Effects of Resistance Training on Left Ventricular Morphology and Systolic Function

Mark Haykowsky, PhD*, **; Jon McGavock, MSc*; Dylan Taylor, MD, FRCPC**

Rehabilitation Medicine*, Division of Cardiology**
University of Alberta, Edmonton, Alberta, Canada

Resistance training (RT) is a popular mode of exercise to improve overall physical fitness as well as an effective form of exercise to enhance athletic performance. In addition, RT has recently gained acceptance as a safe and effective therapeutic exercise intervention to attenuate the age-mediated decline in muscle strength and mass (1). Despite the benefits of RT on skeletal muscle mass and function, this form of exercise has been associated with a brief and marked rise in arterial pressure (ie, >300mmHg) (2,3) that may alter cerebrovascular (4) or left ventricular (LV) morphology (5). A widely held belief in sport cardiology is that the RT-mediated pressure load may be an important stimulus to increase LV wall thickness and estimated LV mass. However, it may be possible that the heightened pressure load may be too brief in duration or of insufficient magnitude to alter LV morphology as a series of investigations have found that RT was not associated with alterations in LV wall thickness (6-8) or estimated LV mass (6-8). Due to this inconsistency, the purpose of this paper is to provide a brief review of the acute and chronic effects of RT on LV morphology and systolic function.

ACUTE EFFECTS OF SUB-MAXIMAL AND MAXIMAL RESISTANCE EXERCISE ON LEFT VENTRICULAR VOLUMES, SYSTOLIC FUNCTION AND WALL STRESS

Currently, there is a paucity of studies that have investigated the acute effects of resistance exercise on LV systolic function. This finding is due, in part, to the extreme difficulty in assessing LV systolic function during repetitive resistance exercise. One of the first groups to assess the acute effects of RT on LV systolic function was performed by Lentini and associates (9). In that study, the acute effects of leg-press resistance exercise on arterial pressure, cardiac volumes and LV systolic function were examined in younger healthy males. The major finding of this investigation was that leg-press exercise was associated with a decrease in end-diastolic and end-systolic volumes when compared to resting values. Despite the attenuated preload reserve and concomitant decline in stroke volume, the leg-press mediated rise in LV contractility combined with the elevated heart rate resulted in an increased cardiac output and ejection fraction during exercise. We recently investigated the acute effects of sub-maximal and maximal leg-press exercise performed with a brief (phase I) Valsalva maneuver on LV cavity areas, fractional area change and LV end-systolic meridional wall stress in younger healthy males (2). The main finding from our study was that repetitive leg-press resistance exercise performed with a brief Valsalva maneuver resulted in a decrease in preload reserve (ie, end-diastolic cavity area) that was counteracted by an increase in LV contractile reserve resulting in an increase in fractional area change during lifting. Of greater interest, we also found that leg-press exercise performed with a brief Valsalva maneuver was not associated with an alteration in LV end-systolic meridional wall stress. Taken together, the above investigations suggest that leg-press exercise may not likely result in an acute decline in LV systolic function in healthy younger males. Moreover, leg-press resistance exercise performed with a brief (phase I) Valsalva maneuver does not appear to be associated with an acute increase in LV end-systolic meridional wall stress.

