Hemodynamic and Vascular Response to Resistance Exercise with L-Arginine

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ABSTRACT

FAHS, C. A., K. S. HEFFERNAN, and B. FERNHALL. Hemodynamic and Vascular Response to Resistance Exercise with L-Arginine. *Med. Sci. Sports Exerc.*, Vol. 41, No. 4, pp. 773–779, 2009. **Purpose**: L-Arginine, the precursor to nitric oxide (NO), has been shown to improve endothelial function in patients with endothelial dysfunction. Resistance exercise has been shown to increase arterial stiffness acutely with no definitive cause. It is possible that a reduction in NO bioavailability is responsible for this. The purpose of this study was to examine the effect of acute L-arginine supplementation and resistance exercise on arterial function. **Methods**: Eighteen ($N = 18$) young men (24.2 ± 0.7 yr) volunteered for this study. In a crossover design, subjects underwent body composition testing, 1-repetition maximum testing for the bench press and the biceps curls and performed two acute bouts of resistance exercise in which they consumed either placebo or 7 g L-arginine before each resistance exercise bout. Anthropometric measures, augmentation index (AIx), arterial stiffness, and forearm blood flow (FBF) were assessed before and after each treatment condition. **Results**: There were significant ($P < 0.05$) time effects after the resistance exercise; there was a reduction in brachial stiffness ($P = 0.0001$), an increase in central aortic stiffness ($P = 0.004$), an increase in AIx ($P = 0.023$), an increase in FBF ($P = 0.000$), and an increase in arm circumference ($P = 0.0001$) after exercise. **Conclusions**: The increase in central arterial stiffness and wave reflection was not attenuated by acute supplementation with L-arginine; furthermore, blood flow was not augmented with supplementation. On the basis of these data, L-arginine does not appear to change the hemodynamic and vascular responses to resistance exercise. **Key Words:** AUGMENTATION INDEX, PULSE WAVE VELOCITY, WAVE REFLECTION, NITRIC OXIDE

L-Arginine is typically a nonessential amino acid in humans but can become essential under catabolic conditions such as surgery or trauma in which growth is accelerated (17). There is a great deal of research supporting the beneficial effects of L-arginine supplementation in clinical populations (1,15,19,31,37). L-Arginine is a precursor to nitric oxide (NO) because L-arginine and L-citrulline are converted to NO synthases (7). In conditions where endothelial NO production is reduced (common in various conditions such as cardiovascular disease, diabetes, hypertension, etc.), oral L-arginine has been used as a means of improving vasodilatory capacity and blood flow (34). In addition, short-term oral L-arginine supplementation increases exercise capacity in patients with pulmonary hypertension and improves muscular performance in healthy young males (37,41).

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Despite limited scientific data, L-arginine is also being marketed as an ergogenic aid aimed at augmenting NO production and increasing blood flow in healthy individuals (14). L-Arginine and supplements containing L-arginine are advertised as being capable of increasing blood flow during resistance exercise for greater delivery of oxygen and nutrients during exercise and also cause a transient increase in muscle size (the "pump") during and immediately after exercise (11). Considering that acute exercise has been shown to increase NO production (6), it is plausible that increasing L-arginine availability by supplementation before exercise may further enhance the vascular responsiveness to an acute resistance exercise bout via augmented NO synthesis. However, this is by no means a certainty as NO production may (8,36,42) or may not (10,24) contribute substantially to skeletal muscle blood flow during exercise. NO may play a lesser role in exercise blood flow during endurance exercise (10,24) compared with a more central role during resistance-type exercise (8,36,42). Although oral L-arginine supplementation may not impact resting blood flow in healthy individuals (1), it is currently unknown if L-arginine supplementation will affect blood flow after a bout of acute resistance exercise.

