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Gravitational Changes in Hand -Wrist Volume are Smaller in Older Adults as Compared to Younger Adults

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Abstract

Vascular compliance is a characteristic of the blood vessel wall to expand or contract with changes in pressure, and is reduced with aging or diseases like arteriosclerosis. Our goal was to investigate how hand-volume changes differ with age and to provide a simple non-invasive method to assess vascular compliance. We hypothesized that gravity-related, hand-wrist volume changes are greater in younger than in older healthy volunteers. Thirty-five healthy volunteers were classified into two age groups: young (18-35 years, n=16) and old (50-65 years, n=19). Volunteers were not on any blood pressure medication and did not have any history of vascular disease or surgery on examined extremities. Hand-wrist volume was measured by water displacement for five minutes during two randomly-ordered conditions: 1) arm lowered and 2) arm raised. In condition #2, blood flow was occluded using an arm cuff inflated to 180 mmHg to prevent arterial inflow and venous return. The study was performed in the same building in the same room under room temperature conditions over the course of approximately 6 weeks. Percent differences in volume between the conditions were compared. Means ± SD were compared and significance was set at $p < 0.05$.

All subjects showed higher volume of displaced water in the arm-lowered position (463.3 ± 80.5 ml) than the arm-raised position (447.7 ± 79.7 ml) (p=0.418). Percent difference in hand-wrist volume in the younger group (8 males, 8 females) was significantly greater (4.1±1.7%) than the older group (2.8±1.4%) (9 males, 10 females) (p=0.017). Age was negatively correlated with percent difference in hand-wrist volume (r=-0.388). Vascular compliance within older subjects' hands was significantly less than younger subjects based upon our simple method for measuring blood volume shifts with gravity. This study introduces a simple approach for measuring blood volume shifts with gravity which may provide clinically-relevant information about vascular compliance in aged populations.

Keywords: Arterial structure and compliance; Aging; Blood pooling; Cardiovascular disease

Introduction

Approximately one in three Americans has at least one type of cardiovascular disease and almost half of these patients are estimated to be 65 years or older [1]. Aging induces a dramatic decrease in vascular compliance and consequently, lower vascular compliance may play a role in hypertension and cardiovascular risk [2,3]. Vascular, or more specifically, arterial compliance is the ability of an artery to expand and recoil with cardiac contraction and relaxation [4]. Further evidence indicates that with age, blood vessel walls become more rigid due to deposition of plaque, fraying and fragmentation of elastin and an increase in the number of cross-linking fibers [5].

Standard methods for measuring large artery stiffness or compliance include central pulse wave velocity, elastic modulus, brachial artery pulse pressure and stroke volume pressure. Pulse wave velocity is a simple measurement for vascular compliance, but fails to represent the entire vasculature. The elastic modulus is a more technical method and is limited to larger arteries. Brachial artery pulse pressure is simpler but does not take into account central circulation. Finally, stroke volume pressure demands advanced equipment such as M-mode echocardiography and also depends on brachial pulse pressure [6]. All of these methods lack a practical way of measuring compliance in the clinical setting due to the limitations associated with incomplete assessments, technical equipment and high cost.

Arm elevation causes vascular emptying by which hand volume markedly decreases but recovers upon returning the arm to its normal dependent position [7]. Furthermore, local arterial and venous pressures are reduced during arm elevation, and a transient vasodilation response occurs in the dependent position [8]. Thus, it may be inferred that age-induced vascular inelasticity will cause a smaller change in forearm volume. The properties of upper extremity volumeter measurements are well documented and the method has been shown to be reproducible [9-11]. The hand volumeter is considered the "gold standard" method for measuring hand volume of edematous hands and is regarded as one of the most useful standardized tools for measuring hand edema because it can be quantified and used to assess the effectiveness of treatment [11].

We hypothesized that older individuals have a reduced hand-volume response than younger individuals with vascular emptying and filling due to gravity. Previous studies for assessing vascular compliance found that age is one of the most highly correlated factors [12-14]. The purposes of this study were to assess if a hand-wrist volumeter is a simple and noninvasive method for determining vascular compliance and to investigate how gravitational changes in hand volume differ with age [15]. We hypothesized that gravity-related changes in hand-wrist volume are greater in younger than in older healthy volunteers. A simple, accurate and convenient method for measuring a patient's vascular compliance is needed, especially in developing nations.

