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**Abbreviations:**

ALST.....Appendicular lean soft tissue

CRF.....Cardiorespiratory fitness

DXA..... Dual-energy absorptiometry

FFM..... Fat free mass

FM..... Fat mass

MET.....Metabolic equivalent of task

MVPA.....Moderate to very vigorous physical activity

NDSR.....Nutrition data system for research

RMR.....Resting metabolic rate

TDEE ..... Total daily energy expenditure

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**Abstract**

Objective: To determine if moderate cardiorespiratory fitness (CRF) or moderate to vigorous physical activity (MVPA) is associated with elevations in resting metabolic rate (RMR) similar to findings previously observed in endurance athletes.

Participants and Methods: Using a cross-sectional design, we measured CRF, RMR, body composition, energy expenditure and time in MVPA via an arm-based activity monitor in 423 young adults (mean age=27.6 years). Based on the results of a fitness test, participants were classified into CRF tertiles (low, moderate, or high) by sex.

Results: There were significant differences between the low, moderate, and high CRF groups for body mass index (mean±SD) (28.1±4.1, 25.1±3.4, 23.6±2.5, respectively; $P<.001$) and fat mass (28.8±9.7, 20.5±8.2, 14.8±6.5 kg, respectively; $P<0.05$), but not fat-free mass (53.1±11.5, 53.5±12.4, 54.7±12.1 kg, respectively; $P=0.49$). There were no differences in unadjusted RMR expressed as kcals/day between the groups (1533.2±266.2, 1519.7±267.6, 1521.9±253.9 kcals/day, respectively). However, after statistical adjustment for differences in body composition, both moderate and high CRF groups had a higher RMR compared to low CRF individuals by 40 and 60 kcals/day, respectively ($P<0.05$). After further adjustment for MVPA, RMR was higher in the high CRF group compared with the low fitness group by 51 kcals/day ($P<0.05$).

Conclusions: In this large sample of young adults representing a range of CRF, there was a positive stepwise gradient in RMR across tertiles of CRF independent of body composition. MVPA was also independently associated with RMR, though this relationship was modest. These findings underscore the multi-dimensional role of CRF and MVPA on health.

## Introduction

There is no consensus on the specific causes of the current levels of overweight and obesity seen in most of the developed world and affluent sectors in the developing world.[1] Much of the research focuses on excess energy intake or deficient physical activity energy expenditure.[2-5] However, resting metabolic rate (RMR) represents the largest contribution to total energy expenditure (60-80%) [6] and has been hypothesized as a potential predictor of weight gain. [7] Some analyses have found a low RMR predictive of weight gain,[7,8] while others have not, [9] and yet others show somewhat ambiguous results.[10]

While RMR is relatively stable within individuals (<5% day-to-day variation), variability between individuals is much higher (±25%).[11] RMR is primarily determined by fat-free mass (FFM, approximately 63%), fat mass (FM, 6.7%), and age (1.7%) leaving over 25% of the variability unexplained.[12-14] Identifying other determinants of RMR is important in order to understand energy balance and, concomitantly, the etiology of obesity.[15]

Levels of physical activity and cardiorespiratory fitness (CRF) have long been considered to influence RMR, beyond known post-exercise increases in oxygen consumption, and may partially explain the large inter-personal variability of RMR previously described. The majority of studies previously conducted indicate a 5-20% higher RMR among individuals who participate in regular activity compared to sedentary controls,[16,17] and CRF is significantly correlated with RMR among middle aged men and women ($r=0.79$, $P<.001$).[18] However, studies have typically examined the role of physical activity on RMR in the context of highly fit individuals (e.g., endurance runners),[19,20] which limit the translation to the broader public health

context. It is unclear if moderate amounts of physical activity or CRF significantly explain any of the interpersonal variance found in RMR.

Given recent technical advancements, it is now possible to assess objectively an individual's daily physical activity with great accuracy and reliability, in terms of both absolute total energy expenditure and in time spent at a given level of intensity (e.g., moderate intensity activity).[21] Pattern recognition monitors worn on the body integrate information from multiple sensors to provide a highly sensitive and valid assessment of both structured exercise and complex lifestyle tasks, such as carrying loads, walking up grades, and non-ambulatory activities.[21,22] These technical advances now permit the assessment of physical activity energy expenditure among large samples of individuals over extended periods of time.

The purpose of the present study is to examine the role of CRF and objectively measured physical activity in explaining interpersonal variance of RMR among a cohort of young adults across a broad range of activity and CRF levels.