In addition to impacting vasodilation, it has been shown that basal NO production influences large-artery distensibility (49). Aortic stiffness is recognized as an independent predictor of stroke, related to the development of left ventricular hypertrophy, and has negative implications for

coronary perfusion (9,29,30). An acute bout of resistance exercise has been shown to increase arterial stiffness (16,21). Similarly, chronic resistance training has also been shown to increase arterial stiffness (35), but this is not a universal finding (40). It is possible that the increase in arterial stiffness seen with resistance exercise is related to a reduction in NO bioavailability, especially if NO plays a more central role during this type of exercise. Thus, supplementation with L-arginine before resistance exercise may attenuate these changes.

The purpose of this study was to examine the effect of combining resistance exercise and L-arginine supplementation on peripheral blood flow, muscle size, arterial stiffness, and arterial wave reflection. We hypothesized that L-arginine supplementation would increase peripheral blood flow, muscle size, and vasodilatory capacity but decrease arterial stiffness and wave reflection after an acute bout of resistance exercise.

METHODS

Participants. A total of 18 young healthy male subjects participated in this study. Exclusion criteria included the following: any known cardiovascular, pulmonary, or metabolic disease (asthma, diabetes, hypertension, dyslipidemia, etc.); orthopedic problems; use of any medication, and smoking. Participants completed a medical history questionnaire to screen for other possible problems preventing full compliance with the study protocol. Before participation, all participants gave written informed consent. One subject was excluded after completion of the study as a statistical outlier, and one subject was excluded from the pulse wave analysis due to a heart arrhythmia. Data analyses were performed on the remaining subjects (n = 17; pulse wave analysis n = 16). This research was approved by the institutional review board of the University of Illinois at Urbana-Champaign.

Study design. This study was a randomized, double-blind, crossover design. Data collection occurred in four major steps (Fig. 1): body composition assessment, one-repetition maximum testing (1-RM testing), and a bout of resistance exercise combined with either L-arginine supplementation or placebo.

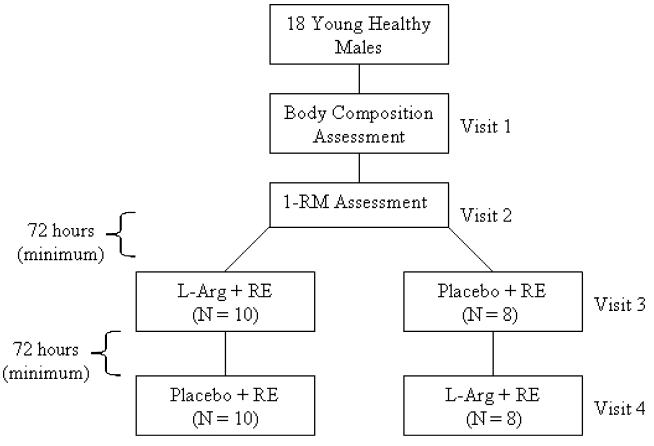

FIGURE 1—Study design.

Each participant reported to the research laboratory on four separate occasions. Participants reported to the research laboratory in the morning after an overnight fast (at least 8 h postprandial). Participants were instructed to not to consume caffeine or alcohol for 24 h before testing and to not engage in exercise or any other strenuous physical activity for 24 h before testing.

1-RM testing was performed before the resistance exercise bouts (visits 3 and 4). Visits 3 and 4 were randomized, and visits 2, 3, and 4 were performed at least 72 h apart to ensure that muscular fatigue was not a factor. Initially, participants were required to rest quietly in a temperature-controlled room for a minimum of 5 min. With the participant in the supine position, brachial blood pressure, radial augmentation index (AIx), brachial pulse wave velocity (bPWV), central pulse wave velocity (cPWV), forearm blood flow (FBF), and forearm vasodilatory capacity (reactive hyperemia) measurements were performed (in that order). In a standing position, circumferences of the upper arm with the arm in a hanging relaxed position and in a flexed position (with the arm abducted to 90° and elbow flexed at 90°) were taken. After these measurements, participants ingested either 7 g of pharmaceutical-grade L-arginine encapsulated in pill form or 7 g of placebo in identical pill form. Pills were taken with 591 mL (20 oz) purified bottled drinking water. After ingestion of the pills, participants rested quietly in a room for 30 min to allow absorption. This 30-min period is based on current recommendations of supplements containing L-arginine and in line with the literature that has shown arginine levels to peak in the blood at 60 min after ingestion of (13). After 30 min, the resistance exercise bout began. Immediately (<1 min) after the resistance exercise bout, circumference measurements of the arm were repeated followed by a repeat of all the supine measurements mentioned above (in the same order). Blood pressure, AIx, and arterial stiffness were measured within 15 min of exercise cessation. FBF and vasodilatory capacity were measured within 25 min of exercise cessation.

