FT), and vertical oscillation (VO).

Statistical analysis

Tau-U single-case research technique was used to observe the effect that each condition had on running kinematics (GCT, FT, and VO). The Tau-U effect size represented a percentage of nonoverlap between phases and will be described as percent effectiveness of the BCAA condition (28).

Results

Vertical oscillation (VO) during a constant-pace run was significantly reduced by 13.0% from 88mm to 76mm when athlete was on SUP vs PLA condition ($p = 0.00$, $\text{Tau-U} = 0.40$). Statistical significance was not achieved for differences in GCT (-2.05%) (0.206s vs 0.211s, $p = 0.06$, $\text{Tau-U} = 0.17$ for PLA and SUP, respectively) and FT (8.05%) (0.037s vs 0.034s, $p = 0.28$, $\text{Tau-U} = 0.10$ for PLA and SUP, respectively). However, weighted Tau-U results suggest

that the BCAA supplement was overall 11% effective in improving measures of running kinematics ($p = 0.04$, $\text{Tau-U} = 0.11$) likely due to the highly favorable results from a reduction in VO where Tau-U indicated that SUP was 40% effective in reducing VO. In addition, while a reduction in flight time was not statistically significant, we did observe an 8% improvement while on SUP. See Tables 4.2 and 4.3, and Figures 4.1, 4.2, and 4.3, below.

Table 4.2. Tau-U results for SUP vs PLA on running kinematics (GCT, FT, and VO)

CONDITION	TAU	SDtau	P Value	CI 90%
S-GCT vs P-GCT	-0.1791	0.0962	0.063	-0.337<>-0.021
S-FT vs P-FT	0.1037	0.0962	0.281	-0.055<>0.262
S-VO vs P-VO	0.4056	0.0962	0.000	0.247<>0.564

Table 4.3 Means and percent change in running kinematics (GCT, FT, and VO) between SUP and PLA

CONDITION	GCT(s)	FT(s)	VO(mm)
SUP	0.211	0.034	76
PLA	0.206	0.037	88
% Difference	-2.05%	8.05%	13.14%

