Left Atrial Enlargement and Reduced Physical Function During Aging

Andrew A. Pellett, Leann Myers, Michael Welsch, S. Michal Jazwinski, and David A. Welsh

Diastolic dysfunction, often seen with increasing age, is associated with reduced exercise capacity and increased mortality. Mortality rates in older individuals are linked to the development of disability, which may be preceded by functional limitations. The goal of this study was to identify which echocardiographic measures of diastolic function correlate with physical function in older subjects. A total of 36 men and women from the Louisiana Healthy Aging Study, age 62–101 yr, received a complete echocardiographic exam and performed the 10-item continuous-scale physical-functional performance test (CS-PFP-10). After adjustment for age and gender, left atrial volume index ($\rho=-0.59; p=0.0005$) correlated with the total CS-PFP-10 score. Increased left atrial volume index may be a marker of impaired performance of activities of daily living in older individuals.

Keywords: diastolic function, left atrial volume, echocardiography, elderly, diastolic dysfunction

As a consequence of aging, the left ventricle (LV) typically develops diastolic dysfunction, defined as reduced LV relaxation and/or increased stiffness, while maintaining a normal ability to contract (systolic function; Abhayaratna, Marwick, Smith, & Becker, 2006; Redfield et al., 2003). Diastolic dysfunction is a frequent cause of symptoms in heart failure (Zile, Baicu, & Gaasch, 2004) and is associated with increased mortality (Halley, Houghtaling, Khalil, Thomas, & Jaber, 2011). Moreover, diastolic function appears to correlate with exercise capacity better than systolic function in middle-aged and older patients with heart failure (Gardin et al., 2009; Yoshino, Nakae, Matsumoto, Mitsunami, & Horie, 2010).

Decreases in LV relaxation or compliance can increase LV end-diastolic pressure (LVEDP), left atrial pressure, and, over time, left atrial volume (Pritchett et al., 2005; Tsang, Barnes, Gersh, Bailey, & Seward, 2002). Left atrial volume may increase as a result of normal aging (Aurigemma et al., 2009; Boyd, Schiller, ...
Leung, Ross, & Thomas, 2011; Triposkiadis et al., 1995) and as a consequence of cardiovascular disease (Gottdiener, Kitzman, Aurigemma, Arnold, & Manolio, 2006; Pritchett et al., 2003). Left atrial enlargement correlates with decreased exercise capacity (Kjaergaard et al., 2005; Wong & Yeo, 2010), increased risk of cardiovascular events (Leung et al., 2010; Pritchett et al., 2003), and a poor prognosis (Leung et al., 2010; Moller et al., 2003; Rossi et al., 2002).

According to the “disablement process” (Verbrugge & Jette, 1994), functional limitations resulting from pathologic impairment contribute to early disability and loss of independence. Subsequently, mortality rates are closely linked to disability in older individuals (Landi et al., 2010). The presumption, therefore, is that diastolic dysfunction may lead to physical limitations, which, in turn, contribute to disability. However, insufficient data are available to confirm the pathway linking diastolic heart function with a reduced ability to perform tasks involving physical function.

Diastolic dysfunction can be diagnosed by obtaining thinly sliced images of the heart with ultrasound (two-dimensional echocardiography) and by measuring cardiac blood flow and tissue velocities with Doppler echocardiography. Measures of diastolic function obtained with echocardiography include left atrial volume, LV inflow velocities associated with rapid filling (E velocity) and atrial contraction (A velocity), E-velocity deceleration time, mitral annular velocities during rapid LV filling (e′) and atrial contraction (a′), and atrial contraction reversal velocity obtained in the right superior pulmonary vein (Nagueh et al., 2009).

The purpose of our study was to identify the echocardiographic diastolic function variables, specifically those related to elevated LVEDP, that correlate with physical function in subjects age 60 years and older. We hypothesized that an increase in left atrial volume would be associated with a reduction in physical performance involving everyday tasks, as measured by the 10-item continuous-scale physical-functional performance test (CS-PFP-10).

Methods

Participants

The Louisiana Healthy Aging Study (LHAS) was a community-based study conducted in the greater Baton Rouge area from 2002 to 2008. The overarching aim of LHAS was to determine the genetic, physiologic, and metabolic characteristics that predispose individuals to healthy aging. In the parent study, population-based sampling was performed via random selection using voter-registration lists and Medicare beneficiary enrollment data files from the Centers for Medicare and Medicaid Services. Nonagenarians were oversampled as the experimental group, with control subjects ranging from age 25 to 89. The study was approved by the institutional review boards of the involved institutions, and informed written consent obtained.