Anthropometric measures. Standing height and weight measurements were completed with participants wearing light-weight clothing and no shoes. Height was obtained using a stadiometer with measures obtained to the nearest 0.1 cm. Weight was measured on a calibrated digital scale (Tanita, Model BWB-627A). Arm circumferences (AC) were measured with a standard tape measure at the widest portion of the arm between the tip of the elbow and the tip of the shoulder.

Body composition. Body composition was assessed using dual-energy x-ray absorptiometry (DXA; Hologic QDR 4500A, software version 11.1:3). Participants wore light-weight cotton clothing free from metal during the scanning (i.e., medical scrubs). Before testing, the DXA instrument was calibrated as per the manufacturer's

TABLE 1. Subject characteristics (N = 17).

Age (yr)	24.2 ± 0.7
Height (cm)	178.3 ± 1.8
Weight (kg)	86.7 ± 4.9
Body mass index (kg·m^{-2})	27.0 ± 1.2
% body fat	16.1 ± 1.5
1-RM bench press (kg)	115.2 ± 5.8
1-RM bicep curl (kg)	53.4 ± 2.6

All data reported as mean ± SE. 1-RM, one-repetition maximum.

guidelines. Participants were positioned on a DXA as per the manufacture's recommendations, and whole-body scans were performed.

1-RM testing. One repetition maximum (1-RM; defined as the maximum amount of weight lifted with proper form through a full range of motion for a single repetition) for the bench press and the biceps curl using a two-arm curl bar was ascertained in accordance with established guidelines (20). For both exercises, participants first completed a brief warm-up consisting of 10 repetitions of a submaximal load. A second warm-up was completed (three to five repetitions) using a submaximal load within the participant's perceived capacity. Weight was added in 2.3- to 11.4-kg increments until participants could no longer successfully complete one repetition. The heaviest weight successfully lifted was recorded as the 1-RM. Participants were allowed 3–5 min of rest between sets to ensure that a maximal effort was exerted with each attempt. Maximal values were attained for all participants in less than five attempts. A spotter was present at all testing sessions to ensure the safety of the participant during testing.

Acute resistance exercise bouts. The resistance exercise bout consisted of a warm-up on the bench press with 50% of the 1-RM for 10 repetitions. This was followed by four sets of five repetitions using 80% of the 1-RM bench press. After the bench press, four sets of 10 repetitions using 70% of the 1-RM biceps curl were completed for the biceps curl using a two-arm curl bar. A 2-min rest was given between all sets. Each resistance exercise bout lasted approximately 20 min. A spotter was present during all exercise to ensure proper form and to assist the participant if volitional fatigue was reached.

Brachial artery blood pressure assessment. Resting systolic and diastolic blood pressures (SBP and DBP, respectively) were measured in the supine position using an automated oscillometric cuff (HEM-907 XL; Omron Corporation, Japan). All brachial blood pressure were made in duplicate, and the average of the two values was recorded and used for subsequent analysis.

