Draxler et al. (2018) *Int J Res Ex Phys*. 14(1):44-52.

Sponsored by:
Exercise and Sport Science Program
Western Colorado University

International Journal of Research in Exercise Physiology

Original Research Article

Dose Response Impact of Resistance Training on Arterial Stiffness

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Abstract

Introduction: Arterial stiffness, the decrease in elasticity of the arteries, is a strong indicator of future health issues related to cardiovascular diseases but can often be decreased with physical activity. There is limited research on the dose response relationship between the volume of resistance training and arterial stiffness. The purpose of this study was to evaluate and assess the dose effect of total weekly load volumes on arterial health over a four-week time span. **Methods:** Twenty-two college-aged male (n=9) and female (n=13) participants (20.4 + 2.0 years) were separated into three resistance training (RT) groups (one-, two-, and three-days/wk) and completed a 4-week resistance training intervention. The program consisted of seven machine-based and one free-weight resistance training exercises, with each exercise session lasting 30-45 minutes. Arterial stiffness and segmental lean body mass were measured prior to and after completing the RT intervention. Arterial stiffness was measured using pulse wave analysis and represented by augmentation index standardized to a heart rate 75 bpm (AIx75). Segmental lean body mass was obtained using dual-energy x-ray absorptiometry. **Results:** After adjusting for pre-AIx75, there were no significant differences in post-AIx75 between groups (p = .906). There were no differences in pre-post AIx75 controlling for changes in upper body lean body mass (p= .222) or lower body mass (p=.226). However, a trend demonstrated an overall negative impact on arterial stiffness for the one-day (6.5 ± 14.8%) and two-day (7.6 ± 17.4%) groups but a positive impact on arterial stiffness for the three-day group (-4.6 ± 13.9%). **Conclusions:** The results of this study suggest that an acute resistance-training program does not have a significant impact on arterial stiffness; regardless of gender. However, a trend was observed indicating a positive impact on arterial stiffness for the three-day group. Professionals prescribing RT programs should prescribe them based on their professional opinion rather than any benefits for arterial health, as there is no noticeable impact of RT.

Key Words: Arterial Compliance, Arterial Health, Augmentation Index, Cardiovascular Disease, Exercise Volume, Resistance Training

Introduction

The gradual stiffening of the arteries, measured by changes in augmentation index, is noted as a strong indicator for future health issues related to coronary artery disease and stroke. Currently, cardiovascular disease (CVD) is the leading cause of mortality worldwide and is projected to continue as the leading cause through 2030[1]. As the vasculature dynamically responds to negative arterial changes throughout the lifespan, the growing risk for CVD and other chronic diseases increase. Recent research suggests that physical activity can reduce CVD risk by 35%, as well as a decrease all-cause mortality by 33%[2]. The remaining factors that reduce the risk of CVD include adequate endothelial function, positive remodeling of the arteries, and an increase in the compliance of those arteries. The American College of Sports Medicine recommends an individual participate in 150 min of moderate aerobic exercise per week, along with 2 or more days of resistance training (RT) for the purposes of preventing chronic disease risk. However, only one out of five Americans meet physical activity guidelines[3].

Both acute and chronic aerobic exercise have shown beneficial effects on cardiovascular health by reducing and/or preventing negative changes in arterial health[1,4]. A recent meta-analysis examined the impact of aerobic, resistance, and concurrent training on arterial stiffness and found that a combination of light RT accompanied with aerobic training is the most effective at decreasing arterial stiffness while RT programs containing heavy loads may actually promote arterial stiffening[4]. Other research has commented on the largely inconclusive findings within the body of literature surrounding the impact of RT on arterial stiffness[5]. Variability in the manipulation of resistance training variables between studies prove drawing any conclusions regarding RT and arterial stiffness to be difficult. Interestingly, there may be an effect of RT to mitigate arterial stiffening via preservation of muscle mass and the subsequent changes in autonomic control of peripheral blood flow[6]. Therefore, increases in segmental lean body mass have the potential to explain underlying changes to central arterial stiffness. For this reason, further research is needed to examine the impact of specific resistance training variables on arterial stiffness while controlling for lean body mass changes.