CHRONIC EFFECTS OF RESISTANCE TRAINING ON LEFT VENTRICULAR MORPHOLOGY

A series of short-term longitudinal or cross-sectional investigations have assessed the effects of RT on LV morphology and found that this form of exercise was associated with an increase in ventricular septal wall thickness (10-12), posterior wall thickness (5,10-14), relative wall thickness (10,11), and estimated LV mass (5,10-14). A limitation of a number of the previous studies that have assessed the effects of RT
on LV morphology was that the subjects were younger (≤25 years) athletes who had been training for ≤5 years. Therefore, the effects of long-term RT (>15 years) on LV dimensions and mass are not well known. During the last six years, our sport cardiology research group has performed a series of investigations that assessed the effects of short (<5 years), moderate (10 years) and long-term (>15 years) RT on LV morphology in elite male powerlifters who competed at the Canadian Junior, Open or Master Powerlifting Championships (Table 1). The major finding of these investigations was that short-to-long-term RT was not associated with an alteration in LV septal wall thickness, posterior wall thickness, relative wall thickness and estimated LV mass compared to age-matched sedentary controls. In addition, no RT athlete was found to have a LV mean wall thickness above clinically acceptable normal upper limits (ie, >12mm) (7,8). Finally, we also found that short-to-long term RT was not associated with an alteration in LV systolic function. These findings are consistent with previous studies that found that RT was not associated with an alteration in ventricular septal wall thickness (14-16), posterior wall thickness (15,17,18), or estimated LV mass (15,16). However, they are dissimilar to the previously discussed studies that found that RT was associated with an alteration in LV morphology. The disparity between our findings and those of others may be due to 1) the type of RT-athlete studied (ie, bodybuilder versus powerlifter versus olympic weightlifter) and 2) the underlying use of anabolic steroids.

**Table 1.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>JPL (n=8)</th>
<th>YC (n=8)</th>
<th>OPL (n=21)</th>
<th>OC (n=10)</th>
<th>MPL (n=12)</th>
<th>MAC (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (ys)</td>
<td>21±1</td>
<td>22±3</td>
<td>33±6</td>
<td>31±4</td>
<td>46±6</td>
<td>47±4</td>
</tr>
<tr>
<td>Years Training</td>
<td>4±3</td>
<td>-</td>
<td>10±5</td>
<td>-</td>
<td>18±7</td>
<td>-</td>
</tr>
<tr>
<td>Squat-1RM (kgs)</td>
<td>213±38</td>
<td>-</td>
<td>252±2</td>
<td>-</td>
<td>216±46</td>
<td>-</td>
</tr>
<tr>
<td>Bench press-1RM (kgs)</td>
<td>141±20</td>
<td>-</td>
<td>155±17</td>
<td>-</td>
<td>130±32</td>
<td>-</td>
</tr>
<tr>
<td>Deadlift-1RM (kgs)</td>
<td>229±26</td>
<td>-</td>
<td>258±14</td>
<td>-</td>
<td>219±30</td>
<td>-</td>
</tr>
</tbody>
</table>

(JPL, junior powerlifter; YC, young control; OPL, open powerlifter; OC, open control; MPL, master powerlifter; MAC, middle-aged control)

**EFFECT OF THE TYPE OF RESISTANCE TRAINING PERFORMED AND SUBSEQUENT ALTERATIONS IN LEFT VENTRICULAR MORPHOLOGY**

Previous studies that have investigated the effects of RT on LV morphology have typically included olympic weightlifters (ie, athletes that perform the snatch and clean and jerk as the main competition lifts), powerlifters (ie, athletes that perform the squat, bench press and deadlift as the main competition lifts) and bodybuilders as the study subjects. Although all of these athletes perform various types of resistance exercises as part of their training routines, the acute cardiac volume responses may differ between these athletes when they perform RT. More specifically, Falkel and associates (19) have shown that bodybuilders have a significantly higher stroke volume and cardiac output response compared to powerlifters when performing sub-maximal and maximal unilateral knee-extension and squatting resistance exercises. The consequence of the bodybuilding-mediated volume overload is that this form of training, if repeated over time, may be a greater stimulus to alter LV morphology compared to powerlifting training. The latter hypothesis is reinforced by a recent finding that revealed that bodybuilders had a larger LV internal diastolic dimension and estimated LV mass compared to powerlifters or olympic weightlifters (20). Therefore, it is possible that the disparity between studies that have found that RT was
associated with an alteration in LV morphology and those that did not may be due to the underlying type of RT athletes studied.

**EFFECTS OF ANABOLIC STEROIDS ON LEFT VENTRICULAR MORPHOLOGY**

Wagman and associates (21) revealed that 66% of elite powerlifters admitted to using anabolic steroids to improve their athletic performance. Previous investigations have shown that anabolic steroids may be associated with LV morphologic adaptations including an increase in LV internal diastolic cavity dimension (22), posterior wall thickness (22-24), ventricular septal wall thickness (22,24), and estimated LV mass (22,23,25). Therefore, it may be possible that the disparity between investigations that have shown that RT is associated with an increase in LV wall thickness and mass compared to those that have not may be related to the underlying use of anabolic steroids by the study participants.