Pulse contour analysis (AIx). Radial artery pressure waveforms were attained in the supine position from a 10-s epoch using applanation tonometry and a high-fidelity strain-gauge transducer (Millar Instruments, Houston, TX). Using a generalized validated transfer function, a central aortic pressure waveform was reconstructed from the aforementioned radial artery pressure waveform (SphygmoCor, AtCor Medical, Sydney, Australia). Augmentation index (AIx) was calculated as the ratio of amplitude of the pressure wave above its systolic shoulder (i.e., the difference between the early and the late systolic peaks of the arterial waveform) to the total pulse pressure (PP). The result was expressed as a percentage and was used as an index of aortic pressure wave reflection. Because AIx is influenced by HR (48), AIx values also were normalized to an HR of 75 bpm. Also derived from the aortic waveform was the travel time of the forward pressure wave from the aorta to the peripheral reflection site and back (time delay of the reflected wave (TR)).

Regional arterial stiffness—pulse wave velocity. All measurements were conducted following the guidelines of the Clinical Application of Arterial Stiffness, Task Force III (46). A high-fidelity strain-gauge transducer (Millar Instruments) was used to obtain the pressure waveform from 1) the right common carotid artery and the right femoral artery and 2) the right common carotid artery and the right radial artery. Distances from the suprasternal notch to the femoral artery, the carotid artery to the suprasternal notch, and the radial artery to the suprasternal notch were measured as straight lines with a tape measure. The distance from the carotid artery to the suprasternal notch was then subtracted from both the suprasternal notch to femoral artery segment length and the suprasternal notch to radial

TABLE 2. Central and peripheral hemodynamics and arterial properties before and after resistance exercise.

	Prearginine	Postarginine	Preplacebo	Postplacebo
HR (bpm)*	55.59 ± 2.28	74.76 ± 3.37	53.65 ± 1.97	73.06 ± 3.79
SBP (mm Hg)*	121.82 ± 2.89	134.29 ± 3.10	122.71 ± 2.72	133.35 ± 2.75
DBP (mm Hg)*	63.18 ± 1.60	57.47 ± 1.31	63.71 ± 1.89	55.82 ± 1.51
PP (mm Hg)*	58.65 ± 2.63	76.82 ± 3.27	59.00 ± 2.91	77.53 ± 2.53
MAP (mm Hg)	82.34 ± 1.71	82.65 ± 1.40	82.99 ± 1.72	81.24 ± 1.61
AIx (%)*	9.41 ± 2.93	11.24 ± 2.72	3.82 ± 3.39	12.35 ± 2.40
AIx75 (%)*	0.00 ± 2.73	11.18 ± 3.23	−7.56 ± 3.17	11.41 ± 3.45
TR (ms)*†	166.82 ± 7.63‡	156.65 ± 4.79	187.76 ± 7.04	164.41 ± 7.85
Vascular resistance (U)*	24.50 ± 2.52	9.82 ± 0.83	27.64 ± 1.75	10.50 ± 1.44
FBF_{peak} (mL·min^{-1}·100 mL^{-1} tissue)*	27.46 ± 2.36	30.96 ± 2.06	24.71 ± 1.56	33.11 ± 2.82
Flexed AC (cm)*	38.65 ± 1.12	40.03 ± 1.15	38.79 ± 1.16	40.18 ± 1.14
Relaxed AC (cm)*	35.15 ± 1.04	37.06 ± 1.06	35.47 ± 1.10	37.15 ± 1.03

N = 17 unless otherwise indicated.
* Significant time effect ($P < 0.05$).
† Condition effect ($P < 0.05$).
‡ Significant from Pre Placebo ($P < 0.05$).
HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; AIx, augmentation index; AIx75, augmentation index at HR = 75 bpm; TR, reflection time; FBF_{peak}, peak forearm blood flow; AC, arm circumference.

artery segment length to account for differences in the direction of pulse wave propagation. PWV was calculated from the distances between measurement points and the measured time delay between 10 proximal and distal waveforms (SphygmoCor, AtCor Medical). The peak of an in-phase R wave as attained from sequential ECG monitoring (CM5 configuration) was used as a timing marker.