While there appear to be similar reductions in arterial stiffness from both high- and low-intensity RT programs in young resistance-trained individuals[5], any changes in arterial health resulting from the effect of total weekly load volume (weight x repetitions x sets x days) remains to be examined. Furthermore, insights comparing a single RT bout on augmentation index between young males and females have shown similar responses between sexes, but none have examined sex differences from the training effect of total weekly load volume[7]. The current study sought to investigate arterial stiffness in response to weekly load volume doses of RT while controlling for changes in segmental lean body mass in young resistance trained males and females.

Methods

Participants

Twenty-two college-aged students (20.4 ± 2.0 years), thirteen females and nine males participated in this research study. Subjects were recruited via word of mouth throughout the University campus. Subjects that expressed interest in this study completed a screening questionnaire to elaborate on their health history, along with RT experience. Exclusion criteria were as follows: self-reported RT less than 2 days/wk for the past six months, known cardiovascular, pulmonary, or metabolic disease, presence of musculoskeletal injuries, or currently pregnant. This research study was approved by the Institutional Review Board and all subjects were provided with and signed an informed consent sheet prior to their participation in the study.

Experimental Design

Participation in this study required a pre-testing session, in which participants signed an informed consent and had baseline measures for augmentation index, body composition, and muscular strength. Following pre-testing, subjects were randomized into three groups with each group varying in total weekly load volume dose of a full body RT program per week. Group 1 was assigned to complete the program one day per week, Group 2 for two days per week, and Group 3 for three days per week, with the program remaining constant throughout the study. Participants completed the intervention, utilizing Matrix (Matrix Fitness USA, Cottage Grove, WI) exercise machines and dumbbells, in the University student recreation weight room. Table 2 identifies the RT program followed. To ensure adherence, all RT sessions were supervised by a member of the research team. Subjects were encouraged to refrain from any additional RT or aerobic training. To avoid the potential effects of detraining, all subjects were told to continue any current aerobic training program. The experimental flow chart is presented in Figure 1.

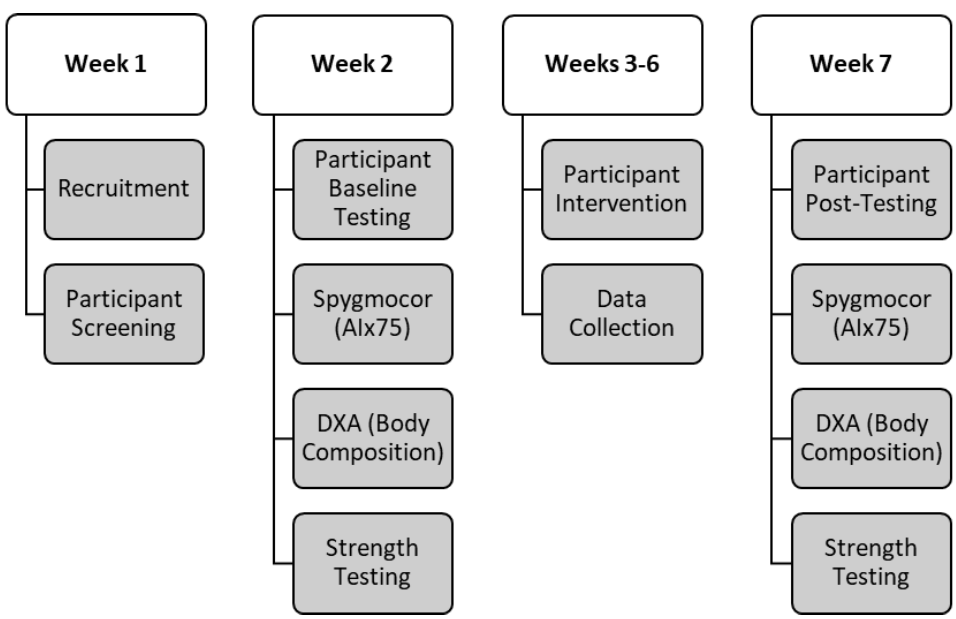

Figure 1. Experimental Flow Chart.