Figure 4.1. Ground contact time for SUP and PLA conditions

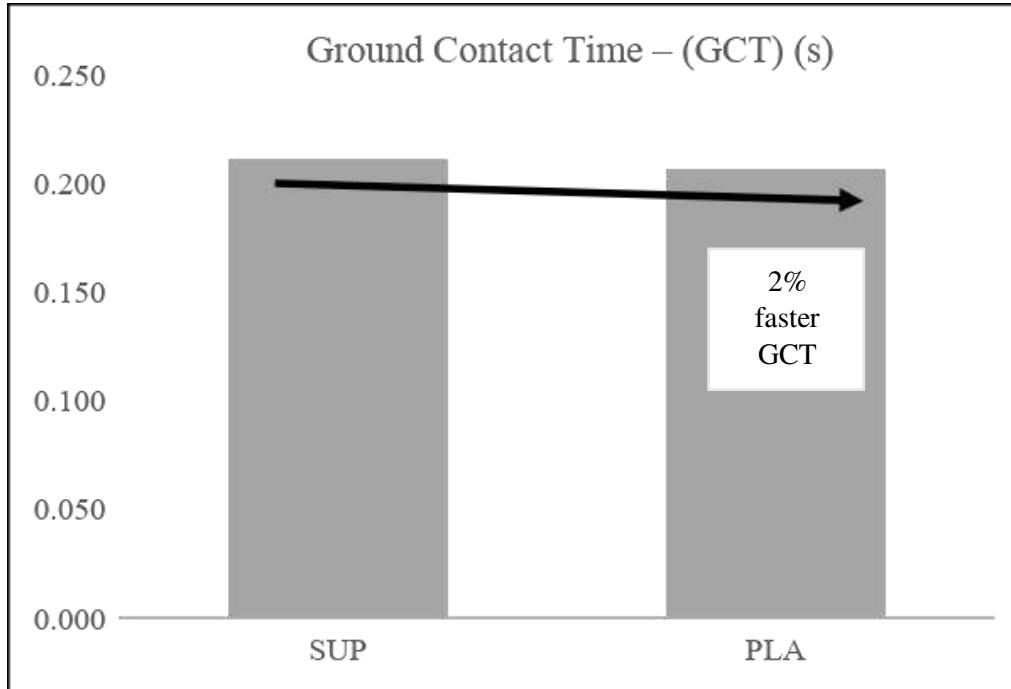


Figure 4.2. Flight time on SUP vs PLA conditions

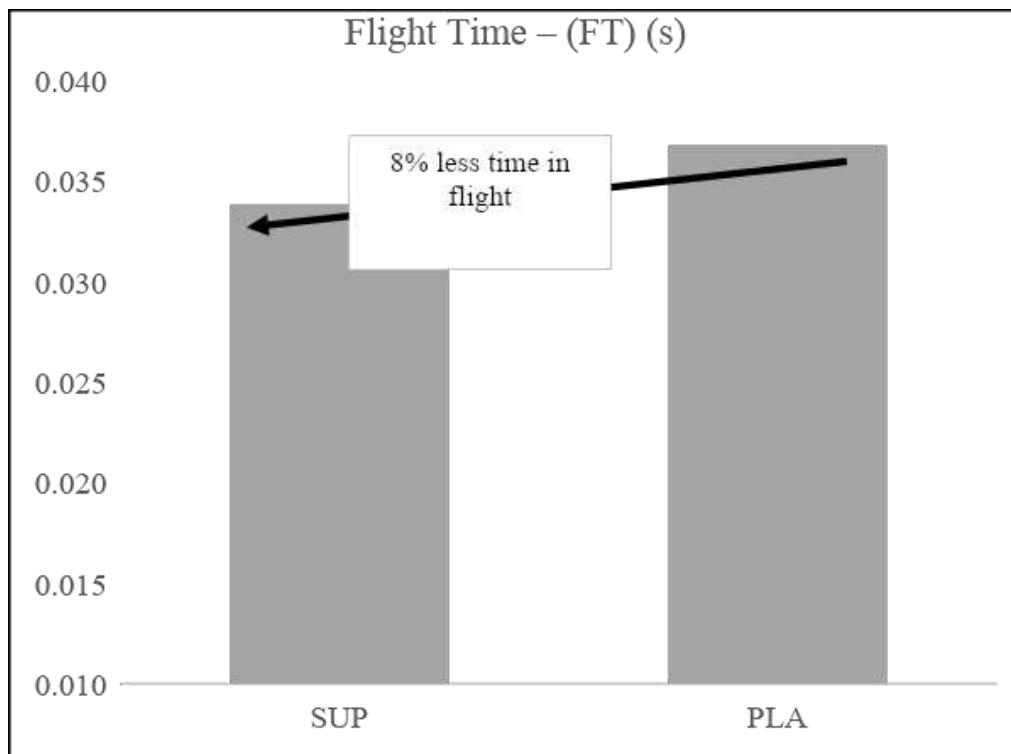
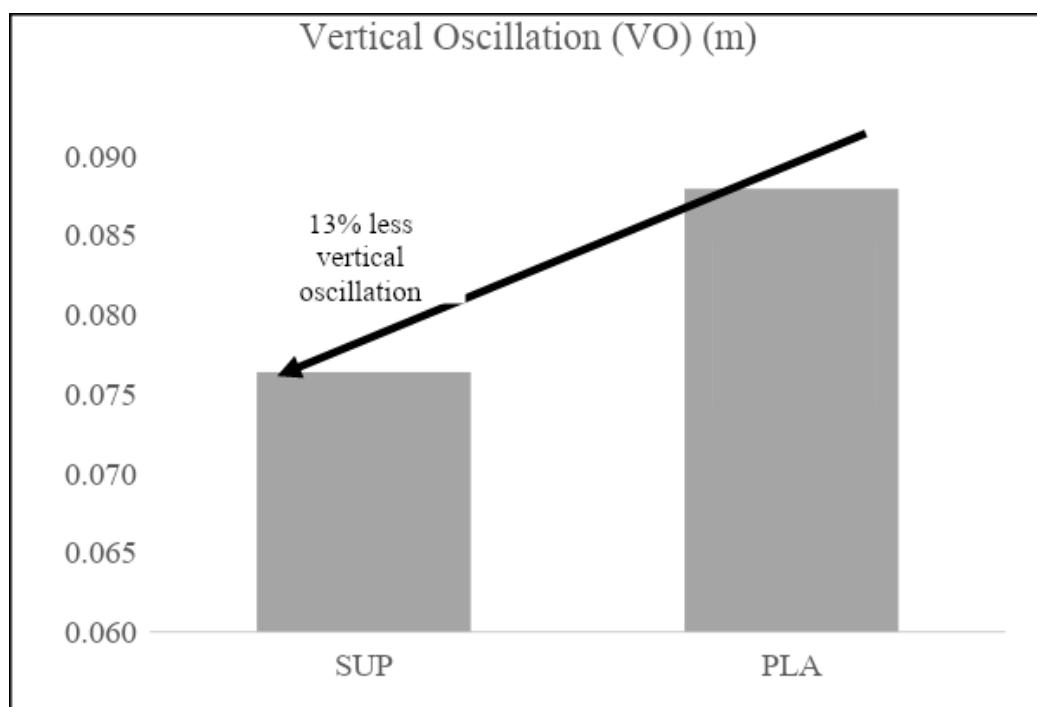