Forearm blood flow. Resting forearm blood flow (FBF) was measured in the supine position, using strain-gauge plethysmography (EC-4, D.D.; Hokanson, Inc., Bellevue, WA). A standard blood pressure cuff was placed around the upper arm, a strain-gauge around the widest part of the forearm, and an additional cuff around the wrist to occlude hand circulation. Before determination of FBF, the wrist cuff was inflated and held at 250 mm Hg pressure. The FBF was determined by inflating the upper cuff to 50 mm Hg for 7 s, followed by an 8-s deflation during each 15-s cycle (25). An average of five to six 15-s plethysmographic cycles was used for resting FBF. FBF was expressed as millimeters per minute per 100 mL tissue of forearm tissue. Vascular resistance was calculated as the mean arterial pressure (MAP) divided by the average FBF (MAP / FBF).

Vasodilatory capacity (reactive hyperemia). Vasodilatory capacity was measured immediately after resting FBF. Arm blood flow was occluded by inflating a blood pressure cuff on the upper arm to a pressure of 250 mm Hg for 5 min. One minute before release of the upper arm cuff, the wrist cuff was inflated to 250 mm Hg. After rapid release of the upper arm cuff, changes in forearm volume were measured in 15-s cycles as described above for 3 min (13 readings altogether). The highest reading observed was recorded as the peak blood flow (BF_{peak}). Readings taken 1 to 3 min after cuff release (readings 4 through 13) were plotted into a curve, and the area under the curve (AUC) was taken as a measure of reactive hyperemia (AUC_{2min}). This portion of the reactive hyperemic response has previously been shown to be endothelial dependent (NO dependent) (44).

Statistical analysis. Descriptive statistics were calculated for all variables. Student *t*-tests were used to determine possible baseline differences between conditions. Time-course changes in FBF, AUC_{2min}, flexed and relaxed AC, vascular resistance, cPWV, bPWV, AIx, AIx75, TR, HR, SBP, DPB, MAP, and PP were compared using a two-way ANOVA (condition × time) with repeated measures. Data are presented as the mean (SE). Statistical significance was set at $P \leq 0.05$. We also conducted an *a priori* power analysis to estimate the number of subjects needed. Because no prior study has been conducted on exactly this topic, we used the following approach. If L-arginine could prevent the increase in central arterial stiffness (an increase in pulse wave velocity of 0.5 $m \cdot s^{-1}$) associated with acute resistance training, we would need seven to eight subjects per group. If L-arginine produced postexercise increases in blood flow and vasodilatory capacity consistent with changes observed in clinical populations at rest, then 10 to 11 subjects per group would be needed. Because we expected these effect size estimates to by higher than what we would observe, we estimated statistical power based on a 10% reduction in this effect size, suggesting 16 subjects per group would be needed. However, because we conducted a crossover study using a within-subjects design, our power would actually be higher than calculated. We also overrecruited to ensure we would have an appropriate sample size. A statistical software program SPSS (version 15.0 for Windows) was used for all analyses.

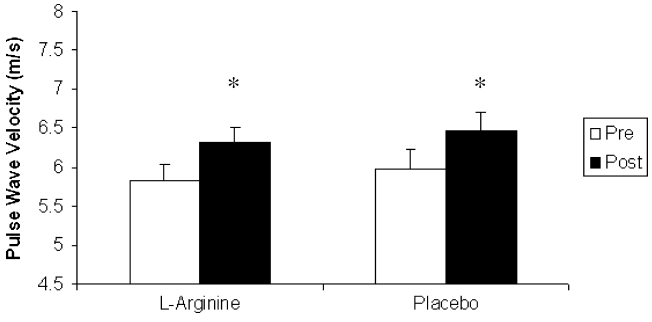

FIGURE 2—cPWV before and after resistance exercise. *Signifies time effect ($P < 0.05$).