## Participants and Methods

**Participants and enrollment process** The design and rationale for this study have been described in detail previously.[23] Briefly, recruitment occurred from August 2011 - July 2012 and all participants were required to have a BMI ≥20 and ≤35 kg/m$^2$ and age ≥21 and ≤35 years. Exclusion criteria included use of medications to lose weight, starting or stopping smoking in the previous 6 months, or planned weight loss surgery. Further, individuals were excluded for resting blood pressure >150 mmHg systolic and/or >90 mmHg diastolic, an ambulatory blood glucose level of >145 mg/dl, or if currently diagnosed with/or taking medications for a major chronic health condition. Individuals with a history of depression, anxiety, or panic were excluded, as were those taking selective serotonin inhibitors for any reason. All women were eumenorrheic. Informed consent was obtained from each participant prior to data collection.

**Anthropometrics** A dual energy X-ray absorptiometer (DXA) provided data on bone mineral density, FM, and FFM, both overall and for various body regions (arms, legs, etc.). The scan was completed with a Lunar DPX® system (version 3.6; Lunar Radiation Corp, Madison, WI). Skeletal muscle mass was calculated from appendicular lean soft tissue (ALST) mass using the following linear regression equation:

$$\text{Skeletal muscle mass} = (1.13 \times \text{ALST}) - (0.02 \times \text{age}) + (0.61 \times \text{sex}) + 0.97$$

where sex= 0 for females and 1 for males.[24] This equation was developed (N=321) and validated (N=93) with ethnically diverse men and women using magnetic resonance imaging (MRI) and DXA, and correlations between skeletal mass derived from the equation and MRI were high ($R^2$= 0.96, P< 0.0001).[24] Residual mass, including brain, liver, kidneys, heart gastrointestinal tract, and other organs and tissues, was then calculated using the following equation:[25]

Residual mass= body weight – fat mass – skeletal mass – bone mass

**Cardiorespiratory fitness** Fitness testing was conducted on a treadmill (Trackmaster 425®, Carefusion, Newton, Kansas) with respiratory gases sampled using a TrueOne 2400 Metabolic Measurement Cart® (ParvoMedics, Salt Lake City, Utah) using a Modified Bruce protocol. Given no broadly accepted criteria exist to categorize fitness levels, participants were classified as 'Low' if they were in the bottom tertile for CRF (mL/kg/min) among the entire cohort for each gender, 'Moderate' ('Mod') if they were in the middle tertile, or 'High' if they were in the upper tertile. This stratification resulted in a close match to CRF levels of a widely cited population-based fitness classification system [26] based on low, moderate, and high levels of CRF.

**Resting Metabolic Rate** RMR was measured via indirect calorimetry using a ventilated hood and an open-circuit system, TrueOne 2400 Metabolic Measurement Cart® (ParvoMedics, Salt Lake City, Utah), over a 30-minute period with data collection beginning after a 15-minute resting period. Participants arrived for a morning visit following a 12-hour dietary fast and at least 24 hours after the last bout of structured exercise.

**Energy Expenditure** Total daily energy expenditure (TDEE) was estimated using the SenseWear Mini Armband® (BodyMedia Inc. Pittsburgh, PA), an activity monitor shown to be valid assessing TDEE and activity. [21,22,27] This portable, multi-sensor device, worn on the upper arm, incorporates tri-axial accelerometry, heat flux, galvanic skin response, skin temperature, and near-body ambient temperature. Time spent in physical activity was classified by intensity according to calculated metabolic equivalent of task (MET) based on the following criteria: Sedentary, 1.0 to ≤1.5 METs; Light, >1.5 to ≤3.0 METs; Moderate, >3.0 to ≤6.0 METs;

Vigorous, >6.0 METs. Due to low amounts of time spent in vigorous activity among participants, all activity >3.0 METs was also summed to identify moderate – vigorous (MVPA) activity.

**Energy Intake** Energy intake was estimated from responses to interviewer-administered 24-hour dietary recalls over a telephone. The Nutrient Data System for Research (NDSR Version 2012) was utilized to conduct the dietary interviews and is considered the state-of-the-art research software for conducting dietary recalls.[28] In this study, the dietary recalls were collected by a team of experienced (> 6 years using NDSR) registered dietitians specifically trained in using the NDSR protocol employing the multi-pass approach, which utilizes prompting to reduce omissions, and standardizes the interview methodology across interviewers.[29] Interviews were conducted on three randomly selected, non-consecutive days during the time participants were wearing the armband, and cold calls are made to the participants to minimize preparation that could bias recall.[30]