Materials and Methods

Thirty-five healthy volunteers were recruited who were not on any blood pressure medication and did not have any history of vascular disease or surgery on examined extremities. The subjects were classified into the young (18-35 years old) and old (50-65 years old) groups. The young group consisted of 8 males and 8 females, and the old group consisted of 9 males and 10 females. The average ages of young male and female and old male and female groups were 25.4 ± 4.1, 25.8 ± 4.8, 58.1 ± 5.6, and 56.1 ± 5.0 years, respectively. All measurements were performed in the same building in the same room over the course of approximately six weeks. This study was approved by UCSD Human Research Protection Program and all subjects signed informed written consent forms.

Hand and wrist volume was measured using a hand volumeter (Volumeters Unlimited, Phoenix, AZ) filled with 3% alcohol (Figure 1). A previous study confirmed that using a hand volumeter is an accurate and reliable method for measuring hand volume, especially for the purpose of measuring limb swelling [16]. Based on a recent study, 3% water-ethanol mixture was found to yield a more accurate measurement than water, presumably due to the decrease in surface tension [15]. A graduated cylinder was used to fill the volumeter and the fluid from submerging the hand into the volumeter emptied into a beaker. The hand volumeter measured hand and wrist volumes during two experimental conditions: 1) arm lowered for five minutes to allow for normal blood pooling with gravity and 2) arm raised for five minutes in order to induce a blood and fluid shift out of the elevated limb, at which point blood flow was occluded using a sphygmomanometer inflated to 180 mmHg, preventing arterial inflow and venous return [17]. The order was randomized for each subject. If the arm elevation condition was performed first, the subjects rested their hands at the heart level for five minutes to allow normal blood flow to return.

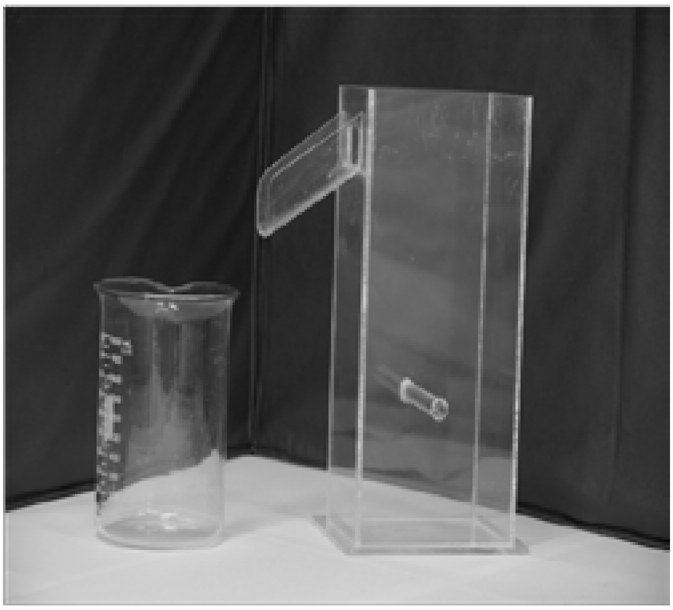

Figure 1: The hand and wrist are submerged in the hand volumeter (right) and the mass of the fluid is displaced to a weighed beaker (left) is multiplied by the density of the water-3% ethanol mixture. The middle and ring finger are separated by a plastic peg in the volumeter.

Subjects were asked to place their hands in the volumeter until the plastic peg was between the middle and ring finger (Figure 1). The plastic peg helped the subjects keep the same position for both trials. The hand was submerged for two minutes and the volume of displaced fluid was recorded, which was obtained by taking the mass of the displaced fluid and then dividing this value by the density of the water-ethanol mixture. The percent difference in hand-wrist volume was calculated as follows: volume difference between the two experimental condition of the study was divided by the volume of lowered position $\left(\frac{[lowered\ -\ raised](ml)}{lowered(ml)}\times 100\right)$

The percent difference was compared between each group. Means were reported as value ± standard deviation (SD). A power analysis was performed (G*Power v3.1.7) using published normative data [18] to establish a minimal group sample size of n=16. Statistical differences were measured by ANOVA to assess percent change of hand volume by age and gender with significance determined to be at $p<0.05$.

Results

Hand and wrist volumes were relatively easy and simple to measure in both younger and older age groups using the hand volumeter. All tests on a given subject were performed within 20 minute. All subjects showed higher volume of displaced fluid with arm in lowered position (463.3 ± 80.5) than at the arm raised position (447.7 ± 79.7), though not statistically significant (p=0.418). The percent difference in hand and wrist volume was 4.1 ± 1.7% in the younger group (n=16) and 2.8 ± 1.4% in the older group (n=19) (Table 1). This difference was significantly greater in the younger group than that in the older group (p=0.017, Figure 2). The percent difference in hand and

