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*Am J Physiol Endocrinol Metab* 281:633-639, 2001.

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# Age-related decline in RMR in physically active men: relation to exercise volume and energy intake

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**Van Pelt, Rachael E., Frank A. Dinneno, Douglas R. Seals, and Pamela Parker Jones.** Age-related decline in RMR in physically active men: relation to exercise volume and energy intake. *Am J Physiol Endocrinol Metab* 281: E633–E639, 2001.—We tested the hypothesis that resting metabolic rate (RMR) declines with age in physically active men (endurance exercise  $\geq 3$  times/wk) and that this decline is related to weekly exercise volume (h/wk) and/or daily energy intake. Accordingly, we studied 137 healthy adult men who had been weight stable for  $\geq 6$  mo: 32 young ( $26 \pm 1$  (SE) yr) and 34 older ( $62 \pm 1$  yr) sedentary males (internal controls); and 39 young ( $27 \pm 1$  yr) and 32 older ( $63 \pm 2$  yr) physically active males (regular endurance exercise). RMR was measured by indirect calorimetry (ventilated hood system) after an overnight fast and  $\sim 24$  h after exercise. Because RMR is related to fat-free mass (FFM;  $r = 0.76$ ,  $P < 0.001$ , current study), FFM was covaried to adjust RMR (RMR<sub>adj</sub>). RMR<sub>adj</sub> was lower with age in both the sedentary ( $72.0 \pm 2.0$  vs.  $64.0 \pm 1.3$  kcal/h,  $P < 0.01$ ) and the physically active ( $76.6 \pm 1.1$  vs.  $67.9 \pm 1.2$  kcal/h,  $P < 0.01$ ) males. In the physically active men, RMR<sub>adj</sub> was related to both exercise volume (no. of h/wk, regardless of intensity;  $r = 0.56$ ,  $P < 0.001$ ) and estimated energy intake ( $r = 0.58$ ,  $P < 0.001$ ). Consistent with these relations, RMR<sub>adj</sub> was not significantly different in subgroups of young and older physically active men matched either for exercise volume (h/wk;  $n = 11$  each) or estimated energy intake (kcal/day;  $n = 6$  each). These results indicate that 1) RMR, per unit FFM, declines with age in highly physically active men; and 2) this decline is related to age-associated reductions in exercise volume and energy intake and does not occur in men who maintain exercise volume and/or energy intake at a level similar to that of young physically active men.

endurance exercise; aging; resting metabolic rate

RESTING METABOLIC RATE (RMR), which is responsible for  $\sim 60$ – $80\%$  of 24-h energy expenditure, decreases markedly with advancing age in sedentary populations (7, 20, 25). Such a decline in energy expenditure likely contributes to an impaired ability to regulate energy balance with age. Recently, we demonstrated that, in

contrast to sedentary women, significant age-related differences in RMR, adjusted for fat-free mass (FFM), are not observed between young and older women who regularly perform aerobic (endurance) exercise (24). However, it is not clear on the basis of cross-sectional (9, 15, 16) and longitudinal evidence (14, 27) whether this is the case in men.

We postulate that RMR, independent of changes in FFM, may decline significantly with age among regularly physically active men for two reasons. First, there is some evidence in men that the amount of endurance exercise performed (exercise volume) is positively related to RMR (22). Because exercise volume is known to decline with age in endurance-trained males (17, 21), it may be associated with a reduction in RMR. Second, RMR is related to total energy intake (2), which should decline with age-related reductions in exercise volume to maintain energy balance.

Accordingly, the present investigation tested the hypotheses that 1) RMR is lower with age in men who regularly perform endurance exercise, and 2) this age-related decline in RMR is related to declines in exercise volume and/or estimated energy intake. To test these hypotheses, we determined RMR, body mass and composition, average weekly exercise volume, and daily energy intake in healthy young and older adult endurance exercise-trained males. We then determined RMR in subgroups of young and older exercise-trained men who were matched for either exercise volume or energy intake. We also studied groups of healthy young and older sedentary men as an internal control to document the age-related decline in RMR in this population under the present experimental conditions.

