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The “Fit but Fat” Paradigm Addressed Using Accelerometer-Determined Physical Activity Data

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Abstract

Background:

No studies have addressed the “fit but fat” paradigm using accelerometer data.

Aim:

The study was to determine if 1) higher levels of accelerometer-determined physical activity are favorably associated with biomarkers in overweight or obese persons (objective 1); and 2) overweight or obese individuals who are sufficiently active have better or similar biomarker levels than normal weight persons who are not sufficiently active (objective 2).

Materials and Methods:

Data from the 2003-2006 National Health and Nutrition Examination Survey were analyzed and included 5,146 participants aged 20-85 years.

Results:

Regarding objective 1, obese active individuals had more favorable waist circumference, C-reactive protein, white blood cells, and neutrophil levels when compared to obese inactive individuals; similar results were found for overweight adults. Regarding objective 2, there were no significant differences between normal weight inactive individuals and overweight active individuals for nearly all biomarkers. Similarly, there were no significant differences between normal weight inactive individuals and obese active individuals for white blood cells, neutrophils, low-density lipoprotein cholesterol, total cholesterol, triglycerides, glucose, or homocysteine.

Conclusions:
Physical activity has a protective effect on biomarkers in normal, overweight, and obese individuals, and overweight (not obese) active individuals have a similar cardiovascular profile than normal weight inactive individuals.

**Keywords:** Accelerometry, Biomarkers, Fit but fat, Obesity

**Introduction**

Obesity is related to an increased risk of morbidity and mortality.[1] However, research over the last several decades has demonstrated that adequate physical activity and cardiorespiratory fitness may have a protective effect among overweight and obese individuals. For example, research from the Aerobics Center Longitudinal Study (ACLS) has shown that people with higher levels of body mass index (BMI) who are fit had death rates lower than unfit people with a similar body habitus.[2] Also, overweight or obese individuals from diverse populations who are active (via self-report) and fit tend to have morbidity and mortality rates that are at least as low, and in some cases lower, than normal weight individuals who are unfit.[3,4,5]

The purpose of the present study was to extend this knowledge-base by using an objective-measure of physical activity to answer the following questions:

1. Is higher levels of accelerometer-determined physical activity favorably associated with biomarkers in overweight or obese persons; and
2. Do overweight or obese individuals who are sufficiently active have better or similar biomarker levels than normal weight persons who are not sufficiently active?

**Materials and Methods**

**Study design**

Data from the present study were obtained from the 2003 to 2006 National Health and Nutrition Examination Survey (NHANES). Further details about NHANES can be found elsewhere.[6] NHANES study procedures were approved by the National Center for Health Statistics ethics review board, with informed consent obtained from all participants prior to data collection. Approval by the authors’ institutional review board was exempt given that the data utilized for the present study (2003-2006 NHANES) were de-identified to the authors and was previously approved by the National Center for Health Statistics ethics committee.

**Measurement of physical activity**

Participants of age 6 years and older were eligible for the accelerometer monitoring component. Physical activity was measured using an ActiGraph 7164 accelerometer during all activities, except water-based activities and while sleeping. Estimates for moderate-to-vigorous physical activity (MVPA) were summarized in 1-minute time intervals. Activity counts per minute greater than or equal to 2020 were classified as moderate-to-vigorous physical activity intensity.[7] Only those participants with activity patterns for at least 4 days of 10 or more hours per day of monitoring data were included in the analyses.[7] To determine the amount of time the monitor was worn, nonwear was defined by a period of a minimum of 60 consecutive minutes of zero activity counts, with the allowance of 1-2 minutes of activity counts between 0 and 100.[7]

Participants were classified as meeting physical activity guidelines if they engaged in 150-minutes of moderate-intensity or 75-minutes of vigorous-intensity physical activity per week or some combination of the two.[8] To account for the combination of moderate and vigorous physical activity, vigorous-intensity was multiplied by 2 before being added to moderate-intensity.[9] SAS (version 9.2) was used to reduce the accelerometry data using the SAS code provided the National Cancer Institute. Using the SAS code, each
participants’ average time spent per day in physical activity from valid individual data were analyzed.

**Measurement of weight status**

Measured body mass index (BMI) was used to determine weight status; normal weight was defined as a BMI 18.5-24.9 kg/m²; overweight as 25-29.9 kg/m²; and obese as ≥30 kg/m².