Subjects included in this analysis represent the subset of LHAS participants over the age of 59 who underwent digital echocardiographic assessment and also performed the CS-PFP-10. Exclusion criteria consisted of active atrial fibrillation and a calculated mitral valve area of less than 1.5 cm².
Medical History and Physical Exam

Medical history was recorded by interview using a standardized instrument. Weight was measured to ±0.1 kg with an electronic scale (Detecto, Webb City, MO). Height was measured to ±0.5 cm with a wall-mounted stadiometer (Holtain, Crymych, Dyfed, UK), and body mass index (BMI) was calculated as weight divided by height squared (kg/m²). Blood pressure was measured in a quiet room with minimal temperature fluctuations after a 5-min rest period. All measurements were taken twice (and averaged) on the participant’s right arm with a manual sphygmomanometer (Baum, Coplaque, NY).

Echocardiography

All echocardiograms were performed by the same experienced registered cardiac sonographer using a Toshiba Apio echocardiograph (Toshiba America Medical Systems, Tustin, CA). Two-dimensional color-flow Doppler and spectral Doppler echocardiography were used to screen for valvular disease. Echocardiographic variables were measured in triplicate and averaged.

LV and left atrial volumes were measured with the biplane method of disks (Khankirawatana, Khankirawatana, & Porter, 2004; Schiller et al., 1989). Briefly, this method involves imaging each chamber in two orthogonal planes. Both images of a chamber are then divided into 20 slices. The area of each slice is calculated, and by combining the two images and then measuring the length of the chamber and dividing by 20, the volume of each presumed elliptical disk can be calculated. Summing the volumes of the 20 disks yields the volume of the chamber. Measuring the volume of the LV at end-diastole and end-systole permits the calculation of ejection fraction (EF), a common clinical measure of ventricular systolic function: EF = (end-diastolic volume – end-systolic volume)/end-diastolic volume.

Using two-dimensional linear measurements, LV mass was calculated with an equation that modeled the LV as a prolate ellipse (Devereux et al., 1986). LV mass, as well as LV end-diastolic and left atrial volumes, was indexed to body surface area.

Echocardiographic diastolic function variables were obtained according to previous recommendations (Appleton, Jensen, Hatle, & Oh, 1997; Hill & Palma, 2005). A 1-mm pulsed Doppler sample volume was positioned at the mitral leaflet tips in the apical four-chamber view to record mitral inflow E and A velocities and E-wave deceleration time. Mitral A-wave duration was measured after advancing the sample volume toward the level of the mitral annulus. In the same view, mitral lateral and septal annular e’ and a’ velocities were measured by sequentially placing 5-mm and 3-mm pulsed Doppler sample volumes, respectively, at the lateral and septal aspects of the mitral annulus. The mitral E velocity was divided by e’ velocity obtained from the lateral mitral annulus to yield E/e’, a measure of LV filling pressure. Pulmonary venous velocity waveforms were obtained in the apical four-chamber view by advancing a 5-mm pulsed Doppler sample volume 0.5–1 cm into the right superior pulmonary vein. From these traces pulmonary venous systolic and diastolic peak velocities were measured, as well as atrial reversal wave velocity and duration. The criteria for the diagnosis of diastolic dysfunction consisted of a mitral E:A <0.75 combined with a deceleration time >240 ms, a mitral
lateral e′ velocity <10 cm/s, or a mitral septal e′ velocity <8 cm/s (Nagueh et al., 2009; Redfield et al., 2003).

**Measure of Physical Function**

The measure of physical function used in our analysis was the CS-PFP-10 (Cress, Petrella, Moore, & Schenkman, 2005). Briefly, the CS-PFP-10 involves the performance of 10 standardized tasks representing activities of daily living, including carrying groceries, donning clothes, sweeping the floor, unloading a washer and loading a dryer, climbing stairs, and a 6-min timed walk. Participants are instructed to perform the activities at peak effort but within the bounds of safety and comfort. The time required to complete the tasks, distance covered, and/or weight carried are compiled and converted to a set of continuous-scale scores ranging from 0 to 100. The test battery provides scores in five physical domains (balance and coordination, endurance, upper body flexibility, and upper and lower body strength) and a summed total score. Details of the scoring method can be found elsewhere (Cress et al., 1999). The CS-PFP-10, which is a shortened version of the Continuous-Scale Physical Functional Performance Test developed by Cress et al. (1996), has been shown to be valid, reliable, and sensitive and a good community-based substitute for the original 16-item laboratory test (Cress et al., 2005).