## METHODS

**Subjects.** One hundred thirty-seven healthy men aged 19–36 or 52–75 yr were studied: 32 young and 34 older sedentary men, 39 young and 32 older physically active men. The young and older physically active men were local runners and triathletes who placed in the top 25% of their age divisions in either 10-km

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running events or triathlon competitions. All of the physically active men were endurance athletes whose training consisted of running and one or more types of cross training (biking, swimming, hiking, or skiing). The sedentary subjects performed no regular physical activity. All subjects had been weight stable ( $\pm 2$  kg) during the previous 6 mo. All subjects were healthy as assessed by self-reported medical history. Older subjects were further evaluated for clinical evidence of cardiopulmonary disease with a physical examination and electrocardiograms during rest and maximal exercise. All subjects were nonsmokers. Subjects were not using any medications. Fasting levels of plasma thyroid hormones were determined to assure normal thyroid function in all subjects. The nature, purpose, and risks of the study were explained to each subject before written informed consent was obtained. The experimental protocol was approved by the Human Research Committee at the University of Colorado at Boulder.

**Body mass and composition.** Total body mass was measured to the nearest 0.1 kg on a physician's balance scale (Detecto, Webb City, MO). Body mass index (BMI) was calculated from weight and height ( $\text{kg}/\text{m}^2$ ). Dual-energy X-ray absorptiometry (model DPX-IQ, Lunar Radiation, Madison, WI, software version 3.2) was used to measure whole body fat mass and FFM as described in detail previously (12).

**RMR.** Subjects were studied after a 12-h overnight fast. Because the physically active men exercise daily, RMR was measured  $\sim 24$  h after the last exercise session to be most representative of their normal physiological state. All men drove themselves into the laboratory first thing after waking in the morning. Measurements were performed between 6:00 and 9:00 AM in a dimly lit room at a comfortable temperature ( $\sim 23^\circ\text{C}$ ). Subjects remained awake in a semirecumbent position. After a 15-min habituation period, oxygen consumption and carbon dioxide production were measured each minute for 30 min by indirect calorimetry with a ventilated-hood system (DeltaTrac Metabolic Monitor, SensorMedics, Yorba Linda, CA). RMR was then calculated from the average of the 30 min using the Weir formula (26). The reliability of this method has been established previously by our laboratory (24).

**Maximal exercise capacity.** Maximal oxygen consumption ( $\dot{V}\text{O}_{2\text{max}}$ ) was used as a measure of maximal exercise capacity and was determined during exhaustive treadmill exercise with an on-line computer-assisted open-circuit spirometry system, as previously described (5).

**Estimated energy intake.** Energy intake was estimated from food diaries recorded for four consecutive days (3 weekdays and 1 weekend day). Subjects were individually instructed by a registered dietician to keep accurate and complete diet records. Each subject weighed (Dayton Hudson diet scale, 8 oz. capacity) or measured (using standard measuring cups and spoons) and recorded all food and beverages consumed. The same registered dietician then reviewed the records with the subjects and analyzed all diets for energy and macronutrient intake using the Nutritionist IV computer software program (version 4.1, The Hearst, San Bruno, CA). Subjects who were unable to comply with the instructions for diet records, or whose energy intake was determined to be under- or overreported on the basis of established criteria for the ratio of energy intake to RMR [EI/RMR between 1.35 and 2.4 (10)] are excluded from analyses involving energy intake.

**Estimated exercise volume.** Physically active subjects were interviewed for precise determination of weekly exercise type, frequency, and duration. Exercise training volume was then calculated as the number of hours per week of endurance exercise. This expression of exercise volume does not quantify exercise intensity.

**Estimated daily energy expenditure.** To determine possible age-related differences in habitual physical activity levels in the sedentary men, daily energy expenditure was estimated using the Stanford Physical Activity Questionnaire (19), as previously described by our laboratory (13). Briefly, this questionnaire recalled the activities of daily living over 7 days, differentiating activities as being either Heavy [5.1–7.0 metabolic energy equivalents (METs)], Moderate (3.1–5.0 METs), Light (2.1–3.0 METs), or Very Light (0.9–2.0 METs). METs expended during the week in activity were then calculated and converted to kilocalories per week.