**Classification of weight and activity status**

Six groups were created, including:

1. Normal weight and inactive (defined as not meeting physical activity guidelines);
2. Overweight and inactive;
3. Obese and inactive;
4. Normal weight and active (defined as meeting physical activity guidelines);
5. Overweight and active; and 6) obese and active.

**Measurement of biological and anthropometric markers**

The following biological and anthropometric markers that have previously been shown to associate with physical activity or weight status were assessed: Tricep skinfold, waist circumference, systolic blood pressure (SBP), diastolic blood pressure (DBP), C-reactive protein (CRP), white blood cells (WBC), neutrophils, fasting low-density lipoprotein (LDL)-cholesterol, total cholesterol, fasting triglycerides, fasting glucose, fasting insulin, glycosylated hemoglobin A1c (HbA1c), and homocysteine (marker of endothelial function). Details on the assessment of these markers can be found elsewhere.[10,11]

**Measurement of covariates**

Covariates included age, gender, race-ethnicity, poverty-to-income ratio (PIR), comorbidity index, serum cotinine, medication use and energy intake. The comorbidity index was assessed by summing the number of self-reported comorbidities including coronary heart disease, stroke, cancer, diabetes, or kidney disease. Hypertension was also included as a comorbidity, with the presence of hypertension defined as a measured systolic blood pressure ≥140 mmHg, a measured diastolic blood pressure ≥90 mmHg, or reported use of blood pressure-lowering medication. As a marker of smoking status, serum cotinine (continuous variable) was measured by an isotope dilution-high performance liquid chromatography/atmospheric pressure chemical ionization tandem mass spectrometry. Energy intake was assessed using the average of the two dietary interviews from the MEC.

**Statistical analysis**

Statistical analyses (Stata, version 12.0, College Station, TX) accounted for the complex survey design used in NHANES, and were analyzed in 2014. To account for the sample design, sample weights, stratum and primary sampling units were used. For non-fasting variables, MEC weights were used. Recalculated sample weights for the subsamples with 4 or more days of valid accelerometer data were used to make the selected samples nationally representative. These re-calculated sample weights were then divided by 2 to account for the use of combined NHANES cycles (i.e., 2003-2004 and 2005-2006).[12] For the fasting variables (i.e., LDL-cholesterol, triglycerides, glucose, and insulin), the fasting sample weights were used.

Mean values for each biological and anthropometric variable were calculated for the 6 weight status and activity status groups. Differences between groups were assessed using an adjusted Wald test. Multivariable linear regression was used to examine the association among the 6 groups and the biomarker levels and adjusting for age, gender, race-ethnicity, cotinine, PIR, comorbidity index, energy intake, and medication use. Blood pressure was adjusted for a comorbidity index without hypertension; similarly, glucose and
insulin was adjusted for a comorbidity index without diabetes. However, blood pressure variables did adjust for blood pressure-lowering medication and glucose and insulin models were adjusted for anti-diabetic medication. Lastly, cholesterol-related variables adjusted for cholesterol-lowering medication. Statistical significance was set at a Bonferroni correction of $P < 0.003$.

**Results**

After excluding participants younger than 20 years, pregnant women, those with insufficient accelerometry data (i.e., <4 days of 10+ hrs/day of monitoring), those underweight (BMI < 18.5 kg/m$^2$), and those with missing covariate data, 5,146 participants aged 20-85 years remained and constituted the analytic sample. **Table 1** shows the weighted crude means for the biological and anthropometric markers for inactive and active participants according to weight status.

**Question 1:** Are higher levels of physical activity favorably associated with biomarkers and anthropometric markers in overweight or obese persons?

As shown in **Table 1**, overweight individuals who met physical activity guidelines compared to overweight individuals who did not meet guidelines, had more favorable unadjusted levels of tricep skinfold, waist circumference, SBP, HbA1C, and homocysteine (as denoted by †). Obese individuals who met guidelines compared to obese individuals not meeting guidelines had more favorable unadjusted levels of tricep skinfold, waist circumference, systolic blood pressure, CRP, WBC, neutrophils, HbA1c, and homocysteine (as denoted by ‡).

As denoted by the single cross (†) in **Table 2**, overweight active individuals had more favorable tricep and waist circumference adjusted levels when compared to overweight inactive individuals. Similarly, after adjustments, and as denoted by a double cross (‡), obese active individuals had more favorable waist circumference, CRP, WBC, and neutrophil levels when compared to obese inactive individuals.