Figure 4.3 Vertical oscillation on SUP vs PLA conditions



Discussion

Many studies suggest that BCAAs do not directly enhance performance, however most do not look at exercise training quality and the effect that this may have long term beyond the 10-12 weeks of observation seen in most studies (29). If exercise sessions can be performed with increased quality, it can be assumed that over time, an athlete may experience an improved adaptive response to their training program and ultimately improve performance.

For a given aerobic activity like running, some individuals are more economical than others (30). Running economy is an important performance indicator as variability in economy among a homogenous group of distance runners accounts for 20-30% of the differences in performance of trained distance runners at a given submaximal running speed as measured by oxygen consumption (ml/kg/min) (31–34). Many factors influence these inter-individual differences in running economy such as training, environment, physiology, biomechanics, and anthropometry – with each category having many additional influencing factors (15). Our study looked at factors that directly influence running biomechanics such ground contact time, flight time, and vertical oscillation.

In agreement with (30), GRF characteristics such as GCT and FT did not exhibit a statistically significant difference in running economy, and in our study we observed no difference in these characteristics between SUP or PLA. Our study did show a statistically significant difference in VO when the runner was on SUP vs a PLA, possibly indicating greater coactivation between two-joint muscles of the leg during stance (35). Greater co-activation among two-joint muscles of the leg during stance allows the neuromuscular system to transfer joint rotations more efficiently into desired external forces (36). In addition, greater co-activation between two-joint muscles of the leg provides greater stability to the runner during ground

contact, reducing potentially wasteful vertical motion (VO), as reflected by vertical impulse measurements (30). While we did not directly measure force characteristics such as vertical impulse, we did measure vertical displacement of the center of mass through video analysis and found that when on SUP, the athlete had significantly reduced vertical displacement by 13% with a corresponding 8% decrease in flight time, possibly suggesting a greater co-activation between two-joint muscles of the leg and better stability during stance (36).

While many studies demonstrate improved muscle recovery characteristics with BCAA supplementation, the author of this study did not uncover any research that looked directly at whether or not improved recovery altered running mechanics as a result of improved force-time characteristics. (37) and (30) showed that more economical runners exhibited less vertical oscillation and that this can contribute to a significant amount of variability (36%) in running economy. Because our runner exhibited less VO while on the BCAA supplement, we theorize that greater muscle recovery underpinned by changes in MPS, might contribute to an improved running economy, or a reduction in aerobic demand for a given task (11). Nutrition to support optimal muscle recovery to sustain high work outputs during repeated exercise bouts may ultimately enhance training adaptations and performance as indicated by force generating capabilities (11, 30, and 35). Since direct force measurements were not utilized in this study, further research may want to repeat this experiment with force measuring devices in a similar capture zone.

Conclusions

Our study suggests that BCAA supplementation surrounding key training sessions may help improve force-time characteristics of running mechanics during running. This may be attributed to improved muscle recovery and a reduction in associated fatigue symptoms caused

by regular training, which in turn may increase preparedness to train. Our athlete consumed approximately 10g of amino acids per day surrounding exercise sessions and this amount has been confirmed in the research as an effective dosage to stimulate and increase MPS postexercise (4,19,38). Based on these findings, we recommend BCAA supplementation for athletes who are undergoing chronic endurance training.