**Plasma thyroid hormone concentrations.** Fasting blood samples were taken after subjects had rested in the supine position for 20 min on a separate day under the same conditions as the RMR session. Serum thyroid-stimulating hormone (TSH) and total thyroxine ( $\text{T}_4$ ) concentrations were measured using competitive binding radioimmunoassays (1, 6). Only men who had normal thyroid function were studied.

**Statistics.** Group differences for key variables were determined by analysis of variance (ANOVA). Because FFM was strongly related to RMR ( $r = 0.76$ ;  $P < 0.001$ ) in this study and because we wished to study the effect of age-related declines in exercise volume and energy intake on RMR independent of FFM, RMR was adjusted for FFM by analysis of covariance (ANCOVA); the adjusted means ( $\text{RMR}_{\text{adj}}$ ) are presented. A Newman-Keuls post hoc test for multiple comparisons was used to analyze differences among the dependent variables. *T*-tests were used to compare the exercise volume- and energy intake-matched subgroups. Univariate correlations and partial regression analyses were performed to determine relations between variables in the overall study population and within groups. The level of statistical significance was set at  $P < 0.05$ . Values are means  $\pm$  SE.

## RESULTS

**Sedentary men.** The older sedentary men had higher levels of body mass, BMI, and total body fatness than the young sedentary men ( $P < 0.05$ ), whereas FFM did not differ with age (Table 1). Estimated total daily energy expenditure was not different between the young and older men ( $37.8 \pm 0.5$  vs.  $36.2 \pm 0.7$   $\text{kcal}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ ), but  $\dot{V}\text{O}_{2\text{max}}$  was lower in the older men ( $P < 0.001$ , Table 1). On the basis of an analysis of diet records, estimated total energy intake did not differ significantly between groups, although the percentage of kilocalories from carbohydrate intake was greater in the young (Table 2). There were also no differences in mean TSH levels ( $1.6 \pm 0.2$  vs.  $2.2 \pm 0.3$   $\mu\text{U}/\text{ml}$ ) or mean  $\text{T}_4$  levels ( $6.0 \pm 0.2$  vs.  $6.0 \pm 0.2$   $\mu\text{g}/\text{dl}$ ) between the young and older men.  $\text{RMR}_{\text{adj}}$  was 11% lower in the older compared with the young sedentary men (Fig. 1A,  $P < 0.01$ ).

**Physically active men.** Body mass and BMI were not different between the young and older physically active men. The older physically active men had higher body fat levels and lower FFM compared with the young physically active controls (Table 1).  $\dot{V}\text{O}_{2\text{max}}$  ( $P < 0.01$ , Table 1) and exercise training volume ( $5.7 \pm 0.4$  vs.  $9.9 \pm 0.7$  h/wk,  $P < 0.01$ ) were lower in the older compared with the young men. Resistance training in both groups was minimal ( $\sim 30\%$  of subjects in each group participated in weight lifting 1–3 times/wk) and did not differ between groups ( $39 \pm 11$  vs.  $41 \pm 13$