**Statistical analysis** Participant characteristics were based on demographic and physiological measurements using means and standard deviations for continuous variables and percentages for categorical variables. Statistical significance for comparisons among groups for unadjusted variables was tested using analysis of variance (ANOVA) with Tukey's test adjustment. Linear regression analyses were completed to adjust for differences in covariates (e.g., FFM) between the groups, with the dependent variable RMR expressed as kcals/day. The linear regression models were initially adjusted by race, age, and sex; subsequent models were created by including skeletal muscle mass, residual mass, FM, and bone mass. Additional models were created and included all previously mentioned covariates and (i) time spent in in sedentary, light, moderate, vigorous, and very vigorous activity, (ii) time spent in MVPA, (iii) energy

intake, and (iv) macronutrient content of the diet (e.g., percent of kcals from carbohydrates). Analysis of covariance (ANCOVA) was used to compare RMR between low, moderate, and high fitness groups after adjustment for covariates. Linear modeling results are presented as least squares means with standard errors. Statistical significance was defined as $P \leq 0.05$ (2-tailed). All computations were performed using SAS 9.3 (Cary, N.C.).

## Results

Participant body composition characteristics are presented in **Table 1** overall and by CRF level. There were significant differences in several variables, with an inverse significant stepwise gradient in body weight, BMI, FM, and fat mass percent between low-, medium-, and high-CRF groups, respectively, and positive stepwise gradient in skeletal mass percent, residual mass percent, and bone mass percent. **Table 2** describes the levels of CRF across the groups, with the low fitness group 37.2% lower than the high CRF group and 22.1% lower than the moderate CRF group (expressed as mL/kg/min). There were no differences in RMR expressed as kcals/day among the groups (overall mean±sd= 1524.8±262.1), but RMR expressed relative to body weight had a significant direct gradient across CRF levels (low= 2.72±0.33, moderate= 2.98±0.29, high 3.18±0.30 mL/kg/min, $P<.001$, Table 2).

**Table 3** describes energy expenditure and energy intake information for the three CRF categories. Compliance with armband wear was excellent, with mean wear time of 23 hours and 14 minutes per day (no differences between groups). There were no differences in TDEE among the groups when expressed as kcal/day. However, there were significant group differences when TDEE was expressed relative to body weight, with lowest TDEE level among the low-fitness group and progressive increases in the moderate- and high-CRF groups (33.1±4.3 vs. 37.3±4.7 vs. 40.6±5.2 kcals/kg/day). There was a significant inverse relationship across fitness groups in time spent each day in sedentary activities, and a positive stepwise gradient in time spent in MVPA. High-fitness individuals spent less time than low-fitness individuals in light activity. Compliance with the dietary assessments was excellent, with a mean of 2.76±0.05 assessments completed per participant (out of a maximum of 3, no differences between groups). The low-fitness group reported lower levels of total kcals consumed and received a lower percentage of

their kcals from alcohol each day compared to the moderate- and high-fitness groups, and consumed more energy from carbohydrates than the high-fitness group. There were no differences between groups for percentage of kcals as fat or protein in the diet.

Linear regression models were created to adjust RMR for differences in body composition and the results are presented in **Table 4**. The base model adjusted RMR by race, age, and sex, which have been widely described previously in the literature as predictive of RMR; they accounted for 45% of the variability of RMR in the present study. The four body compartments (skeletal muscle mass, residual mass, FM, and bone mass) were then added to subsequent models. The model that included race, age, sex, and skeletal muscle mass explained 69% of the variance in RMR, and adding residual mass explained 74%. Adding FM to the model explained 79% of the variance, and this did not change with the addition of bone mass or minutes of MVPA.

Following additions of skeletal muscle mass and residual mass to the linear model, RMR became statistically higher in the low-fitness group compared to the high-fitness group (1554.5±11.7 vs. 1494.7±11.6 kcals/day, $P<.001$). After adjusting for the differences in FM between the groups, RMR became lower in the low-fitness group (1491.4±12.6 kcals/day) and higher in the moderate- (1531.1±10.2 kcals/day) and high-fitness groups (1551.3±12.1 kcals/day, $P=.04$ for differences between low- and moderate-fitness groups, $P=0.01$ between the low- and high-fitness groups). The RMR values adjusted for skeletal, residual, fat, and bone mass are displayed in **Figure 1,** and demonstrate the positive relationship between RMR and CRF at any given body weight.