**Statistics**

Data were summarized using means and standard deviations. Associations between echocardiographic and physical-performance variables were assessed using partial Spearman rho correlation coefficients, and the Bonferroni method was used to correct for multiple comparisons. All analyses were conducted using SAS version 9.2.

**Results**

Thirty-six subjects received both echocardiographic and CS-PFP-10 evaluations. Left atrial volume index (LAVI) could not be measured in 4 individuals due to poor image quality, nor could EF in 3 of the same subjects. Pulmonary venous waveforms could not be measured adequately in 7 individuals. Subject characteristics are presented in Table 1, and echocardiographic and CS-PFP-10 data for the study population are presented in Tables 2 and 3, respectively.

Of the 32 subjects in whom LAVI was measured, 24 exhibited at least mild atrial enlargement (LAE), defined as LAVI >28 ml/m² (Lang et al., 2005). The subjects with LAE included 17 with diastolic dysfunction, 7 with coronary artery disease, and 5 with diabetes. Eight of the subjects with LAE had a history of heart failure, but only 3 exhibited a reduced EF (<50%) at the time of the echocardiogram. Twenty-one of the 32 subjects (66%) exhibited diastolic dysfunction, 17 of whom (81%) had LAE.

Correlations between echocardiographic variables related to LVEDP and the total CS-PFP-10 score were assessed. After adjustment for age and gender, LAVI was found to correlate inversely with the total CS-PFP-10 score, as well as with all domains. After adjustment for multiple comparisons, however, LAVI only correlated
### Table 1  Baseline Subject Characteristics

<table>
<thead>
<tr>
<th>Age Group</th>
<th>60–69, n = 2</th>
<th>70–79, n = 6</th>
<th>80–89, n = 12</th>
<th>≥90, n = 16</th>
<th>Overall, N = 36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men, n</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>Women, n</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>12</td>
<td>21</td>
</tr>
<tr>
<td>SBP (mm Hg), $M \pm SD$</td>
<td>$132.5 \pm 7.8$</td>
<td>$136.0 \pm 7.3$</td>
<td>$146.2 \pm 12.2$</td>
<td>$142.8 \pm 18.9$</td>
<td>$142.4 \pm 15.2$</td>
</tr>
<tr>
<td>DBP (mm Hg), $M \pm SD$</td>
<td>$66.5 \pm 12.0$</td>
<td>$71.6 \pm 8.6$</td>
<td>$73.3 \pm 10.4$</td>
<td>$70.9 \pm 7.4$</td>
<td>$71.6 \pm 8.6$</td>
</tr>
<tr>
<td>Heart rate (beats/min), $M \pm SD$</td>
<td>$51.0 \pm 1.4$</td>
<td>$71.7 \pm 10.0$</td>
<td>$61.6 \pm 11.5$</td>
<td>$66.8 \pm 14.6$</td>
<td>$65.0 \pm 13.1$</td>
</tr>
<tr>
<td>Cardiovascular history, n</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dysrhythmia</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>high blood pressure</td>
<td>0</td>
<td>5</td>
<td>10</td>
<td>12</td>
<td>27</td>
</tr>
<tr>
<td>heart failure</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>CAD&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>atrial fibrillation</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>diabetes</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

*Note.* SBP = systolic blood pressure; DBP = diastolic blood pressure; CAD = coronary artery disease.

<sup>a</sup>History of any of the following: heart attack, angina, angioplasty, coronary bypass surgery.
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significantly with the total CS-PFP-10 score and the endurance domain (Figure 1; Table 4). Pulmonary venous atrial reversal velocity was directly associated with the total CS-PFP-10 score but did not correlate significantly after Bonferroni adjustment. The following echocardiographic variables did not correlate significantly with the total CS-PFP-10 score: mitral E-to-A ratio ($\rho = -0.2$, $p = .27$, $n = 36$), mitral $a$-wave duration ($\rho = -0.34$, $p = .08$, $n = 30$), deceleration time ($\rho = 0.11$, $p = .53$, $n = 35$), atrial reversal wave duration ($\rho = 0.20$, $p = .32$, $n = 28$), mitral E/e’ ($\rho = 0.12$, $p = .51$, $n = 36$), and LV mass index ($\rho = -0.27$, $p = .12$, $n = 36$).