Table 1. *Subject characteristics*

	Sedentary Men		Physically Active Men	
	Young (n = 32)	Older (n = 34)	Young (n = 39)	Older (n = 32)
Age, yr	26 ± 1	62 ± 1*	27 ± 1	63 ± 1*
Body mass, kg	77.9 ± 2.5	82.1 ± 2.5	72.8 ± 1.2†	72.4 ± 1.3†
Height, cm	179 ± 1	175 ± 1	179 ± 1	175 ± 1
Body mass index, kg/m <sup>2</sup>	24.2 ± 0.7	26.7 ± 0.7*	22.7 ± 0.4	23.5 ± 0.3†
% Body fat	17.8 ± 1.4	26.3 ± 1.0*	11.4 ± 0.5†	17.4 ± 0.9*†
Fat mass, kg	14.6 ± 1.5	21.8 ± 1.5*	8.3 ± 0.5†	12.7 ± 0.8*†
Fat-free mass, kg	63.4 ± 1.6	60.4 ± 1.4	64.5 ± 1.0	59.6 ± 0.9*
$\dot{V}O_{2\max}$ , ml·kg <sup>-1</sup> ·min <sup>-1</sup>	44.2 ± 1.2	31.0 ± 1.1*	61.3 ± 0.9†	42.3 ± 1.3*†
RMR <sub>unadj</sub> , kcal/h	73.4 ± 2.0	66.0 ± 1.3*	75.2 ± 1.1	65.8 ± 1.2*

Values are means ± SE.  $\dot{V}O_{2\max}$ , maximal exercise capacity; RMR<sub>unadj</sub>, unadjusted resting metabolic rate. \* $P < 0.05$  vs. young group (same activity); † $P < 0.05$  vs. sedentary group (same age).

min/wk,  $P = 0.88$ ). Absolute levels of estimated daily total energy and macronutrient intakes were lower in the older men, but there were no differences in relative (%) macronutrient composition of the diet (Table 2). There were also no differences in mean TSH levels ( $1.6 \pm 0.2$  vs.  $1.9 \pm 0.3$   $\mu$ U/ml) or mean T<sub>4</sub> levels ( $5.9 \pm 0.2$  vs.  $5.5 \pm 0.2$   $\mu$ g/dl) between the young and older physically active men. RMR<sub>adj</sub> was 11% lower in the older compared with the young physically active men (Fig. 1B,  $P < 0.01$ ).

*Relation between endurance exercise volume and RMR among the physically active men.* RMR<sub>adj</sub> was significantly related to the number of hours of endurance exercise per week (i.e., exercise volume:  $r = 0.56$ ,  $P < 0.01$ ; Fig. 2A) in the physically active men. Because exercise volume was lower in older compared with young physically active men, subgroups ( $n = 11$  each) with the same level of weekly exercise volume were compared (Table 3). In contrast to the main groups, RMR<sub>adj</sub> was not significantly different between these young and older physically active men matched for weekly exercise volume ( $73.2 \pm 1.5$  vs.  $70.4 \pm 2.2$  kcal/h, Fig. 3A).

*Relation between energy intake and RMR among the physically active men.* Because RMR<sub>adj</sub> was related to total daily energy intake ( $r = 0.58$ ,  $P < 0.001$ ; Fig. 2B)

in the physically active men and was lower in older compared with young men, subgroups ( $n = 6$  each) with similar levels of daily energy intake were compared (Table 4). In contrast to the main groups, RMR<sub>adj</sub> was not different between these young and older physically active men matched for daily energy intake ( $71.8 \pm 1.8$  vs.  $73.8 \pm 3.5$  kcal/h; Fig. 3B).

*Independent relations between energy intake or exercise volume and RMR.* We used partial regression analysis in an attempt to clarify the respective independent contributions of exercise volume and estimated energy intake on RMR<sub>adj</sub> in the physically active men. After control for energy intake, the strength of the relation between RMR<sub>adj</sub> and exercise volume was weakened but remained significant ( $r = 0.40$ ,  $P < 0.001$ ). Likewise, when exercise volume was held constant, the relation between energy intake and RMR<sub>adj</sub> was weakened slightly but also remained significant ( $r = 0.39$ ,  $P < 0.01$ ).