This approach was repeated to determine the influence of physical activity on RMR, with time spent in MVPA added to the previously described model. Time spent in MVPA was statistically associated with RMR, though the effect was small (β coefficient= 0.2267, F value= 4.51, *P*=.03) resulting in adjusted RMR values statistically higher in the high-fitness group compared to the low-fitness group (1546.6±12.3 vs. 1495.3±12.7, *P*=0.03). This indicates that time spent in moderate to vigorous physical activity is independently associated with RMR. The individual components of energy expenditure related to physical intensity (time spent in sedentary, light, moderate, and vigorous activity) were also entered into the model both separately and together, but none was statistically related to RMR (results not shown). Neither energy intake nor any of the diet composition variables were statistically related to RMR (results not shown).

## Discussion

The primary finding of the present study is that higher levels of RMR were observed among young adults with both moderate and high levels of CRF compared to those with low levels of CRF, independent of differences in fat free mass. While higher RMR levels have previously been described in extremely aerobically fit individuals, this study extends these findings to individuals with moderate levels of CRF and demonstrates significant stepwise differences in RMR across CRF categories. Time spent in moderate to vigorous physical activity was also positively and independently related to RMR and varied considerably among the groups, although the influence had little predictive value beyond adjustments for body composition. These statistically significant differences in RMR have the potential for clinically significant influences on weight gain as part of a 'small changes' obesity prevention public health approach.

Previous research suggests a 5-20% higher RMR among those who are highly fit or participate in regular physical activity.[16-20,31-36] However, nearly all of these previous studies have explored differences between highly fit (e.g., endurance athletes) and sedentary individuals. Even studies including non-athletic populations involved participants with very high levels of CRF. For example, Van Pelt et al. explored differences in RMR among physically active and sedentary men; [31] however, the peak CRF (61.3±0.9 mL/kg/min) in the physically active group was well above the 80$^{th}$ percentile (50.4 mL/kg/min) of a widely cited population-based fitness classification system,[26,37] and the sedentary group (44.2±1.2 mL/kg/min) was nearly in the 60$^{th}$ percentile (45.9 mL/kg/min). In contrast, our CRF groups were closely aligned with low (females=24.6±3.6 mL/kg/min, males=35.0±4.0 mL/kg/min), moderate (females=32.5±2.1 mL/kg/min, males=43.9±2.0 mL/kg/min), and high (females=41.7±4.6 mL/kg/min,

males=53.4±3.9 mL/kg/min) classifications previously cited. By studying participants across a wide range of CRF levels, we were able to closely examine the relationship between CRF and RMR, and we found a significant stepwise gradient in RMR from the low- to moderate- to high-fitness groups.

In the present study, time spent in MVPA was positively related to RMR independent of body composition, though this difference was small. Our findings are unique given no previous studies have explored patterns of regular physical activity using accelerometer-based monitors. By objectively measuring activity intensity we are able to accurately evaluate the role of MVPA on RMR, as subjective reporting of physical activity is often limited by misreporting.[38,39] As with the CRF values, there was a wide range of MVPA across the groups, which allows for close examination of various levels of activity on RMR, with participants in the low- fitness group spending 51% fewer minutes engaged in MVPA compared with the high-fitness group and 35% fewer minutes compared with the moderate-fitness group. As previous studies have found age-related declines in RMR can be explained by decreases in physical activity associated with aging,[31,33] it is possible that differences in physical activity at any age is responsible for differences in RMR. Indeed, when time spent in physical activity was included in the linear regression models involving the young adults in our study, differences in RMR between the low- and high-fitness groups remained (Table 4).

Physical activity is thought to affect RMR via at least two distinct pathways: 1) the growth of FFM (i.e. skeletal muscle), and 2) the effect on physiological processes that influence RMR.[40] Given no differences in skeletal muscle between the groups, and the results of the linear modeling indicating CRF predicts RMR independent of skeletal muscle mass, the difference in RMR between CRF groups is likely due to physiological processes. Numerous mechanisms

explaining the role of CRF and physical activity on RMR have been proposed and include regulation of the sympathetic nervous system (SNS),[41-44] changes in muscle cell structure,[45] immune systems responses,[46,47] neuroendocrine function,[48,49] and substrate cycling.[50,51] Examining these mechanisms was beyond the scope of the present study; however, the respiratory quotient (which represents substrate oxidation while at rest) was measured, with a value of 0.7 equaling pure lipid oxidation and 1.0 equaling pure carbohydrate oxidation.[52] The low-fitness group had a statistically higher respiratory quotient (0.80±0.05) compared to the moderate and high CRF groups (0.79±0.04, $P$=.01 and 0.79±0.05, $P$=.01, respectively). This small difference may not be clinically significant, but it may suggest possible differences in substrate oxidation in 'metabolically flexible' aerobically fit individuals that may be more apparent *in vivo*.[53-55]