**Question 2:** Do overweight or obese individuals who are active have better or similar biomarker levels than normal weight persons who are inactive?

**Overweight adults**

When comparing overweight and active participants with normal weight and inactive participants, we found no significant unadjusted differences ($P > 0.003$) for tricep skinfold, SBP, CRP, WBC, neutrophils, LDL cholesterol, total cholesterol, triglycerides, glucose, HbA1C, and homocysteine [Table 1]. However, overweight active individuals had less favorable levels for waist circumference, DBP, and insulin [Table 1] than normal weight and inactive participants. In the multivariable linear regression models that adjusted for age, gender, race-ethnicity, cotinine, PIR, comorbidity index, energy intake, and medication use [Table 2], there were no significant differences between normal weight inactive individuals and overweight active individuals for all the biomarkers with the exception of tricep skinfold, waist circumference, total cholesterol, and insulin.

**Obese adults**

Comparing obese and active participants with normal weight and inactive participants, there were no significant unadjusted differences ($P > 0.003$) for the following biomarkers: SBP, CRP, WBC, neutrophils, LDL cholesterol, total cholesterol, triglycerides, glucose, or HbA1c [Table 1]. However, obese active individuals had less favorable levels for tricep skinfolds, waist circumference, DBP, and insulin [Table 1] than normal weight and inactive participants. In the multivariable linear regression models that adjusted for age, gender, race-ethnicity, cotinine, PIR, comorbidity index, energy intake, and medication use [Table 2], there were no significant differences between normal weight inactive individuals and obese active
individuals for WBC, neutrophils, LDL cholesterol, total cholesterol, triglycerides, glucose, or homocysteine. However, obese active individuals, compared to normal weight inactive individuals, did have less favorable levels for tricep skinfold, waist circumference, SBP, DBP, CRP, insulin, and HbA1C.

Discussion

The two main objectives of this study were to address the following questions:

1. Are higher levels of physical activity favorably associated with biomarkers in overweight or obese persons?; and
2. Do overweight or obese individuals who are active have better or similar biomarker levels than normal weight persons who are inactive?

With regard to the first question, our findings suggest that active overweight people have lower adjusted triceps skinfolds and waist circumference than inactive overweight people. Differences were more pronounced in active obese people who had lower waist circumference and lower levels of CRP, WBC and neutrophils than inactive obese people. With regard to the second question, our findings showed that active overweight people have similar levels for the majority of biomarkers than inactive normal weight people, except for triceps skinfolds, waist circumference, total cholesterol, and insulin. In contrast, active obese adults had less favorable levels for half of the biomarkers examined than inactive normal weight people.

Our findings support other studies suggesting that physical activity has a protective effect on biomarkers in normal, overweight, and obese individuals while at the same time showing that overweight individuals who are active have a similar or more favorable cardiovascular disease risk profile than normal weight inactive individuals.[13,14,15,16] For example, Mora et al.[15] showed that among a sample of 27,158 U.S. women in the Women's Health study, higher physical activity levels, across BMI categories, was favorably associated with nearly all evaluated lipid and inflammatory biomarkers. Further, in a review of the extant literature, Blair and Brodney[16] summarized findings from 24 articles and reported that active or fit adults appeared to be protected against the hazards of overweight or obesity. For example, physically active men had lower rates of coronary heart disease death than inactive men in all studies, and in all BMI strata. Moreover, active men in the high BMI group had lower coronary heart disease death rates than inactive men in the low BMI group. As an example, men with a BMI ≥27 who engaged in regular vigorous exercise had a heart attack rate of 1.3/1000 man-years, compared to a rate of 5.5/1000 man-years among inactive men with a BMI <24. The main limitation of the present study is the cross-sectional design; however, to our knowledge, this is the first study on this topic using an objective-measure of physical activity.

Conclusions

In conclusion, the present findings provide further support that engaging in sufficient physical activity may improve biomarker profiles, which in turn may improve disease outcomes in normal, overweight and obese individuals. Prevention and treatment efforts for overweight and obese individuals should not be limited to weight loss, but should emphasize physical activity, which may provide benefits beyond weight loss. Future prospective and experimental studies examining the aforementioned questions while using an objective-measure of physical activity are warranted.

Footnotes

Source of Support: Nil.

Conflict of Interest: None declared.