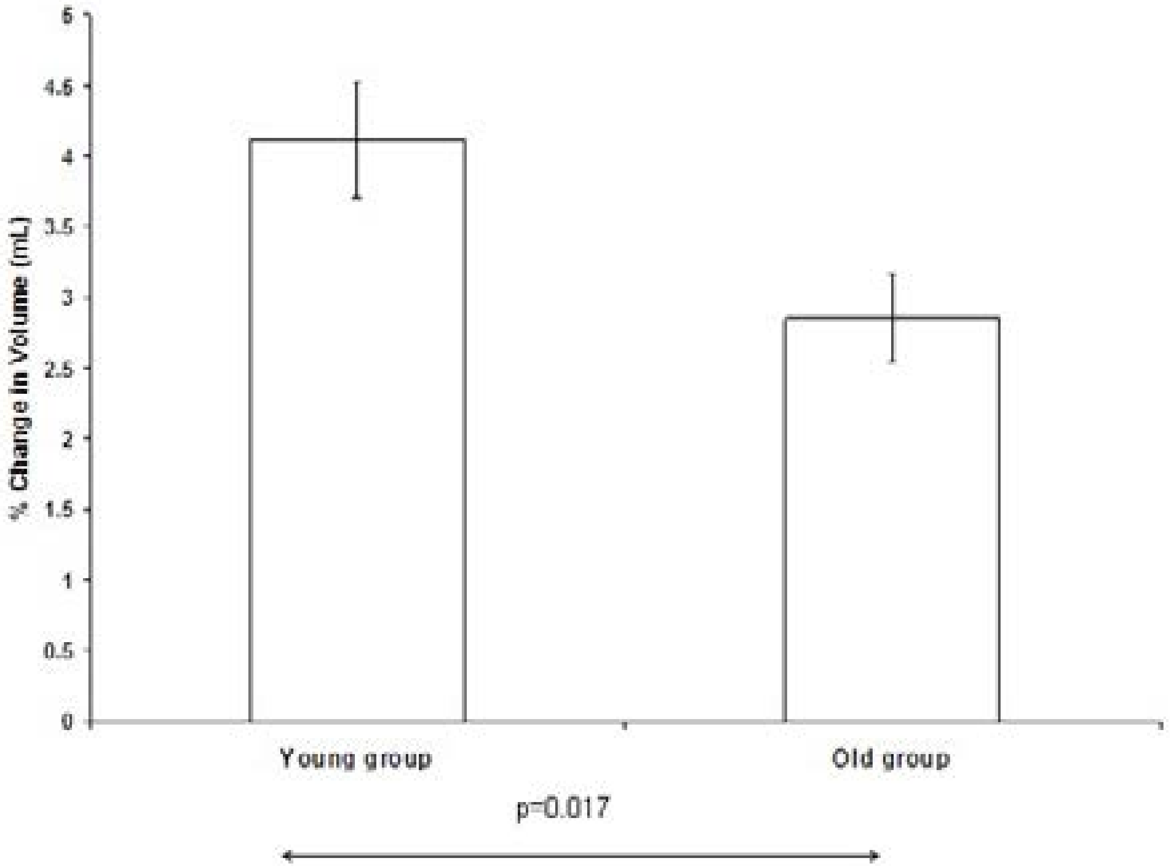

Figure 2: Comparison of the percent change in hand volume between different age groups. The Young group (18-35 years) had a significantly greater percent change in hand volume than the Old group (50-65 years). Values are mean±standard error (SE)

wrist volume was negatively correlated with age in our subjects (r = -0.388). Among the male subjects, the percent difference for the younger male group (n=8) was significantly greater than that in the older male group (n=9) (p=0.046). Among the female subjects, the percent difference for the younger female group (n=8) trended greater than that in the older female group (n=10), but this difference was not statistically significant (p=0.149). Also, the female group (n=18) showed a trend to higher percent difference in hand and wrist volume than the male group (n=17), but again this was not significant (p=0.062). The younger female group (n=8) had the highest percent difference in hand and wrist volume (4.3±0.8%) and the older male group (n=9) had the lowest percent difference in hand and wrist volume (2.6±0.5%) among the four subgroups by age and gender.