There is evidence to suggest that lower levels of RMR result in weight gain over time,[7,56-59] though the literature is equivocal on the topic.[9,10,60] Given that RMR is the largest contributor to TDEE (60-80%), lower than expected levels will result in lower levels of TDEE, and individuals with a low TDEE are more likely to be in energy imbalance.[7] In the present study participants with lower levels of RMR (the low CRF group) did have significantly higher levels of body weight and FM compared to age matched peers. However, given the cross-sectional nature of the study design we cannot determine causation or the temporal nature of these findings. While the differences in RMR between groups (60 kcals/day, low vs. high, 40 kcals/day, low vs. moderate) may seem trivial, a 'small changes' approach to dietary intake and energy expenditure for obesity prevention has been advocated [61,62] and adopted by several organizations including the US Department of Health and Human Services (www.smallstep.gov), the US Surgeon General

(www.surgeongeneral.gov/news/2010/05/pr20100506.html), the US Department of Agriculture through the Dietary Guidelines (www.MyPyramid.gov), and groups including the American Diabetes Association, American Heart Association, American Cancer Society, American Society for Nutrition, Institute for Food Technologists, and the International Food Information Council. [63] Indeed, this small, 60 kcal/day, influence on RMR may account for approximately 6 pounds per year of weight change. Considering the obesity epidemic and the gradual accumulation of weight and FM with aging, this additional impact on RMR has significant potential clinical implications on the long-term prevention of excess adiposity.

The strengths of the present study include a large sample size with nearly equal numbers of men and women across a wide range of CRF levels. Our body composition measurement technique (DXA) allows for the quantification of body mass into segments by metabolic properties (residual mass, skeletal mass, FM, and bone mass). The use of validated multi-sensor technology allowed us to accurately assess energy expenditure cumulatively over a 24-hour period for at least 7-days and by intensity of activity. To our knowledge, this is the first examination of the relationship between objectively determined PA intensity and RMR. The combination of each of these assessment techniques and statistical approaches applied allowed us to uniquely explore the relationship between CRF and RMR and MVPA and RMR. Although we attempted to separate the independent impacts of CRF and PA on RMR, this statistical separation may be somewhat artificial considering the close physiological relationship between MVPA and CRF.

**Conclusion**

Individuals with either a moderate or high level of CRF have an elevated RMR compared to those with a low level of CRF. This positive stepwise gradient in RMR across tertiles of CRF highlights the role of aerobic capacity on resting metabolism. Time spent in moderate to vigorous physical activity was also independently and positively related to RMR, but this influence was relatively small and had little predictive value over adjustments for body composition. Nevertheless, this small influence on RMR may account for weight gains over time that are significant both clinically and from a public health perspective.

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**Table 1. Participant characteristics overall and by fitness level.**

| | **All** (N=423) (mean±SD) | **Low** (n=138) (mean±SD) | **Mod** (n=145) (mean±SD) | **High** (n=140) (mean±SD) | Between group differences (*P* value) |
|---|---|---|---|---|---|
| **Female (%)** | 51.3 | 51.5 | 51.0 | 51.4 | >.99 |
| **Age (years)** | 27.6±3.8 | 28.3±3.8 | 27.41±3.8 | 27.2±3.7 | .02 |
| **Height (cm)** | 171.1±9.4 | 170.4±9.1 | 171.4±10.1 | 171.2±9.0 | .64 |
| **Weight (kg)** | 75.1±13.8 | 81.9±14.7 | 74.0±12.8 | 69.5±10.7 | <.001 |
| **Body Mass Index (kg/m$^2$)** | 25.6±3.8 | 28.1±4.1 | 25.1±3.4 | 23.6±2.5 | <.001 |
| **Fat mass (kg)** | 21.3±10.0 | 28.8±9.7 | 20.5±8.2 | 14.8±6.5 | <.001 |
| **Fat mass (%)** | 28.1±11.0 | 35.0±9.4 | 27.8±10.1 | 21.7±9.3 | <.001 |
| **Fat free mass (kg)** | 53.8±12.0 | 53.1±11.5 | 53.5±12.4 | 54.7±12.1 | .49 |
| **Skeletal mass (kg)** | 27.0±7.5 | 26.6±7.1 | 26.9±7.7 | 27.6±7.6 | .54 |
| **Skeletal mass (%)** | 36.0±7.3 | 32.5±6.5 | 36.1±7.1 | 39.2±6.7 | <.001 |
| **Residual mass (kg)** | 23.8±4.4 | 23.4±4.5 | 23.6±4.5 | 24.2±4.3 | .29 |
| **Residual mass (%)** | 31.9±4.3 | 28.8±3.6 | 32.0±3.7 | 34.9±3.3 | <.001 |
| **Bone mass (kg)** | 2.99±0.5 | 3.1±0.5 | 3.0±0.6 | 2.9±0.5 | .22 |
| **Bone mass (%)** | 4.0±0.5 | 3.8±0.6 | 4.1±0.4 | 4.2±.4 | <.001 |