### Discussion

Using a unique, observer-assessed measure of functional ability, the analyses appear to be consistent with the model in which left atrial dilation affects the performance of activities of daily living. Note that LAVI was identified as a primary echocardiographic metric relevant to the disablement process described by Verbrugge and Jette (1994).

### Diastolic Function, Left Atrial Volume, and Aging

Redfield et al. (2003) found that the prevalence of diastolic dysfunction increased with age in a large-scale survey of randomly selected residents of Olmstead County, Minnesota, age 45 years and older. In the oldest age group in that study ($\geq 75$ years...
Table 3  CS-PFP-10 Scores (M ± SD)

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Total CS-PFP-10</th>
<th>Balance/Coordination</th>
<th>Endurance</th>
<th>Lower Body Strength</th>
<th>Upper Body Strength</th>
<th>Upper Body Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>60–69, n = 2</td>
<td>44.5 ± 58.6</td>
<td>44.5 ± 60.6</td>
<td>45.0 ± 61.4</td>
<td>41.6 ± 57.8</td>
<td>41.4 ± 56.6</td>
<td>57.7 ± 42.7</td>
</tr>
<tr>
<td>70–79, n = 6</td>
<td>45.5 ± 13.4</td>
<td>44.4 ± 12.7</td>
<td>46.7 ± 14.4</td>
<td>40.3 ± 14.1</td>
<td>46.9 ± 15.7</td>
<td>54.6 ± 13.6</td>
</tr>
<tr>
<td>80–89, n = 12</td>
<td>33.2 ± 12.7</td>
<td>30.9 ± 15.4</td>
<td>33.3 ± 13.4</td>
<td>27.1 ± 11.9</td>
<td>30.6 ± 14.1</td>
<td>49.7 ± 20.0</td>
</tr>
<tr>
<td>&gt;90, n = 16</td>
<td>20.3 ± 10.5</td>
<td>15.5 ± 12.9</td>
<td>20.7 ± 10.8</td>
<td>18.2 ± 8.7</td>
<td>16.1 ± 11.5</td>
<td>41.8 ± 18.6</td>
</tr>
<tr>
<td>Overall, N = 36</td>
<td>30.2 ± 17.9</td>
<td>27.1 ± 20.2</td>
<td>30.6 ± 18.6</td>
<td>26.1 ± 16.7</td>
<td>27.4 ± 19.6</td>
<td>47.4 ± 19.6</td>
</tr>
<tr>
<td>Range</td>
<td>3.0–85.9</td>
<td>0.2–87.4</td>
<td>1.6–88.4</td>
<td>0.3–82.5</td>
<td>0.5–81.4</td>
<td>10.9–87.9</td>
</tr>
</tbody>
</table>

Note. CS-PFP-10 = 10-item continuous-scale physical-functional performance test.
years), diastolic dysfunction was found in almost 71% of the subjects. In a similar survey of residents of Canberra, Australia, the prevalence of diastolic dysfunction in subjects 80–86 years of age was about 64% (Abhayaratna et al., 2006). A relationship between left atrial volume and normal aging has been shown in some studies (Aurigemma et al., 2009; Boyd et al., 2011; Triposkiadis et al., 1995) and contradicted by others (Pritchett et al., 2003; Thomas et al., 2002). Previous population-based surveys of middle-aged to elderly segments of the population have shown an association of LAE with cardiovascular disease prevalence (Gottdiener et al., 2006; Pritchett et al., 2003). Twenty-one of the 36 subjects (61%) in the current study exhibited diastolic dysfunction, while LAE was identified in 71% of the 32 subjects in whom left atrial volume was measured. We are not aware of any studies examining diastolic function in a cohort that includes a relatively high percentage of nonagenarians, with or without cardiovascular disease. Given the strong association of cardiovascular disease prevalence with advanced age, it is extremely difficult to obtain a sizeable cohort of nonagenarians without a history of hypertension or heart disease. Because we did not exclude subjects with such a history, our results do not permit us to make definitive conclusions regarding the effects of nonpathological aging. It is likely that our findings represent a combination of the normal aging process and the superimposition of conditions such as coronary artery disease and hypertension, both of which may cause diastolic dysfunction (Hoffmann et al., 2010; Pavlopoulos et al., 2008).

