Associations of Cardiorespiratory and Musculoskeletal Fitness with Body Mass Index and Waist Circumference: *Fitness versus Fatness in a Population-based Sample of Chilean 8th Graders*

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Disclosure

Michael Garber, MPH
No relevant financial relationship exists.

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Felipe Lobelo, MD PhD
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Outline

Background
Objectives
Methods
Results
Conclusions
**Background:** Fitness, Fatness, and Risk of Cardio-Metabolic Disease and Mortality

**Cardiorespiratory fitness**
- Adults: Cardiorespiratory fitness > BMI in determining mortality risk\(^1\)
- Adolescents: Within high fatness group, low fit at four times cardiovascular risk than high fit.\(^2\)

**Musculoskeletal Fitness:**
Independent of cardiorespiratory fitness and body composition, low musculoskeletal fitness is associated with higher cardio-metabolic risk and mortality in adults and adolescents.\(^3,4\)
Background: Associations between Fitness and Fatness in Adolescents

**Cardiorespiratory fitness and fatness**
Strength of association:
Imaging (e.g. CT) > waist circumference > BMI \(^5,6\)

**Musculoskeletal fitness and fatness**
Higher musculoskeletal fitness—assessed through weight-bearing tests such as the standing long jump—associated with lower fatness.\(^5\)
Association of musculoskeletal fitness with fatness has been explored less than cardiorespiratory fitness with fatness

Fitness versus fatness relationship in adolescents has not been studied in a population-based, representative sample in Latin America.
Objectives

In Chilean 8th grade students:

1. To investigate the association between cardiorespiratory fitness and musculoskeletal fitness with body mass index and waist circumference, after adjusting for potential confounders.

2. To examine the prevalence of students with healthy fitness but unhealthy body composition, and vice versa - healthy body composition, but unhealthy fitness.
Methods: Study Design and Population

Design: Cross-sectional

Study Population:
- 2011 National Physical Education Survey (SIMCE)\(^7\)
- \(N=19,904\) 8\(^{th}\) grade students from all regions of Chile (~9\% of 8\(^{th}\) grade pop.)
- Median age=14 y

Responsible Agencies:
- Chile Ministry of Education
- Chile Agency for the Quality of Education
- Chile Ministry of Sport

Source: http://upload.wikimedia.org/wikipedia/commons/6/61/ChileRegions.png
Table 1. Selected health-related,\textsuperscript{8} validated,\textsuperscript{9} and reliable\textsuperscript{10} tests recommended\textsuperscript{11,12} for adolescent fitness assessment.

<table>
<thead>
<tr>
<th>Fitness Indicator</th>
<th>Field Test</th>
<th>Criterion-referenced classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiorespiratory Fitness</td>
<td>20 m shuttle run</td>
<td>FITNESSGRAM\textsuperscript{®} 2011\textsuperscript{13}</td>
</tr>
<tr>
<td>Musculoskeletal Fitness</td>
<td>Standing long jump</td>
<td>Less than 20\textsuperscript{th} percentile European adolescents\textsuperscript{14}</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>Weight/Height\textsuperscript{2}</td>
<td>FITNESSGRAM\textsuperscript{®} 2011\textsuperscript{15}</td>
</tr>
<tr>
<td>Waist Circumference</td>
<td>Midway between the lowest rib margin and the iliac crest</td>
<td>1999-2004 NHANES\textsuperscript{16}</td>
</tr>
</tbody>
</table>
Methods: Statistical analysis

1. **Gender-stratified multivariable logistic regression models**
   1. **Cardiorespiratory Fitness Model**: Dependent variables = Age (continuous), categories of socioeconomic status, gender, region, body mass index, waist circumference, and *musculoskeletal fitness*.
   2. **Musculoskeletal Fitness Model**: Dependent variables = Age (continuous), categories of socioeconomic status, gender, region, body mass index, waist circumference, and *cardiorespiratory fitness*.

   • Model-adjusted prevalence ratios were obtained as function of average marginal predictions\(^{17}\)

2. **Unadjusted cross-tabulations to obtain prevalence of discordant pairs**:
   • Healthy fitness & unhealthy body composition
   • Healthy body composition & unhealthy body composition

• **SUDAAN** used to account for complex sampling design and sample weights.
Results: Unhealthy Cardiorespiratory Fitness versus Fatness

<table>
<thead>
<tr>
<th>Body Composition Characteristic</th>
<th>Gender</th>
<th>Adjusted† Prevalence Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body Mass Index‡</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy (Referent)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Unhealthy</td>
<td>M</td>
<td>1.88 (1.59, 2.23)</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>1.71 (1.55, 1.89)</td>
</tr>
<tr>
<td><strong>Waist Circumference‡</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy (Referent)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Unhealthy</td>
<td>M</td>
<td>1.77 (1.53, 2.06)</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>1.21 (1.10, 1.34)</td>
</tr>
</tbody>
</table>

Figure 1. Association of unhealthy cardiorespiratory fitness‡ with unhealthy body mass index and waist circumference in a representative sample of Chilean 8th graders (N=19,904)

†Adjusted for age (continuous) and categories of socioeconomic status, gender, region, musculoskeletal fitness, body mass index, and waist circumference.
‡Classified according to health-related cut-points.\(^{13-16}\)

*Prevalence ratio significantly different in males versus females.
### Results: Unhealthy Musculoskeletal Fitness versus Fatness

<table>
<thead>
<tr>
<th>Body Composition Characteristic</th>
<th>Gender</th>
<th>Prevalence Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body Mass Index</strong>‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy (Referent)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Unhealthy</td>
<td>M</td>
<td>1.64 (1.46, 1.84)</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>1.32 (1.18, 1.47)</td>
</tr>
<tr>
<td><strong>Waist Circumference</strong>‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy (Referent)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Unhealthy</td>
<td>M</td>
<td>1.11 (1.003, 1.22)</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>1.07 (0.96, 1.19)</td>
</tr>
</tbody>
</table>

*Prevalence ratio significantly different in males versus females.