**Table 2. Oxygen consumption at rest and peak exercise.**

| | **All** (N=423) (mean±SD) | **Low** (n=138) (mean±SD) | **Mod** (n=145) (mean±SD) | **High** (n=140) (mean±SD) | Between group differences (*P* value) |
|---|---|---|---|---|---|
| **Cardiorespiratory fitness (L/min)** | 2.88±0.88 | 2.46±0.77 | 2.85±0.79 | 3.33±0.86 | <.001 |
| **Cardiorespiratory fitness (mL/kg/min)** | 38.5±9.8 | 29.7±6.5 | 38.1±6.1 | 47.4±7.3 | <.001 |
| **Resting energy expenditure (kcals/day)** | 1524.8±262.1 | 1533.2±266.2 | 1519.7±267.6 | 1521.9±253.9 | .90 |
| **Resting metabolic rate (mL/kg/min)** | 2.96±0.35 | 2.72±0.33 | 2.98±0.29 | 3.18±0.30 | <.001 |
| **RMR/FFM ratio (kcals/kg/day)** | 28.8±3.5 | 29.4±3.8 | 28.9±3.4 | 28.3±3.1 | .03 |
| **Respiratory quotient** | 0.79±0.05 | 0.80±0.05 | 0.79±0.04 | 0.79±0.05 | .01 |

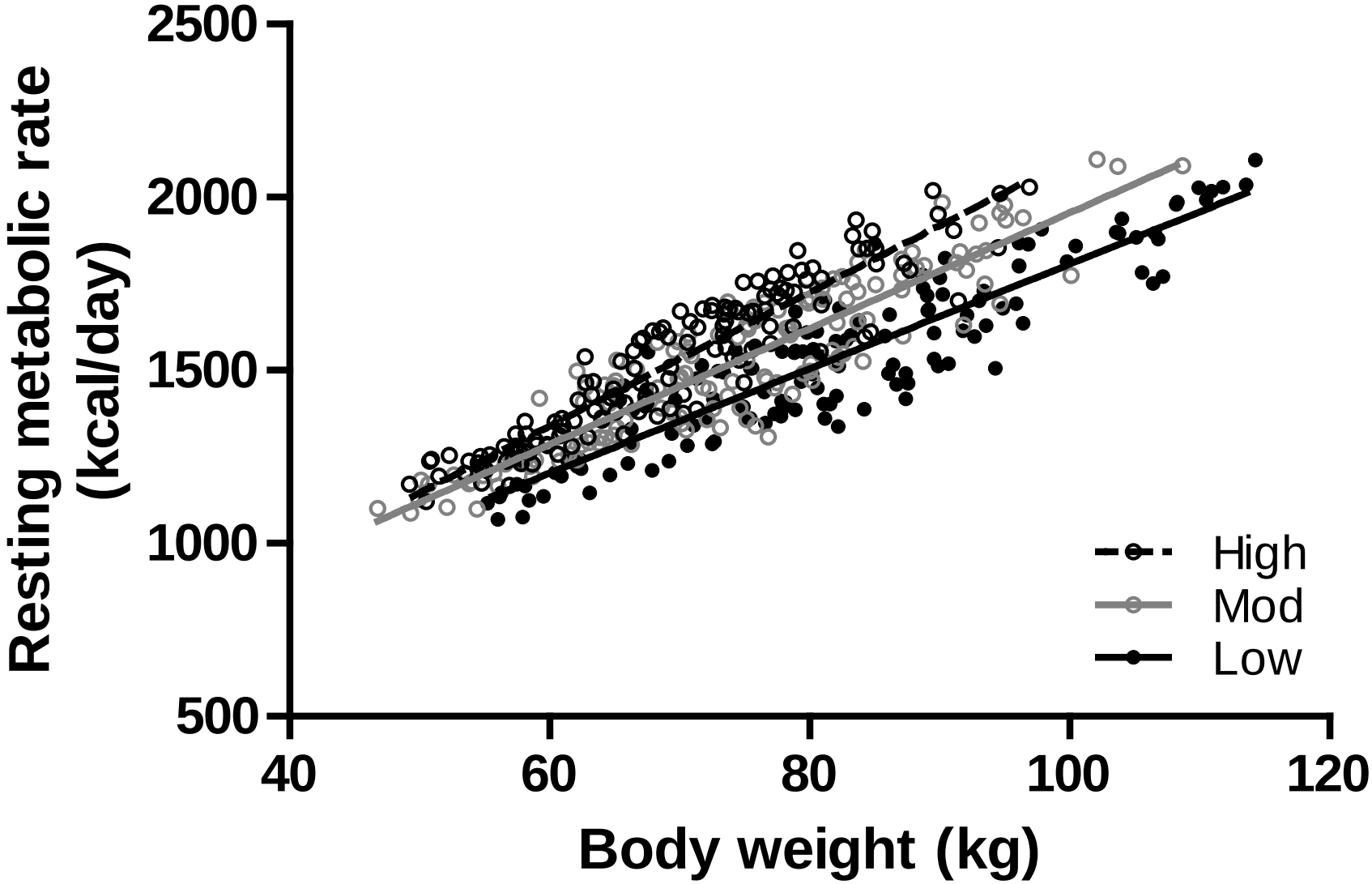
**Table 3. Time spent in physical activity and energy intake by macronutrients.**