**Diastolic Function and Physical Function**

Diastolic dysfunction has been shown to contribute to exercise intolerance in patients with heart failure and normal or decreased systolic function (Gardin et al., 2009; Haykowsky et al., 2011; Kitzman, Higginbotham, Cobb, Sheikh, & Sullivan, 1991; Meyer, Karamanoglu, Ehsani, & Kovacs, 2004; Parthenakis et al., 2000), perhaps

![Figure 1 — Scatterplot of ranked values of left atrial volume index (LAVI) versus ranked values of total score on the 10-item continuous-scale physical-functional performance test (CS-PFP-10).](image)
### Table 4  Correlation of Echocardiographic Variables With CS-PFP-10 Domains

<table>
<thead>
<tr>
<th>Domain</th>
<th>Total CS-PFP-10</th>
<th>Balance and coordination</th>
<th>Endurance</th>
<th>Lower body strength</th>
<th>Upper body strength</th>
<th>Upper body flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAVI (32)</td>
<td>-.59</td>
<td>-.47</td>
<td>-.63</td>
<td>-.44</td>
<td>-.45</td>
<td>-.45</td>
</tr>
<tr>
<td></td>
<td><em>p = .0005</em></td>
<td><em>p = .009</em></td>
<td><em>p = .0002</em></td>
<td><em>p = .01</em></td>
<td><em>p = .01</em></td>
<td><em>p = .01</em></td>
</tr>
<tr>
<td>PVAR (29)</td>
<td>.44</td>
<td>.36</td>
<td>.48</td>
<td>.40</td>
<td>.36</td>
<td>.32</td>
</tr>
<tr>
<td></td>
<td><em>p = .02</em></td>
<td><em>p = .06</em></td>
<td><em>p = .01</em></td>
<td><em>p = .04</em></td>
<td><em>p = .06</em></td>
<td><em>p = .11</em></td>
</tr>
</tbody>
</table>

**Note.** CS-PFP-10 = 10-item continuous-scale physical-functional performance test; LAVI = left atrial volume index; PVAR = pulmonary venous atrial reversal wave velocity. Values are Spearman correlation coefficients (rho) adjusted for age and gender. Numbers in parentheses are n values.

*Statistically significant correlation after Bonferroni correction for multiple comparisons (p < .001).*
due to an increase in LV filling pressures (Packer, 1990). Grewal, McCully, Kane, Lam, and Pellikka (2009) measured diastolic function in a large group of patients referred for exercise echocardiography, excluding individuals with significant valvular disease, an EF <50%, and exercise-induced myocardial ischemia. They found that the grade of diastolic dysfunction, which included measurements of mitral E/A, e′, and E/e′, as well as left atrial volume, exhibited the strongest association with exercise capacity. Resting mitral E/e′, an indicator of increased filling pressures (Ommen et al., 2000), has been shown to correlate negatively with exercise capacity (Eroglu et al., 2011; Hadano et al., 2006; Skaluba & Litwin, 2004). In a convenience sample of community-dwelling older adults without a history of heart failure, Perry et al. (2011) found that 6-min-walk distances in subjects ≥65 years old correlated inversely with the early (E) to atrial (A) transmitral peak inflow velocity ratios and early mitral annular velocities. However, the correlation lost significance after adjustment for age, body-mass index, and cardiovascular morbidity. The current study did not demonstrate a significant relationship between CS-PFP-10 score and mitral lateral E/e′. This finding may be related to the somewhat inhomogeneous nature of our subject population, as the ability of E/e′ to predict filling pressures in patients with reduced EF has recently been questioned (Mullens, Borowski, Curtin, Thomas, & Tang, 2009; Tschope & Paulus, 2009). In addition, the presence of chronic increases in filling pressure may be better reflected by left atrial volume, as opposed to E/e′, which is more affected by transient alterations in left atrial pressure.