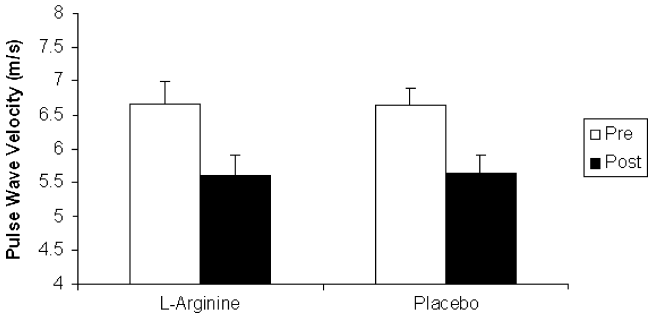

FIGURE 3—bPWV before and after resistance exercise. *Signifies time effect ($P < 0.05$).

RESULTS

Subject characteristics are shown in Table 1. There were no significant ($P > 0.05$) interactions (condition × time) for

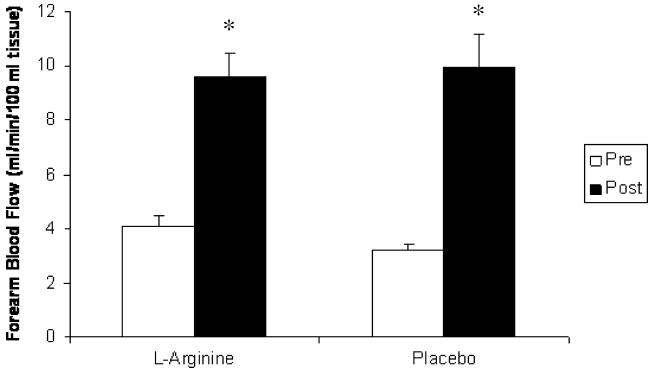

FIGURE 4—FBF before and after resistance exercise. *Signifies time effect ($P < 0.05$).

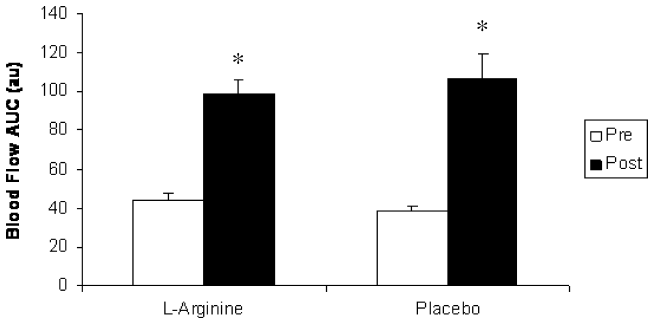

FIGURE 5—Late phase reactive hyperemia blood flow before and after resistance exercise. *Signifies time effect ($P < 0.05$).

any variable. There was a condition effect ($P < 0.05$) for TR. Student *t*-tests detected a significant difference ($P < 0.05$) in baseline TR values but no significant difference ($P > 0.05$) in postvalues. TR prearginine was significantly ($P < 0.05$) lower than TR preplacebo. There were significant ($P < 0.05$) time effects for HR, AIx, AIx75, TR, SBP, DBP, bPWV, cPWV, FBF, vascular resistance, BF_{peak}, AUC_{2min}, flexed AC, and relaxed AC (Table 2). HR, AIx, AIx75, SBP, cPWV, FBF, AUC_{2min}, flexed AC, and relaxed AC were significantly increased ($P < 0.05$) after exercise compared with baseline values regardless of treatment condition (Figs. 2–5). DBP, TR, and vascular resistance were significantly decreased ($P < 0.05$) after the exercise bout. There were no significant changes in MAP ($P > 0.05$).

DISCUSSION

The major findings of the present study are that 1) peripheral artery stiffness decreases and blood flow increases whereas central artery stiffness and AIx increase after resistance exercise and 2) 7 g of L-arginine before resistance exercise does not changes the hemodynamic and vascular responses to resistance exercise in these young healthy subjects.