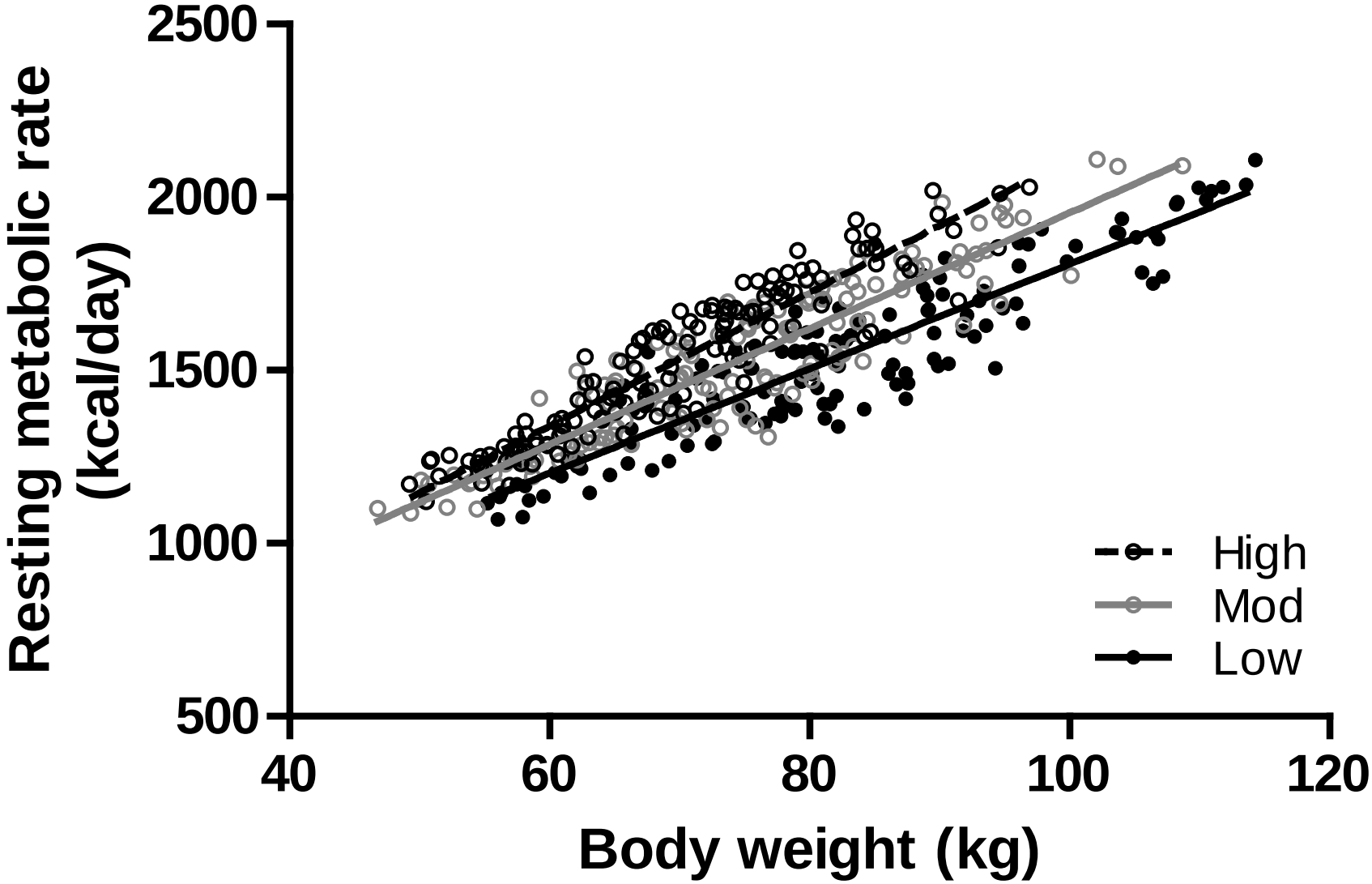
| | **All** (N=423) (mean±SD) | **Low** (n=138) (mean±SD) | **Mod** (n=145) (mean±SD) | **High** (n=140) (mean±SD) | Between group differences (*P* value) |
|---|---|---|---|---|---|
| **Total daily energy expenditure (kcal/day)** | 2740.1±511.0 | 2676.2±474.5 | 2741.0±541.7 | 2802.0±508.8 | .12 |
| **Total daily energy expenditure (kcal/kg/day)** | 37.0±5.6 | 33.1±4.3 | 37.3±4.7 | 40.6±5.2 | <.001 |
| **Sedentary (min/day)** | 1086.9±88.0 | 1135.5±76.3 | 1074.7±79.9 | 1051.9±86.4 | <.001 |
| **Light (min/day)** | 216.1±58.5 | 213.8±61.2 | 227.6±58.9 | 206.3±53.5 | .01 |
| **Moderate-Very Vigorous (min/day)** | 136.0±77.4 | 89.4±52.1 | 136.6±70.4 | 181.2±78.4 | <.001 |
| **Energy intake (kcal/day)** | 2078.4±670.7 | 1912.3±608.1 | 2124.5±718.1 | 2194.5±651.1 | .01 |
| **Carbohydrates (% of total kcals)** | 47.2±9.9 | 49.1±9.3 | 46.5±9.7 | 46.0±10.5 | .02 |
| **Fat (% of total kcals)** | 32.9±7.5 | 32.0±7.0 | 33.4±7.1 | 33.1±8.3 | .21 |
| **Protein (% of total kcals)** | 17.2±5.0 | 17.3±4.9 | 17.1±5.0 | 17.3±5.1 | .92 |
| **Alcohol (% of total kcals)** | 2.8±4.5 | 1.7±3.6 | 3.0±4.7 | 3.6±5.0 | .01 |