Group		Raised Position (ml)	Lowered Position (ml)	1Percent Difference (%)	Young Vs. Old (%)
Young (n=16)	Male (n=8)	523.8±47.6	545.0±47.8	3.9±1.0*	4.11±0.41*
	Female (n=8)	355.5±21.4	371.6±23.6	4.3±2.1	
Old (n=19)	Male (n=9)	484.0±46.7	496.6±42.7	2.6±1.4	2.85±0.31
	Female (n=10)	428.1±74.2	441.5±74.7	3.1±1.3	
Total		447.7±79.7	463.3±80.5	3.4±1.6	

Values are mean±standard deviation (SD)
[1]Percent difference (%) = 100 x (Lowered Position-Raised Position)/Lowered Position *p<0.05

Table 1: Average volume at each position and percent changes in hand-wrist volume of each group, and comparison young versus old groups.`

Discussion

Vascular compliance is the ability of blood vessel wall to expand and contract with changes in pressure. Vascular compliance (C) can be quantified as the change in volume ( ) for given change in distension pressure (ΔP), which is $C = \frac{\Delta V}{\Delta P}$. High vascular compliance suggests the vessels that pool blood are more elastic. Vascular compliance is reduced with aging or diseases like arteriosclerosis or diabetes [17]. The decrease in volume correlates with the increase in pressure and the decrease in vascular compliance that accompanies aging [2]. We hypothesized that older individuals have a reduced increment in hand volume than younger individuals with vascular emptying and filling due to gravity, indicating decreased vascular compliance in older healthy individuals. The results of this study showed that a statistically significant percent change in hand volume was achieved when comparing the two age groups. Our study also illustrated the convenience, effectiveness, and simplicity of using a hand volumeter to assess vascular compliance.

A number of factors contribute to this increased stiffness in vessels, such as intima-media thickening and plaque buildup [19]. The endothelial layer of cells lining the lumen is the primary component of the intima. Endothelium plays an important role in the maintenance of vascular tone as well as modulation of inflammation and coagulation [20,21]. Therefore, endothelial dysfunction probably reduces vascular compliance, especially in the smaller arteries [20]. With aging, compliance decreases steadily as a consequence of increasing stiffness of the vessel walls [12]. Arterial stiffness may enlarge the heart and decrease the ability to regulate blood pressure [22]. Furthermore, decreased vascular compliance is one of the major factors responsible for cardiovascular disease [3]. The common denominator in all patients at risk for cardiovascular disease is reduced small artery compliance [20].

There are several methods for evaluating arterial compliance, but there is no simple gold standard method, performed either invasively or non-invasively [12,20]. Impedance spectra is an invasive method, but is not useful clinically [23]. Calculating the ratio of the stroke volume and pulse pressure, measuring pulse wave velocity, ultrasonic pulsatility, and pulse contour analysis are all used for assessing arterial compliance [6]. The specific equipment for these methods is often expensive and complicated to use. Often results are affected by extraneous factors such as physical, emotional and environmental status. Thus, results are often not reproducible. Our method was designed to simplify the assessment of vascular compliance in clinical practice, especially in developing countries. Water displacement is a quick and easy method which can be performed immediately and in a number of different environments. Hand volume measurements are also reproducible and may be relatively unaffected by external factors. We hypothesized that there is less of an increase in hand and wrist volume with arm position change in older adults as compared to younger adults. Intravascular pressures in both arteries and veins increase during gravitational pooling in dependent position, but these pressures are decreased during arm elevation. With blood pooling due to gravity, there is significantly less volume change in older adults as compared to younger adults in this study. This finding is similar to findings of previous studies using more complicated and expensive methods for assessing vascular compliance [12-14]. In the future it would be valuable to compare hand volumetry to other standardization methods.

Endothelial dysfunction reduces compliance, and in turn, increases the risk for cardiovascular disease [24]. The focus in the prevention and treatment of cardiovascular disease is increasing the compliance of the blood vessel wall [20,25,26]. Implementing a regular exercise [27] or pharmacologic treatment like statin or angiotensin-converting enzyme (ACE) inhibitor [28, 29] improves the vascular compliance, and these can reverse or lessen the risk [30]. The preventative measures for cardiovascular disease increases the importance of a convenient screening technique. With further validation studies, a hand volumeter could be used as a screening method, which may lessen expenses and time spent assessing the patient's risk. There were some limitations of this study. There were some limitations of this study. First, it was difficult to recruit completely healthy older subjects and some may have had undetected cardiovascular disease. Second, our older subjects were within an age group of 50 to 65 years and none were over 65 years, an age that some define as "old." Our study was performed in the same room in the same building, however an additional limitation was that the time of day was not consistent and ambient room temperature was not controlled.

A simple, accurate and convenient method for measuring a patient's vascular compliance is needed, especially in developing nations. Our findings document a significant decrease of vascular compliance in older adults as compared to younger adults. We feel that the hand volumeter can provide a quick, non-invasive and inexpensive measurement of hand-wrist vascular compliance. Potentially the apparatus could be used to evaluate vascular compliance or to follow up after a particular diagnosis or the prescription of a medication that is intended to decrease vascular stiffness. In conclusion, the hand-wrist volumeter provides a simple and convenient method that may provide clinical information of cardiovascular risk in older populations.

Acknowledgments

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