Although L-arginine did not affect any of the measured variables, there were some interesting exercise effects of acute resistance exercise. Central (aortic) stiffness increased by roughly 8% ($\sim$0.5 $m \cdot s^{-1}$). DeVan et al. (16) and Heffernan et al. (21) also showed an increase in central arterial stiffness after acute resistance exercise. This increase in central arterial stiffness has been hypothesized to be due to the large increase in arterial blood pressure that occurs with resistance exercise (32). During the resistance exercise bout, relatively high loads (70% and 80% of 1-RM) were used, which may also have caused individuals to perform the valsalva maneuver, which promotes large increases blood pressure and has been shown to independently increase central arterial stiffness (23). This increase in blood pressure may transpose the load bearing from more elastic elastin to stiffer collagen fibers causing an increase in stiffness (38). Additionally, it has been shown that resistance exercise training can stimulate the sympathetic nervous system activity (39), which may have increased vasoconstrictor tone. However, it has also been shown sympathetic tone increases after aerobic exercise whereas central stiffness decreases, so this may not be the major mechanism (21). Our study did show a significant increase in SBP after the resistance exercise bout consistent with the notion that blood pressure *per se* may have influenced arterial stiffness.

We showed a reduction in peripheral artery pulse wave velocity of roughly 15% ($\sim$1.0 $m \cdot s^{-1}$) after the resistance exercise bout. In contrast to these findings, Heffernan et al. (21) showed no change in peripheral (femoral) stiffness after a bout of full body resistance exercise. However, there is also some evidence that supports our findings showing a decrease in peripheral (femoral) stiffness after acute resistance exercise in the form of unilateral leg resistance exercise (22). One of the novel aspects of our study is that it is the first to show a reduction in brachial artery stiffness with upper-body exercise. This decrease may be a reflection of the increase in vasodilation of arteries in the exercising muscle beds (28). This is supported by the fact that we showed a significant increase in vasodilatory capacity of the forearm resistance vessels after resistance exercise. Bank and Kaiser (2) suggest that vasodilation decreases arterial stiffness by reducing tension generated by the smooth muscle and connective tissue elements in series with the smooth muscle. In addition, the mechanical compression of the arteries during muscular contraction may play a role as Heffernan et al. (22) showed that external mechanical compression caused a decrease in peripheral (leg) stiffness.

The increase in central artery stiffness, AIx, and PP and the decrease in TR all point to an increase in central aortic stiffness after acute resistance exercise. Despite these changes, brachial artery stiffness decreased. If the upper body resistance exercise we used in this study caused an increase in brachial artery diameter, which is a likely vasodilatory response to the exercise, this would, unlike the aorta, shift the load bearing from the stiffer collagen fibers to the more elastic elastin fibers (38). Such a response may explain the differences seen in the stiffness changes between the central and the peripheral arteries. That is, dilation of central arteries results in a stiffer vessel whereas dilation of peripheral arteries results in a less stiff vessel.

L-Arginine did not affect any of the aforementioned changes associated with acute resistance exercise. This finding is in agreement with recently published work by Sharman et al. (43), which suggests that NO does not solely contribute to systemic arterial stiffness or altered PP amplification during exercise. Thus, even if the L-arginine did actually increase NO levels, this may not translate into altered hemodynamic responses. Mariotti et al. (33) provided support for this notion suggesting that additional arginine with a meal does not affect basal endothelial function. In fact, additional arginine may lessen the sensitivity of smooth muscle cells to NO.