Table 1. Resistance Training Program.

Exercise	Weight	Reps	Sets
1a. Seated Row	80% 1-RM	6	3
1b. Leg Press	80% 1-RM	6	3
2a. DB Chest Fly	80% 1-RM	6	3
2b. Calf Raise	80% 1-RM	6	3
3a. Shoulder Press	80% 1-RM	6	3
3b. Lat Pulldown	80% 1-RM	6	3
4a. Leg Extension	80% 1-RM	6	3
4b. Prone Leg Curl	80% 1-RM	6	3

Note: Rest periods of 60 sec were completed between the exercises within each super-set pairing and 2 min between each set.

Procedures

All subjects attended two separate testing sessions separated by the 4-week training intervention. All subjects arrived to testing sessions having fasted for at least 4 hours, refrained from vigorous exercise for 12 hours, and avoided alcohol or caffeine intake for 12 hours. Upon arrival for pre- and post-testing sessions, subjects were seated for a 10-min rest period. After the rest period, aortic blood pressure (BP) and augmentation index set at a heart rate of 75 (AIx75) were obtained using non-invasive, oscillometer (SphygmoCor XCEL, AtCor Medical, Sydney, Australia). To ensure accuracy, a second measurement was obtained 5-min following the first measurement and the two recordings were averaged for further data analysis. Augmentation index normalized to 75bpm was used due to the influence of varying heart rates on standard augmentation index[7]. Calibration was done prior to use via manufacturing guidelines. The SyphymoCor XCEL has been established as a valid and reliable device for measuring BP and AIx75[8]. Immediately following blood pressure measurement, segmental body composition was measured using dual-energy x-ray absorptiometry (DXA for Bone Health, Prodigy for Bone Health GE Healthcare, Maple Grove, Minnesota). Following body composition assessment, maximal strength was measured using procedures previously described[3]. Strength testing was concluded once the subject failed within the 1-5 repetition range.

When appropriate, a predictive 1RM equation was applied and the subsequent 1RM was used for prescribing training load[9]. All testing was performed under trained supervision. A description of all eight exercises and the RT training load can be seen in Table 1. All subjects completed their designated training sessions over a 4-week period. All groups completed their RT sessions on the same day and time of the week throughout the study with at least 24-hours rest between sessions in the two-day and three-day groups.

Statistical analyses

After the participants were placed randomly into groups, separate one-way ANOVA were conducted to determine differences in baseline relative strength and AIx75. A one-way ANOVA was also used to determine the difference in total weekly load volume across groups. To adjust for differences in AIx75 between groups at baseline, a one-way ANCOVA was employed using pre-AIx75 values as the covariate in the model. Once adjusted, post-AIx75 were analyzed to determine between-group differences. Separate one-way ANCOVA were run to examine any group effect on the pre-post change in AIx75 controlling for changes (Δ%) in segmental lean body mass. A two-way ANCOVA was also conducted to examine the effects of sex and group on post-AIx75, controlling for pre-AIx75. Data were analyzed using SPSS version 24.0 (SPSS, Chicago, IL). Significance level was set at $p < 0.05$. Quantitative data are summarized as mean $\pm$ standard deviation (SD).

Results

Twenty-two of the original 25 participants completed the current study. Three participants opted out of being a part of the study due to time-constraints. The overall study included 13 female participants and 9 male participants. The 22 participants were separated into three training groups: one day per week (n=7), two days per week (n=8), and three days per week (n=7). Participant descriptive characteristics are shown in Table 2. Comparisons of RT volume dose on select variables are shown in Table 3.

A one-way ANOVA was utilized to examine differences in baseline relative strength and AIx75 as well as total weekly load volume between groups. There was no significant difference detected for baseline relative strength (p = .245) and AIx75 (p = .233) between groups. There were significant differences of total load volume per week between Group 1 and Group 3 (p = .010), Group 1 and Group 2 (p = .042), but there was no significant difference between Group 2 and Group 3 (p= 1.00).