## DISCUSSION

The primary new findings from the present study are as follows. First, RMR<sub>adj</sub> declines with age in men who are highly physically active. Second, the lower RMR<sub>adj</sub> in the older compared with young physically active

Table 2. *Estimated daily energy intake*

	Sedentary Men		Physically Active Men	
	Young (n = 22)	Older (n = 24)	Young (n = 26)	Older (n = 26)
Energy				
kcal/day	2,587 ± 101	2,380 ± 122	3,564 ± 146†	2,468 ± 90*
kcal/kg	34.9 ± 1.7	30.2 ± 1.9	48.9 ± 2.0	33.9 ± 1.2*†
CHO				
kcal/day	1,415 ± 60 (57%)	1,196 ± 52 (54%)*	1,989 ± 106† (58%)	1,375 ± 72* (58%)
g/kg	4.8 ± 0.2	3.8 ± 0.2*	6.8 ± 0.3†	4.7 ± 0.2*†
Fat				
kcal/day	774 ± 46 (30%)	766 ± 62 (32%)	1,016 ± 61† (28%)	654 ± 45* (27%)
fat g/kg	10.5 ± 0.7	9.7 ± 1.0	14.0 ± 0.9†	9.0 ± 0.6*
Protein				
kcal/day	353 ± 25 (13%)	350 ± 18 (15%)	480 ± 25† (13%)	365 ± 18* (13%)
protein g/kg	1.2 ± 0.1	1.1 ± 0.1	1.7 ± 0.1†	1.2 ± 0.1*
Alcohol, kcal/day	21 ± 11 (<1%)	52 ± 17 (2%)	40 ± 11 (1%)	54 ± 13 (2%)

Values are means ± SE, with % of total energy intake in parentheses. CHO, carbohydrate. \* $P < 0.05$  vs. young group (same activity); † $P < 0.05$  vs. sedentary group (same age).



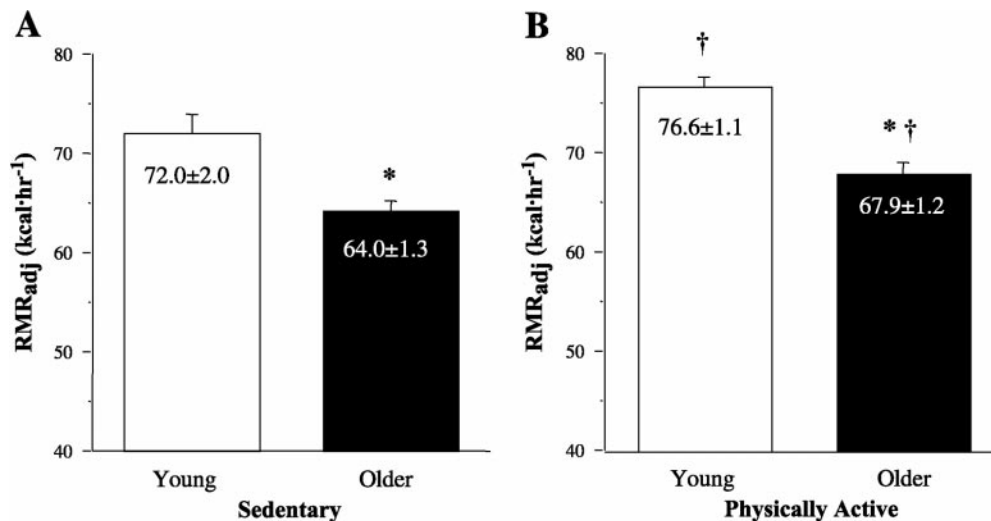


Fig. 1. Mean  $\pm$  SE values for resting metabolic rate (RMR, kcal/h) adjusted for fat-free mass (RMR<sub>adj</sub>) in young and older sedentary men (A) and young and older physically active men (B); \* $P < 0.01$  vs. young group (same activity); † $P < 0.05$  vs. sedentary group (same age).

men is associated with a lower exercise volume and lower estimated daily energy intake. Finally, it appears that both exercise volume and estimated energy intake are independently related to RMR<sub>adj</sub>. It should be noted that FFM remains the primary determinant of the age-related decline in RMR. The present results extend our understanding of the age-related decline by adding insight into other factors that influence RMR after FFM has been accounted for.