**Figure 2.** Association of unhealthy *musculoskeletal* fitness‡ with unhealthy body mass index and waist circumference in a representative sample of Chilean 8th graders (N=19,904)

†Adjusted for age (continuous) and categories of socioeconomic status, gender, region, cardiorespiratory fitness, body mass index, and waist circumference.
‡Classified according to health-related cut-points. \(^{13-16}\)
Results: Fat but fit (Cardiorespiratory)

Figure 3.1 Prevalence of healthy cardiopulmonary fitness among Chilean 8th graders with unhealthy body mass index and waist circumference in a representative sample (N=19,904). Error bars are 95% CI. ‡Classified according to health-related cut-points.¹³⁻¹⁶
Figure 3.2 Prevalence of healthy musculoskeletal fitness among Chilean 8th graders with unhealthy body mass index and waist circumference in a representative sample (N=19,904). Error bars are 95% CI. ‡Classified according to health-related cut-points.13-16
Figure 4.1 Prevalence of healthy body mass index among Chilean 8th graders with unhealthy cardiorespiratory and musculoskeletal fitness in a representative sample (N=19,904). Error bars are 95% CI. ‡Classified according to health-related cut-points.13-16
Results: Unfit but Healthy Waist Circumference

Figure 4.2 Prevalence of healthy waist circumference among Chilean 8th graders with unhealthy cardiorespiratory and musculoskeletal fitness in a representative sample (N=19,904). Error bars are 95% CI. ‡Classified according to health-related cut-points.13-16
Conclusions

1. Cardiorespiratory fitness and weight-bearing musculoskeletal fitness were inversely associated with fatness in adolescents.

2. Fitness ≠ fatness
   - The substantial prevalence of healthy fitness but unhealthy body composition, and vice versa, underscores the need to evaluate physical fitness in addition to body composition for a complete picture of cardio-metabolic risk.
   - Assessment via BMI or waist circumference alone would underestimate cardio-metabolic risk.


Acknowledgments

• Participating students, teachers, and schools
• Chile Ministry of Education
• Chile Agency for Education Quality
• Chile Ministry of Sport
Questions
Table 2. Health-related physical fitness in a representative sample (N = 19,904) of Chilean 8th grade students: The 2011 National Physical Education Survey

<table>
<thead>
<tr>
<th>Fitness Characteristic</th>
<th>Males† (n=10,309)</th>
<th>Females† (n=9,595)</th>
<th>P Value#</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cardiorespiratory fitness (mL/kg/min)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy</td>
<td>46±4 (0.001)</td>
<td>39±2 (0.001)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Needs Improvement</td>
<td>74±3% (0.7%)</td>
<td>44±6% (1.0%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>NI - Health Risk</td>
<td>10±8% (0.4%)</td>
<td>24±8% (0.6%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Musculoskeletal fitness (cm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy</td>
<td>15±0% (0.5%)</td>
<td>30±6% (0.9%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Body mass index (kg/m²)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy</td>
<td>61±2% (0.7%)</td>
<td>55±7% (0.6%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Needs Improvement</td>
<td>17±2% (0.4%)</td>
<td>15±8% (0.4%)</td>
<td>0.009</td>
</tr>
<tr>
<td>NI - Health Risk</td>
<td>21±6% (0.5%)</td>
<td>28±6% (0.6%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Waist circumference (cm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Healthy</td>
<td>74±3 (0.002)</td>
<td>71±9 (0.002)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Health risk</td>
<td>69±2% (0.6%)</td>
<td>69±2% (0.7%)</td>
<td>0.99</td>
</tr>
<tr>
<td>Combined fitness categories</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NI - Health-risk CRF &amp; Health-risk MSF</td>
<td>9±2% (0.4%)</td>
<td>16±1% (0.7%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>NI-Health-Risk CRF &amp; (NI-Health-Risk BMI or health-risk WC)</td>
<td>9±3% (0.4%)</td>
<td>15±9% (0.5%)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Health risk MSF &amp; (NI-Health-Risk BMI or health-risk WC)</td>
<td>15±1% (0.5%)</td>
<td>16±9% (0.6%)</td>
<td>0.004</td>
</tr>
<tr>
<td>Health risk according to all 4 fitness variables</td>
<td>5±0% (0.3%)</td>
<td>6±5% (0.3%)</td>
<td>0.0004</td>
</tr>
<tr>
<td>Health risk according to at least 1 fitness variable</td>
<td>50±0% (0.8%)</td>
<td>61±1% (0.9%)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

1Data are mean (standard error) or percent (standard error) of category within gender.
2NI, needs improvement; CRF, cardiorespiratory fitness; MSF, musculoskeletal fitness; BMI, body mass index; WC, waist circumference
3P-values reflect gender differences within strata.
4Sample size varies for each fitness variable: n, CRF = 17,928; n, MSF = 19,777; n, BMI = 19,904; n, WC = 19,895
5Cardiorespiratory fitness is classified according to FITNESGRAM 2011 maximal aerobic capacity cut-points.32
6Health-risk musculoskeletal fitness is defined as a standing broad jump score <20th percentile of European adolescents.9
7Body mass index is classified according to the FITNESSGRAM 2011 health-related standards.35
8Waist circumference is classified according to health-related cut-points.39

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