LAE and Physical Function

Chronic elevation of LV filling pressures, which may be caused by diastolic dysfunction, increases left atrial volume (Tsang et al., 2002). Increased LAVI has been shown to be an independent predictor of reduced exercise capacity in patients with isolated diastolic dysfunction (Wong & Yeo, 2010) and hypertrophic cardiomyopathy (Kjaergaard et al., 2005). In addition, LAVI determines prognosis in a wide variety of cardiovascular conditions (Leung et al., 2010; Rossi et al. 2002; Sakaguchi et al., 2011). Recently, Tan et al. (2010) demonstrated that impaired left atrial function may contribute to exercise intolerance in patients with heart failure and normal EF. Only about 28% of the subjects in the current study reported a history of heart failure, with about 90% having a normal EF. A majority of the subjects exhibited left atrial enlargement and echocardiographic signs of diastolic dysfunction. It is difficult to say how a larger LAVI may be linked to lower physical function in our cohort. We speculate that increased LAVI and LV filling pressures may contribute to a lower stroke volume, with a subsequent greater reliance on heart rate to perform certain physical tasks. We did not monitor heart rate during the CS-PFP-10 but theorize that the individuals with higher LAVI may have had higher heart-rate responses, which may have contributed to earlier fatigue. It is particularly interesting that the strongest identified association was between LAVI and endurance, which is largely defined by the 6-min-walk test, the last test in the CS-PFP-10 battery.

To our knowledge, ours is the first study to associate LAVI with a quantitative measure of physical performance involving everyday tasks. We used the CS-PFP-10 in place of the original laboratory-based Continuous-Scale Physical-Functional Performance Test, which has been shown to correlate with reduced aerobic reserve in older subjects (Arnett, Laity, Agrawal, & Cress, 2008), as well as with task
Left Atrial Volume and Physical Function

Modification in individuals with preclinical disability (Petrella & Cress, 2004). Our results suggest that left atrial dilation may act as an intermediary (“impairment”) in the disablement process linking pathology to functional limitations, which results in a predisposition to disability. Due to the association with lower scores on the CS-PFP-10, increased LAVI could potentially function as a marker of increased risk of loss of independence in individuals over the age of 65 (Cress & Meyer, 2003). Recently, Leibowitz et al. (2011) reported that 85- and 86-year-olds requiring assistance with at least one activity of daily living (dependent) were likely to have higher LAVI and LV mass index, along with a lower EF, than independent subjects of the same age. Consistent with the results of the current study, no Doppler measures of diastolic function differed between the dependent and independent groups. It is not yet clear what interventions, if any, may be effective in reducing left atrial volume, although it would presumably involve a resolution of the structural myocardial abnormalities that accompany diastolic dysfunction, such as concentric hypertrophy and increased LV stiffness. Clinical trials in patients with heart failure and normal EF have thus far failed to demonstrate a benefit of angiotensin-converting enzyme inhibitors, angiotensin-receptor blockers, and beta-blockers (Paulus & van Ballegoij, 2010). There is recent evidence that exercise training improves diastolic function in patients with heart failure with preserved EF (Edelmann et al., 2011), perhaps secondary to improved calcium kinetics (Petrella, Cunningham, & Paterson, 2000).

Limitations

Due to the cross-sectional design of this study, we are limited in our ability to identify cause-and-effect relationships. The small sample size also reduced our ability to control for all confounding variables, making it difficult to establish a direct link between diastolic dysfunction and left atrial enlargement. An EF <50%, which we did not include as a covariate, may contribute to increases in left atrial volume, although this form of systolic dysfunction was only present in about 9% of the subjects, whereas over 60% exhibited evidence of diastolic dysfunction and >80% of those subjects demonstrated LAE. Mitral regurgitation, which may also increase left atrial volume, was also not a covariate. However, only 3 subjects in whom LAVI was measured exhibited more than mild mitral regurgitation, none of which was severe. In addition, the extrapolation of our results to younger cohorts may not be valid due to the high percentage of octogenarian and nonagenarian subjects in our study. Despite these limitations, we were able to identify a relatively strong association (compared with similar correlational studies in the literature) between LAVI and physical performance. Longitudinal studies involving a greater number of subjects should be performed to better characterize the role of left atrial volume and function (and perhaps other variables) in exceptional longevity.

Conclusions

In a cross-sectional population-based survey examining echocardiographic variables of diastolic function, we demonstrated a significant association between increased LAVI and decreased total and endurance domain scores of the CS-PFP-10. This is consistent with the idea that some form of impairment (left atrial dilation) contributes to a loss of physical function, which in turn leads to disability (the disablement process).
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