References

1. Flegal KM, Kit BK, Orpana H, Graubard BI. Association of all-cause mortality with overweight and


**Figures and Tables**

**Table 1**
Weighted crude means for selected biomarkers for inactive and active participants according to weight status, NHANES 2003-2006

**Table 2**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal weight and inactive (n = 820)</th>
<th>Overweight and inactive (n = 1,133)</th>
<th>Obese and inactive (n = 1,213)</th>
<th>Normal weight and active (n = 690)</th>
<th>Overweight and active (n = 765)</th>
<th>Obese and active (n = 840)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological/Health Markers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triceps Skinfold (mm)</td>
<td>17.1 (16.6-17.6)</td>
<td>21.0 (20.5-21.6)*</td>
<td>26.4 (25.7-27.2)*</td>
<td>14.0 (13.5-14.5)</td>
<td>17.7 (17.2-18.2)</td>
<td>23.0 (22.3-23.9)*</td>
</tr>
<tr>
<td>Waist Circumference (cm)</td>
<td>83.0 (81.5-84.4)</td>
<td>94.2 (93.6-95.7)*</td>
<td>101.3 (99.6-103.0)</td>
<td>82.8 (81.3-84.3)</td>
<td>95.9 (94.4-97.5)</td>
<td>110.1 (108.6-111.7)*</td>
</tr>
<tr>
<td>Systolic Blood Pressure (mm Hg)</td>
<td>127.7 (124.3-131.6)</td>
<td>137.4 (134.5-140.3)*</td>
<td>147.7 (144.2-151.2)*</td>
<td>123.9 (121.6-126.3)*</td>
<td>138.0 (135.7-140.3)</td>
<td>155.4 (153.2-157.6)*</td>
</tr>
<tr>
<td>Diastolic Blood Pressure (mm Hg)</td>
<td>76.8 (75.4-78.1)</td>
<td>81.8 (80.4-83.3)*</td>
<td>92.2 (90.8-93.6)*</td>
<td>74.3 (72.9-75.6)</td>
<td>82.1 (80.8-83.4)</td>
<td>93.8 (92.5-95.0)*</td>
</tr>
<tr>
<td>C-reactive protein (mg/dL)</td>
<td>0.25 (0.23-0.28)</td>
<td>0.42 (0.39-0.45)*</td>
<td>0.70 (0.65-0.74)*</td>
<td>0.19 (0.16-0.22)*</td>
<td>0.29 (0.21-0.36)</td>
<td>0.40 (0.33-0.47)*</td>
</tr>
<tr>
<td>Total Cholesterol (mg/dL)</td>
<td>179.4 (175.2-183.0)</td>
<td>197.4 (193.5-201.2)</td>
<td>224.4 (220.5-228.4)</td>
<td>177.3 (173.4-181.3)</td>
<td>195.9 (191.9-200.0)</td>
<td>217.7 (213.8-221.6)*</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>5.51 (5.36-5.65)</td>
<td>5.85 (5.68-5.98)</td>
<td>6.50 (6.31-6.68)</td>
<td>5.09 (4.95-5.14)</td>
<td>5.40 (5.25-5.54)</td>
<td>5.74 (5.58-5.90)</td>
</tr>
<tr>
<td>Hemoglobin (g/L)</td>
<td>8.56 (8.59-9.13)</td>
<td>8.59 (8.53-9.16)</td>
<td>9.08 (8.95-9.20)</td>
<td>8.29 (8.18-8.39)</td>
<td>8.74 (8.62-8.84)</td>
<td>10.08 (9.83-10.34)*</td>
</tr>
</tbody>
</table>

**Question 1:** Are higher levels of physical activity inversely associated with biomarkers in overweight or obese persons? To address this, adjusted Wald tests were computed to see if differences occurred between overweight and active vs. overweight and inactive, obese and active vs. obese and inactive. Significantly (P < 0.005) different than “overweight and inactive” group. Significantly (P < 0.005) different from “obese and inactive” group. Question 2: Do overweight or obese individuals who are active have better or similar biomarker levels than normal weight persons who are inactive? To address this, adjusted Wald tests were computed to see if differences occurred between overweight and active vs. obese and active vs. normal weight and inactive. Significantly (P < 0.005) different than “normal weight and inactive” group.

Multivariable linear regression analysis examining the association between biomarkers (outcome variable) for inactive and active participants according to weight status, NHANES 2003-2006

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