Our other major finding was the lack of an improvement in blood flow after L-arginine supplementation and

resistance exercise. As expected, acute resistance exercise increased both the resting blood flow and the blood flow response to reactive hyperemia. This increase has previously been shown in response to acute aerobic exercise in both resistance and endurance-trained athletes (3). Resting flow, peak flow, and AUC after reactive hyperemia increased to a similar extent after both conditions in our study (Fig. 4). Because vasodilation can be affected by multiple systems (47), it is possible that changes in other systems affected blood flow after the resistance exercise, which may have masked the changes that would be caused by L-arginine supplementation. These results are in agreement with work by Endo et al. (18), who also showed that the NO pathway was not a large contributor to the increase in blood flow after hand grip exercise. Recent literature has also concluded that NO is only responsible for a small proportion of the increase in muscle blood flow during exercise (45). Another possible explanation is that L-arginine is not the limiting factor in the NO pathway for vasodilation. Previous work would suggest that this may be the case (10,24). Other factors such as acetylcholine and catecholamines, which are elevated during exercise, also increase NO release and NO-dependent dilation, respectively (27). Therefore, further augmenting NO production during exercise via L-arginine supplementation may not be possible.

It has been shown that peak vasodilation is not L-arginine dependent, but instead, L-arginine is involved in maintaining vasodilation after peak vasodilation (44). Consequently, we analyzed BF_{peak} and AUC during the last 2 min after cuff release (previously called late phase). This type of analysis was done to better isolate and evaluate possible effect of L-arginine. As expected, we found no difference in BF_{peak}; however, L-arginine also did not affect blood flow in the late phase of reactive hyperemia. Other factors, including prostaglandins, adenosine, and ATP-sensitive potassium channels, have also been shown to influence the late phase reactive hyperemia (44), which may have overridden the effects of the L-arginine in our study.

Changes in AC after exercise were not different between the L-arginine and the placebo condition. This suggests that L-arginine supplementation has no effect on postexercise muscle hyperemia, contrary to claims of dietary supplement manufacturers. Manufacturers of supplements containing L-arginine often claim their supplements augment blood flow or "the pump" associated with resistance exercise (11), but our data do not support this claim.

Some of the strengths of the present study include the study design (randomized, double blind, placebo controlled). Also, the fact the subjects were tested in the morning, ~8 h postprandial, and before any exercise helped ensure that measurements taken were not influenced by other factors (caffeine, alcohol, food, etc.) and that the L-arginine would be readily absorbed. Unlike other studies examining blood flow with infusion of either L-arginine or other substances known to affect blood flow, the current study had a larger sample size (N = 17) to ensure that differences, if present, would be detected. A power analysis done *a priori* estimated a sample size of 16 to detect a 0.5-$m \cdot s^{-1}$ difference in pulse wave velocity between the treatments. However, unlike these studies, the major limitation of this study is that there was no blood markers measured, which would confirm whether the L-arginine given did in fact increase blood levels of L-arginine. To maximize the potential of finding a significant difference, we used pharmaceutical grade L-arginine at a higher dose (7 g) compared with previous studies, which showed 4 g of arginine to raise plasma L-arginine levels (13). It has been shown that the bioavailability of a similar dose (6 g) of oral L-arginine to be high (68%) and that the vascular effects of L-arginine are closely correlated to the plasma concentration (5). We allowed 30 min to elapse before initiating the exercise protocol with rationale being that arginine levels peak in the blood 1 h after ingestion (13). Additionally, common recommendations for dietary supplements containing L-arginine suggest taking the product 30 min before exercise, which is part of the basis of our study design. One last limitation of our study is that we only included men in this study. This was in part because many studies in this area used only male subjects (4,12,13). Therefore, these results may not be generalizable to women.

In conclusion, the present study demonstrated that the ingestion of L-arginine before resistance exercise had no significant effect on central or peripheral artery stiffness or FBF. This may be because other pathways involved with vasodilation mask the effect of L-arginine, the L-arginine nitric-oxide pathway is not a significant contributor to vasodilation after exercise, or the L-arginine simply does not increase NO. Based on these results, it would appear that L-arginine supplementation before resistance exercise would have no effect on the hemodynamic and the vascular responses to resistance exercise.

The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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