After adjusting for pre-AIx75, there were no significant differences in post-AIx75 between groups (p = .906). Furthermore, no significant difference was found for the pre-post change in AIx75 controlling for individual changes (Δ%) in upper body lean body mass (p = .222) or lower body lean body mass (p=.226).

Table 2. Participant characteristics by sex. (Values are mean + SD).

Characteristics	Group 1	Group 2	Group 3
Age (yrs)	------	------	------
Male	19.0 + 1.0 (n=3)	21.3 + 1.5 (n=4)	22.5 + 3.5 (n=2)
Female	20.0 + 1.4 (n=4)	20.8 + 3.0 (n=4)	19.8 + 1.5 (n=5)
Total	19.8 + 1.3 (n=7)	21.0 + 2.0 (n=8)	20.6 + 2.3 (n=7)
Height (cm)	------	------	------
Male	174.2 + 5.6	179.8 + 9.9	177.3 + 6.7
Female	164.8 + 6.0	169.6 + 5.3	164.0 + 7.3
Total	168.8 + 7.3	174.7 + 9.1	167.8 + 9.2
Weight (kg)	------	------	------
Male	72.4 + 5.6	74.7 + 9.4	85.2 + 9.8
Female	72.4 + 26.0	66.5 + 9.1	61.8 + 5.2
Total	73.0 + 18.5	70.4 + 10.5	69.1 + 14.7
Body Fat (%)	------	------	------
Male	21.0 + 5.6	30.0 + 7.0	34.0 + 1.4
Female	31.0 + 13.4	23.0 + 9.5	30.2 + 8.6
Total	26.5 + 10.1	26.3 + 7.9	30.8 + 7.0

Table 3. Comparison of resistance training dose on select variables. (Values are mean + SD).

Variables	Group 1 (n=7)	Group 2 (n=8)	Group 3 (n=7)	*p-value*
AIX75 (%)	------	------	------	.906
Pre	-0.9 + 12.4	-7.1 + 14.7	3.6 + 5.6	
Post	1.4 + 8.8	.5 + 13.8	-1.0 + 11.7	
Change (pre-post)	6.5 + 14.8	7.6 + 17.4	-4.6 + 13.9	
UB LBM (kg)	------	------	------	.222
Pre	6.13 + 2.0	6.3 + 2.3	5.2 + 2.3	
Post	5.7 + 1.7	6.5 + 2.4	5.4 + 2.1	
Change (%)	0.9 + 38.2	19.8 + 70.9	27.7 + 84.1	
LB LBM (kg)	------	------	------	.226
Pre	16.8 + 4.4	16.9 + 3.9	15.3 + 4.2	
Post	15.8 + 2.9	17.8 + 4.3	16.0 + 5.0	
Change (%)	0.4 + 30.3	11.7 + 41.6	13.1 + 49.3	
Relative Strength (kg/LBM)	------	------	------	
Pre	12.9 + 2.4	13.3 + 3.0	11.2 + 2.0	
Post	13.4 + 1.7	13.4 + 2.3	13.6 + 3.0	
Change (%)	7.5 + 27.0	4.8 + 30.2	24.8 + 34.9	
Total Load Volume (kg/wk)	9188 ± 2786	19443 ± 7448*	22291 ± 9873*	.008

Discussion

The main finding of this study demonstrates a lack of load volume dose effect on arterial stiffness in college-aged resistance-trained males and females. Overall, there were no significant changes between pre- and post-testing for AIx75, indicating minimal effects of total weekly load volume on arterial stiffness after a 4-week exercise intervention. To add, this study is the first attempt to establish a dose-response relationship of total weekly load volume on changes in arterial stiffness while controlling for changes in segmental lean body mass to explain training adaptations.