In the present study, RMR was strongly and directly related to FFM, as observed previously in sedentary male populations (7, 18). The lower RMR with age in the physically active men, however, was not due to a lower FFM, because our analysis was adjusted for this important influence. Rather, our results indicate that RMR per unit FFM is reduced with age in physically active adult males. Because all subjects were

euthyroid, and thyroid hormone levels were similar among groups, differences in thyroid function do not explain our observed differences in RMR. Thus some intrinsic decline in the rate of cellular respiration appears to occur with age in both sedentary and active men.

Recently, we reported that, in contrast to the present findings in men, RMR adjusted for body composition does not decline significantly across age in healthy women who regularly perform endurance exercise (24). These physically active women, however, did not differ with respect to exercise volume or energy intake. In the present study, physically active men were similarly recruited but were much more varied in their exercise volumes and energy intakes. Such variability allowed us to examine the potential influence of these two factors on RMR.

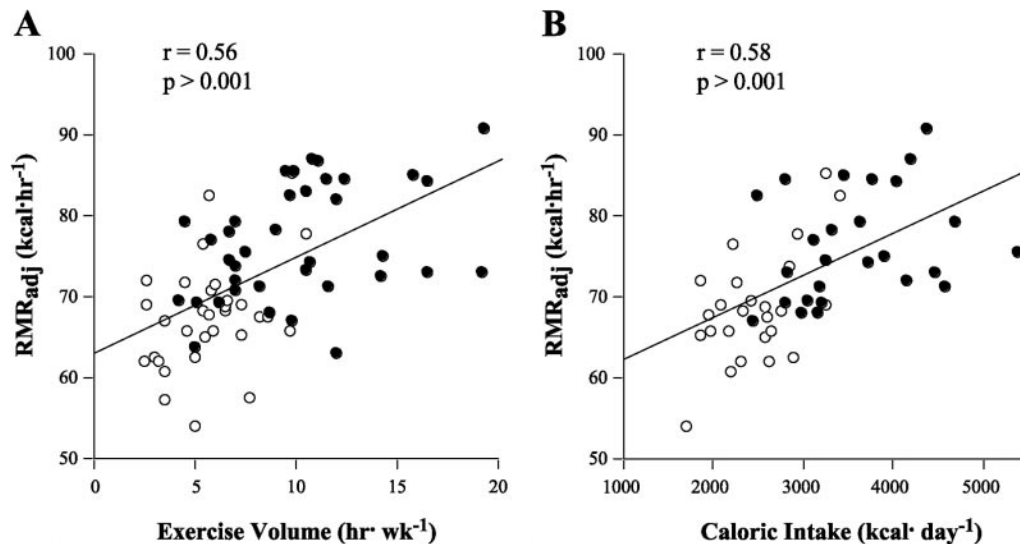


Fig. 2. Simple pairwise regression of RMR (kcal/h) adjusted for fat-free mass (RMR<sub>adj</sub>) vs. exercise volume (h/wk) (A) and vs. energy intake (kcal/day; B) in young (●) and older (○) physically active men.

Table 3. Subject characteristics of the young and older physically active subgroups matched for exercise volume

	Physically Active Men	
	Young (n = 11)	Older (n = 11)
Age, yr	26 ± 1	62 ± 2*
Body mass, kg	71.0 ± 1.6	73.8 ± 2.5
BMI, kg/m <sup>2</sup>	22.2 ± 0.5	23.8 ± 0.4*
% Body fat	11.4 ± 0.8	16.0 ± 1.1*
Fat mass, kg	7.8 ± 0.8	12.0 ± 1.2*
Fat-free mass, kg	63.2 ± 1.4	61.8 ± 1.7
Energy intake, kcal/day	3,448 ± 307	2,573 ± 158*
Energy intake, kcal/kg	47.9 ± 3.0	33.9 ± 1.8*
Exercise volume, hr/wk	7.5 ± 0.6	7.6 ± 0.6
VO <sub>2max</sub> , ml·kg <sup>-1</sup> ·min <sup>-1</sup>	60.8 ± 1.4	44.7 ± 1.4*

Values are means ± SE. BMI, body mass index. \*P < 0.05.