**Table 4. Analysis of covariance assessing resting metabolic rate between fitness groups controlling for body compartments (kg) and time spent in physical activity (minutes/day) (mean±standard error).**

| | **Low** | **Mod** | **High** | **$R^2$** | Between group differences- Low vs. Mod (*P* value) | Between group differences- Low vs. High (*P* value) |
|---|---|---|---|---|---|---|
| **Unadjusted (mean±SD)** | 1533.2±22.7 | 1519.7±267.6 | 1521.9±253.9 | NA | .67 | .72 |
| **Race + age + gender** | 1545.6±16.9 | 1517.5±16.3 | 1511.9±16.7 | 0.45 | .46 | .34 |
| **Race + age + gender + skeletal muscle** | 1552.1±12.8 | 1523.2±12.2 | 1499.2±12.6 | 0.69 | .24 | .01 |
| **Race + age + gender + skeletal muscle + residual mass** | 1554.5±11.7 | 1525.6±11.2 | 1494.7±11.6 | 0.74 | .18 | .01 |
| **Race + age + gender + skeletal muscle + residual mass + fat mass** | 1491.4±12.6 | 1531.1±10.2 | 1551.3±12.1 | 0.79 | .04 | .01 |
| **Race + age + gender + skeletal muscle + residual mass + fat mass + bone mass** | 1491.4±12.6 | 1531.1±10.2 | 1551.3±12.1 | 0.79 | .04 | .01 |
| **Race + age + gender + skeletal muscle + residual mass + fat mass + bone mass + minutes in MVPA** | 1495.4±12.7 | 1531.8±10.2 | 1546.6±12.3 | 0.79 | .07 | .03 |

**Figure 1. A positive stepwise gradient in resting metabolic rate was observed across fitness levels after adjustment for differences in body composition between groups (Difference for slopes between groups: P= 0.003).**


Resting metabolic rate (kcal/day)
2500
2000
1500
1000
500
40
60
80
100
120
Body weight (kg)
High
Mod
Low


Resting metabolic rate (kcal/day)
2500
2000
1500
1000
500
40
60
80
100
120
Body weight (kg)
High
Mod
Low