A study of similar training duration by Collier et al. (2008) examined the impact of a 4-week full-body machine-based resistance training program on markers of arterial stiffness in pre- and stage-1 hypertensive men and women. Their results demonstrated a 14.5% increase in central arterial stiffness in response to the moderate intensity (65% 10RM) RT training program. Differences in multiple training variables make a direct comparison difficult; however, the group exercising at the same 3 day/wk frequency in the current study trended toward an overall improvement in central arterial stiffness. Perhaps the 1 day and 2 day/wk groups were performing less total weekly load volume than accustomed to, and a 'detraining' effect could explain the unfavorable changes in those groups. The contrast between studies may be explained by the difference in the study population, where the Collier et al. (2008) group examined an older (47 years) and untrained group while the current study examined young individuals with previous training experience. Noted by Au et al. (2017), the baseline level of arterial stiffness in a group prior to an RT intervention has the potential to explain any findings, particularly when groups with low baseline arterial stiffness tend to have greater arterial stiffening in response to a RT interventions. Group 3 was the only group with normal baseline AIx75 where both Group 1 and 2 had lower baseline AIx75. This trend confirms with findings by Au et al. (2017) and may help explain the difference between the current study and Collier et al. (2008).

The increase in arterial stiffness from resistance training has already been well-documented in men[11, 12], therefore, we sought to identify the impact of gender on any dose-effect changes. Similar to a study by Kingsley et al. (2017), we found that men and women have similar changes in arterial stiffness in response to RT. It should be noted that the Kingsley et at. (2017) study examined the impact of a single bout of resistance training where the currently study examined the dose-response over a 4-week training period. It could be postulated that the differences in sex steroid concentrations between males and females may have explained subsequent changes in arterial stiffness but perhaps that discrepancy exists only after the sixth decade of life and not in a young resistance-trained population.

The novelty of the current study design results in difficulties drawing direct comparisons with other studies, particularly the fashion in which total weekly load volume was delivered. One study has commented on the impact of RT volume and arterial stiffness and found that 12 weeks of both high load (~75-90% 1RM) and low load (~30-50% 1RM) resulted in similar improvements on central arterial stiffness[5]. Time-course measurements within the Au et al. (2017) could have shown that the positive changes from RT occurred within the first few weeks and remained unchanged throughout the remained, agreeing with the current study; however, these data are not reported along with differences in total weekly load volume.

Limitations

The proposed study controlled multiple variables within the study; however, limitations were present. Prior to beginning the intervention, volunteers were asked to self-report their involvement with physical activity. These responses were not regulated and may have been inaccurate to better the chances of participating in the study. Research results with both men and women lacks the confidence to generalize conclusions on a larger population, due to the small sample size of this study. Considering characteristics of the participants involved, results cannot explain the outcomes in an older or younger population involving similar studies. Diet was not taken into consideration for the intervention, resulting in an additional limitation. By not regulating dietary habits with the study, overall arterial health is affected by the nutrients and foods ingested by participants. Varying diets could include high or low caloric intake restrictions, as well as commercial meal replacements.

Future studies should focus on evaluating a more diverse population in terms of age, gender, and health status. Controlling dietary intake during the four-week intervention in further studies may account for external factors that may affect the study results. The addition of a control group in future studies may be a resource to further discover potential vascular changes in relation to RT. Research needs to look into a dose-response impact of RT volume on arterial stiffness over a longer intervention period. Given the factors that can potentially explain changes in arterial compliance and accompanying CVD risk, metrics of total body arterial stiffness as well as blood markers for inflammation (such as endothelin-1) should be coupled with segmental changes in lean body mass. Furthermore, future studies should seek to examine the impact of other RT variables on arterial compliance such as a frequency dose with equated total weekly load volume.

CONCLUSION

The present research study investigated the impact of a dose response relationship on arterial stiffness using AIx75 in college-aged males and females. The results suggest that a 4-week RT program does not have a significant impact on arterial stiffness but trended toward improved compliance in the 3 day/wk group. Accordingly, professionals prescribing RT in young resistance trained individuals should be encouraged to maintain a higher rather than lower total weekly load volume to avoid a potential detraining effect.

Acknowledgements

We would like to thank our volunteer Courtney Lillie, for monitoring subjects during their training sessions. We would also like to thank the McPhee Strength and Performance Center for allowing subjects to utilize the facilities. Thank you to Dr. Marquell Johnson for his guidance throughout the entire research process. Lastly, thank you to the Kinesiology Department of the University of Wisconsin-Eau Claire for allowing the researchers to utilize the Kinesiology lab for pre- and post-testing.

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