We first hypothesized that an age-associated decline in exercise volume might play a role in the lower RMR<sub>adj</sub> with age in the active men. This hypothesis was supported by the observation that there was no

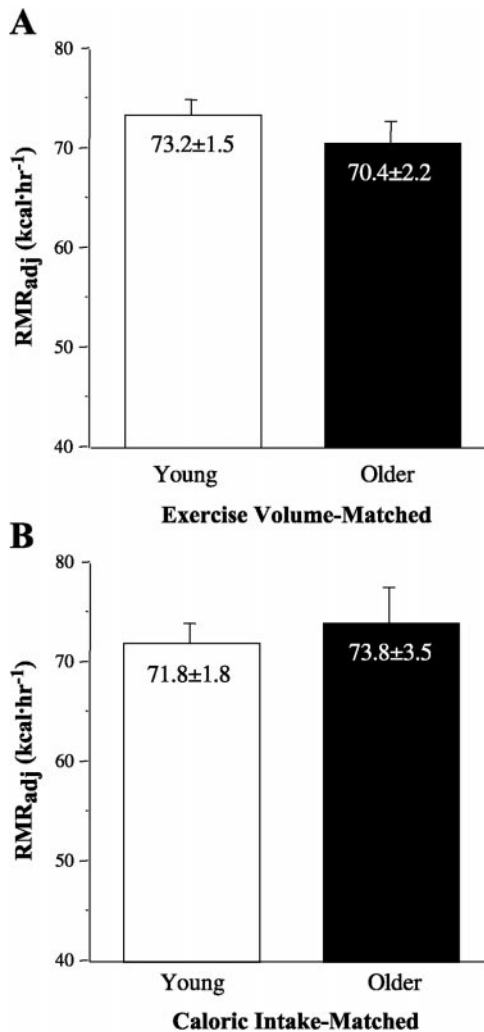


Fig. 3. Mean ± SE values for RMR (kcal/h) adjusted for fat-free mass (RMR<sub>adj</sub>) in young and older physically active men matched for exercise training volume (h/wk; A) and for energy intake (kcal/day; B).

age-related difference in RMR<sub>adj</sub> in subgroups of young and older physically active men matched for total weekly hours of endurance exercise. It should be noted that subjects were not matched for exercise intensity, and it is likely that the young subjects exercised at a higher intensity than the older subjects did, because their energy intake was significantly higher. Thus they were likely expending more energy per hour of exercise. Nevertheless, our results are consistent with the findings in young males of Tremblay et al. (23), who used a similar quantification of exercise volume and reported that RMR was higher in a subgroup who exercised 12–16 h/wk compared with a subgroup exercising 6–10 h/wk.

We additionally hypothesized that age-associated declines in energy intake might play a role in declines in RMR<sub>adj</sub> with age in active men. In the present study, reductions in daily energy intake across age were the single strongest univariate correlate of age-associated differences in RMR<sub>adj</sub>. Moreover, when subgroups of the men matched for estimated energy intake were compared, there were no age-related differences in RMR<sub>adj</sub>. Furthermore, both estimated energy intake and exercise volume remained significantly correlated with RMR<sub>adj</sub> when the other was held constant by use of partial correlation analysis, supporting the concept that exercise volume and energy intake may exert independent influences on age-associated differences in RMR<sub>adj</sub>.

The common link between RMR<sub>adj</sub>, exercise volume, and energy intake may involve the concept of “energy flux.” Bullough et al. (2) reported that young endurance exercise-trained males studied in a high state of energy flux (i.e., high exercise-induced energy expenditure matched by high daily energy intake) had an elevated RMR compared with a low energy flux state. Thus, in the present study, it is possible that the older physically active men were in a relatively lower state of energy flux than their younger counterparts, who exercised more and consumed more energy. Our observation that subgroups of men matched for exercise volume or energy intake do not differ with respect to

Table 4. Subject characteristics of the young and older physically active subgroups matched for total energy intake