**EFFECTS OF RESISTANCE TRAINING ON LEFT VENTRICULAR MORPHOLOGY IN HEALTHY OLDER INDIVIDUALS**

Currently, there is a paucity of investigations that have assessed the effects of RT on LV morphology and systolic function in healthy older individuals. We recently assessed the effects of 16 weeks of upper and lower extremity RT, in previously sedentary healthy older males (mean age: 68 years), on LV morphology, end-systolic meridional wall stress and LV systolic function (26). Resting two-dimensional echocardiograms were performed after 4, 8, 12 and 16 weeks of moderate (60% one repetition maximum, 1RM) to high (80% 1RM) intensity upper and lower extremity RT. The major finding of this investigation was that 16 weeks of RT was a sufficient stimulus to increase upper (+16%) and lower (+29%) extremity maximal muscular strength but was insufficient of a stimulus to alter LV posterior wall thickness, ventricular septal wall thickness, systolic or diastolic cavity dimensions, relative wall thickness and estimated LV mass (26). In addition, this form of training was not associated with an alteration in LV wall stress or systolic function (26). These findings extend an earlier investigation that found that 12 weeks of low-intensity RT (30% maximal voluntary contraction) was not associated with an alteration in LV septal wall thickness, posterior wall thickness or LV systolic function in older (mean age: 68 years) males (27). Taken together, these findings may suggest that older individuals who begin a RT routine later in life may require a training duration greater than 12-16 weeks to alter LV morphology. However, our previous finding that >18 years of RT did not alter LV morphology reinforced by the finding that RT was not associated with an acute or chronic alteration in LV wall stress may suggest that this form of exercise is of an insufficient stimulus to alter LV morphology. More importantly, short-term RT does not appear to negatively alter LV systolic function in older healthy males. Currently, there is a paucity of information regarding the effects of RT on LV morphology or systolic function in older females. Therefore, future studies are required to assess the effects of this form of exercise on LV morphology and systolic function in older females.

**SUMMARY**

A widely held belief in sport cardiology is that the RT-mediated arterial pressure load may be an important stimulus to increase LV wall thickness and estimated LV mass. However, this hypothesis may not be entirely correct as we have recently found that sub-maximal and maximal resistance exercise was not associated with an acute increase in LV end-systolic meridional wall stress (2). Furthermore, a series of recent investigations from our laboratory have also revealed that short (<5 years), moderate (10 years), or long-term (>15 years) RT was not associated with an alteration in LV wall thickness, diastolic cavity dimension or estimated LV mass (7,8). Moreover, no RT athlete was found to have a LV mean wall thickness above clinically acceptable normal limits (ie, >12 mm). Therefore, it may be that the heightened pressure load is too brief in duration or of insufficient magnitude to alter LV morphology. Although other studies have shown that RT may result in an increase in LV wall thickness and estimated LV mass, the disparity between our results and those of others may be due to the type of RT athletes studied (ie, bodybuilder versus powerlifter) or to the underlying use of anabolic steroids which is not uncommon in elite RT athletes (21).

**REFERENCES**


Your questions, contributions and commentaries will be answered by the lecturer or experts on the subject in the Exercise list. Please fill in the form (in Spanish, Portuguese or English) and press the "Send" button.

Question, contribution or commentary:

Name and Surname:

Country: Argentina

E-Mail address:

Send  Erase

2nd Virtual Congress of Cardiology

Dr. Florencio Garófalo
Steering Committee
President
fgaro@fac.org.ar
fgaro@satlink.com

Dr. Raúl Bretal
Scientific Committee
President
rbretal@fac.org.ar
rbretal@netverk.com.ar

Dr. Armando Pacher
Technical Committee - CETIFAC
President
apacher@fac.org.ar
apacher@satlink.com

Copyright© 1999-2001 Argentine Federation of Cardiology
All rights reserved

This company contributed to the Congress

Gador