Abbreviations

BCAA = branched-chain amino acid

SUP = supplemental BCAA condition

PLA = placebo condition

MPS = muscle protein synthesis

GRF = ground reaction forces

GCT = ground contact time

FT = flight time

VO = vertical oscillation

Declarations

Ethics approval and consent to participate

This study was approved by the East Tennessee State University's Institutional Review Board. Participant read and signed an informed consent document as approved by the Institutional Review Board.

Consent for publication

Not applicable.

Availability of data and material

The data sets and analysis are available upon request to the corresponding author.

Competing interests

The authors declare that there are no competing interests with this manuscript.

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The nutrition supplements used in this study were provided by Amino Vital.

Authors' contributions

K.S. conceived the idea for this study and obtained nutritional supplements from Amino Vital as the project lead. T.W. carried out this research project and wrote the manuscript as part of her dissertation work. C.B. and B.H.D. served as T.W.'s dissertation committee members and editors to this manuscript. M.H.S. served as chair to T.W.'s dissertation committee in approving and editing this research on behalf of the Sport, Exercise, Recreation, and Kinesiology department at East Tennessee State University.

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Authors' information

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Figures

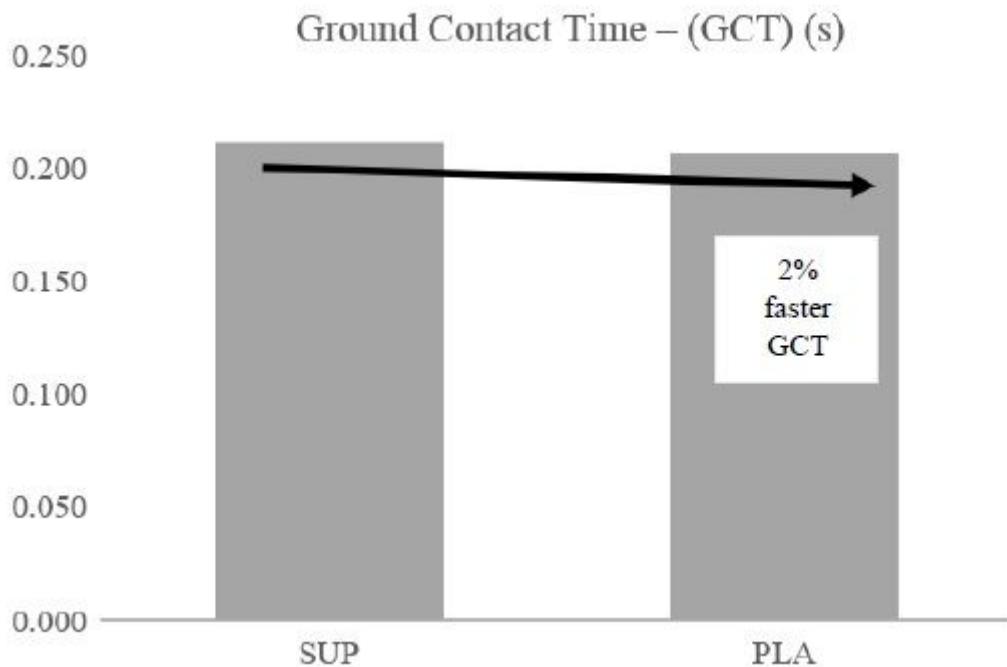


Figure 1

Ground contact time for SUP and PLA conditions

Flight Time – (FT) (s)