	Physically Active Men	
	Young (n = 6)	Older (n = 6)
Age, yr	29 ± 2	66 ± 3*
Body mass, kg	70.9 ± 2.9	74.2 ± 2.3
BMI, kg/m <sup>2</sup>	22.3 ± 0.7	23.3 ± 0.6
% Body fat	12.9 ± 2.1	14.7 ± 1.2
Fat mass, kg	9.4 ± 1.9	10.9 ± 0.9
Fat-free mass, kg	61.6 ± 1.3	63.2 ± 2.2
Energy intake, kcal/day	2,988 ± 134	2,999 ± 149
Energy intake, kcal/kg	42.2 ± 1.4	40.3 ± 1.1
Exercise volume, h/wk	9.5 ± 1.5	6.9 ± 0.8
VO <sub>2max</sub> , ml·kg <sup>-1</sup> ·min <sup>-1</sup>	58.0 ± 2.5	38.1 ± 1.9*

Values are mean ± SE. \*P < 0.05.

RMR<sub>adj</sub> supports this possibility. A comprehensive study of all components of energy balance could add further insight into potential age and exercise-related changes in energy flux.

In the present study, RMR<sub>adj</sub> and  $\dot{V}O_{2\max}$  were positively related in the overall population ( $r = 0.42$ ,  $P < 0.001$ ). However, it seems unlikely that there is a direct causal relationship between these two variables, as there were no differences in RMR<sub>adj</sub> between the young and older physically active men matched for either exercise volume or energy intake despite lower  $\dot{V}O_{2\max}$  in the older men. It may be that there is a genetic component of energy-consuming processes that is common to both  $\dot{V}O_{2\max}$  and RMR<sub>adj</sub> and thus, at least partially, determines their relation.

There are at least three limitations to the present study that should be noted. First, as with all cross-sectional studies, we cannot discount the possibility that genetic or constitutional factors influenced our findings. Second, there is error inherent in the self-reported measures of energy intake. However, we do not have reason to believe that under- or overreporting of dietary intake was more prevalent in one group compared with another. Thus relative differences among the four groups should be valid. Furthermore, a recent study has related energy intake to basal metabolic rate (EI/BMR) to categorize subjects as either under (EI/BMR  $< 1.35$ )- or over (EI/BMR  $> 2.4$ )-reporters (10). Our young and older physically active men appear to be reporting energy intakes accurately on the basis of EI/RMR ratios of  $1.69 \pm 0.05$  and  $1.68 \pm 0.04$ , respectively (not different,  $P = 0.83$ ). Third, our quantification of exercise volume is based on duration of endurance exercise/week and does not quantify potential differences in exercise intensity between young and older subjects. It is likely that young subjects expended more energy for any given exercise volume due to higher intensity of exercise.

In conclusion, the results of the present study support the idea that RMR<sub>adj</sub> declines with age in men who regularly perform endurance exercise. Moreover, it appears that age-associated reductions in exercise volume and daily energy intake contribute to this decline in RMR<sub>adj</sub>. Our results have important physiological and clinical implications regarding the role of regular endurance exercise in the prevention of age-related obesity. In men, body weight and fatness increase with age (4, 11) and are associated with increased morbidity and premature mortality from cardiovascular and metabolic diseases (3, 8). Declines in energy expenditure that occur disproportionate to declines in energy intake likely contribute to these age-related increases in body weight and fatness. Although RMR<sub>adj</sub> declined with age in our physically active men in conjunction with declines in exercise volume and energy intake, RMR<sub>adj</sub> did not differ between young and older physically active men who performed the same volume of endurance exercise (in terms of hours/week, regardless of intensity) and/or consumed the same number of calories per

day. This would suggest that men who are able to maintain high levels of exercise and energy intake with age might better maintain RMR (per unit of fat-free tissue), which in turn might play a role in their lesser increase in body weight and fatness with age. This is supported by our observation of smaller age-related differences in percent body fat in the subgroups matched for energy intake and exercise volume, as well as similar RMR<sub>adj</sub> and adiposity in older physically active and young sedentary subjects. Furthermore, the higher energy diet appropriate for physically active older adults increases the likelihood that older physically active individuals can meet their daily micronutrient needs.

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