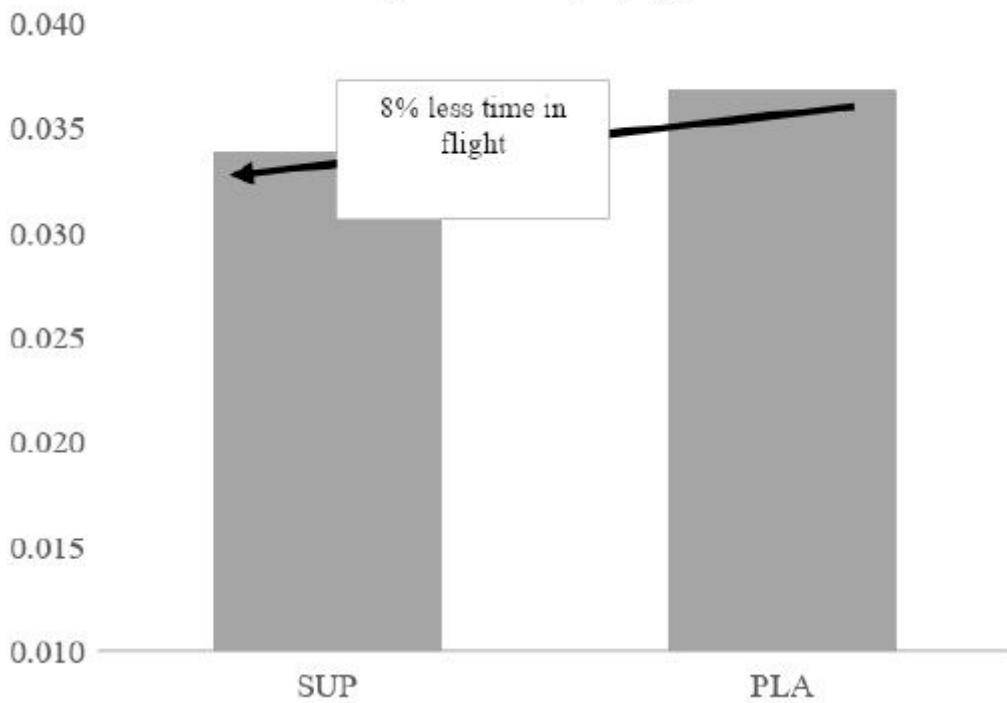


Figure 2

Flight time on SUP vs PLA conditions

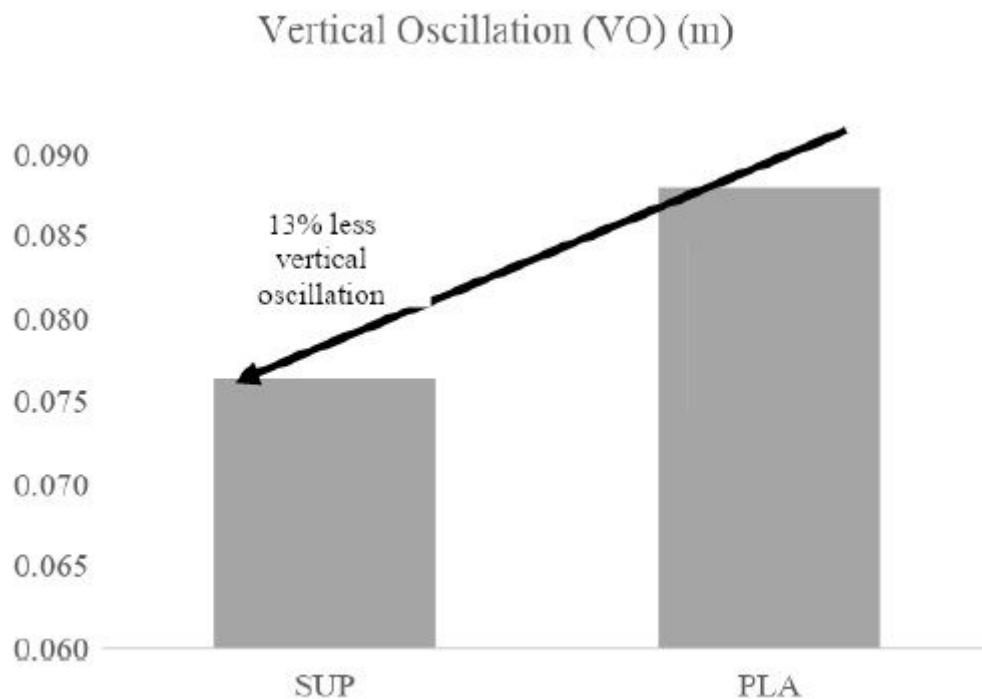


Figure 3

Vertical oscillation on SUP vs PLA conditions