Effect of intensity of physical activity on body fatness and fat distribution[1,2]

Angelo Tremblay, Jean-Pierre Després, Claude Leblanc, Cora Lynn Craig,
Blake Ferris, Thomas Stephens, and Claude Bouchard

ABSTRACT To evaluate the effect of intensity of physical activity on body fatness and fat distribution, observations of 1366 women and 1257 men who participated in the 1981 Canada Fitness Survey were analyzed. Subjects were tested for energy expenditure of leisure-time activities and estimated maximal oxygen uptake ($\dot{V}O_2$max), body fatness was measured by subcutaneous skinfold thicknesses, and anthropometric measurements were made. Subjects of both sexes were categorized into four subgroups on the basis of their participation in leisure-time activities of various intensities. In general, subjects practicing vigorous activities on a regular basis had lower subcutaneous skinfold thicknesses and waist-to-hip ratios (WHRs) than those not performing these activities. These differences remained statistically significant after a covariance analysis was used to remove the effect of total energy expenditure of leisure-time activities on subcutaneous fat and fat distribution. Moreover, the WHR remained significantly lower in subjects performing high-intensity exercise after the effect of subcutaneous fat on fat distribution was adjusted for. *Am J Clin Nutr* 1990;51:153–7.

KEY WORDS Fatness, adiposity, energy expenditure, physical activity

Introduction

Exercise training is frequently used during the course of a weight-reducing program and its beneficial effects on fitness are well accepted. The potential of regular exercise to induce weight loss has not been systematically demonstrated, however. Indeed, some investigators observed that exercise training can induce a substantial reduction in body weight (1–3), whereas others found essentially no morphological change in obese individuals subjected to this treatment (4, 5). A close examination of the training protocols used in these investigations reveals that the quantity of exercise performed was much higher in studies that showed a substantial weight loss in comparison with those not demonstrating this effect. This suggests that the impact of training on body weight and fat is to some extent dependent on the level of energy expenditure induced by exercise.

Exercise intensity is another dimension of exercise prescription that may influence energy balance independently of the effect of exercise duration. The common belief among health professionals is that the optimal exercise prescription to be recommended in weight-reducing programs is a low-intensity exercise. This obviously represents a secure approach but a low-intensity exercise is also considered the most appropriate prescription because the proportion of lipid oxidized is higher than that observed during a vigorous effort (6). If one considers only the physiological adaptations that occur during exercise, this hypothesis seems to be justified. However, if the postexercise adaptations are also taken into account, it becomes unclear whether a low-intensity exercise really represents the prescription that will maximize the postexercise negative energy balance. Indeed, Stevenson et al (7) found that enforced exercise induced a short-term suppressing effect on energy intake, which might be associated with the stress generated by exercise. In a recent study Lennon et al (8) obtained results suggesting that the increase in resting metabolic rate (RMR) induced by training might depend on the intensity of the exercise. Thus, these observations suggest that vigorous exercise is more likely to create a negative energy balance than is low-intensity exercise. If this hypothesis is valid, it could mean that for a given level of energy expenditure of activities, people regularly participating in vigorous activities during their leisure time are characterized by reduced adiposity. To examine this notion, we analyzed data of the 1981 Canada Fitness Survey (9) in which body fatness, fat distribution, and energy expenditure of leisure-time activities accounting for frequency, intensity, and duration were measured in a large cohort of men and women.

Methods

Subjects

The subjects were women (*n* = 1366) and men (*n* = 1257) aged 20–49 y who participated in the 1981 Canada Fitness Survey (9). They were measured for energy expenditure of leisure-time activities, estimated maximal oxygen uptake ($\dot{V}O_2$max), and subcutaneous fat and anthropometric characteristics. The

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[1] From the Physical Activity Sciences Laboratory, Laval University, Ste-Foy, Québec, and the Canadian Fitness and Lifestyle Research Institute, Ottawa.

[2] Address reprint requests to A Tremblay, Physical Activity Sciences Laboratory, PEPS, Laval University, Sainte-Foy, Québec, Canada G1K 7P4.

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TABLE 1
Energy expenditure of activities (EEA), $\dot{V}O_2max$, and anthropometric characteristics in women categorized by intensity of usual daily leisure-time activities*

	Activity intensity					
	A	B	C	D	Statistical analysis	
Variable	($x < 5$ METS) ($n = 848$)	($5 \leq x < 7$ METS) ($n = 252$)	($7 \leq x < 9$ METS) ($n = 112$)	($x \geq 9$ METS) ($n = 154$)	ANOVA	ANCOVA†
EEA ($kcal \cdot kg^{-1} \cdot y^{-1}$)	297 ± 1192	333 ± 913	503 ± 1605	257 ± 546	NS	—
$\dot{V}O_2max$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	32.3 ± 5.0	33.6 ± 5.0	34.7 ± 4.9	35.7 ± 4.2	A ≠ B, C, D; B ≠ D	A ≠ B, C, D
Body weight (kg)	60.3 ± 10.7	59.5 ± 9.9	59.2 ± 9.0	59.8 ± 8.2	NS	NS
BMI (kg/m^2)	23.0 ± 3.8	22.4 ± 3.4	21.9 ± 2.7	22.2 ± 8.2	A ≠ C	A ≠ C
Waist-to-hip ratio	0.76 ± 0.06	0.74 ± 0.05	0.75 ± 0.11	0.73 ± 0.04	A ≠ B, D; C ≠ D	A ≠ B, D; C ≠ D
Circumferences (cm)						
Waist	73.0 ± 8.9	71.1 ± 7.6	70.5 ± 7.1	69.9 ± 5.3	A ≠ B, C, D	A ≠ B, C, D
Hip	96.2 ± 8.2	95.5 ± 6.6	94.7 ± 8.1	95.5 ± 6.0	NS	NS

* $\bar{x}$ ± SD. NS, $p > 0.05$.

† Covariance analysis, controlling for the statistical effect of the total energy expenditure of activities.

procedures followed in this study conformed to the Helsinki Declaration of 1975 as revised in 1983.

Protocol

Energy expenditure of leisure-time activities was estimated by use of a questionnaire similar to the Minnesota Leisure Time Activity Questionnaire (10). As reported elsewhere (9), the questionnaire was designed to collect extensive details on leisure-time physical activity, including type, frequency, duration, and intensity, for periods ≤ 1 y. The complete questionnaire and further details on its administration and analysis were already published (11, 12). A description of the 1981 Canada Fitness Survey is also presented in one of these reports (9).

Total energy expenditure of activities was calculated as follows:

$$\text{Total energy expenditure } (kcal \cdot kg^{-1} \cdot y^{-1}) = \sum (N_i \times D_i \times mets_i)$$

where N is the number of occasions of activity i in the past 12 mo, D is the average duration in hours of that activity, and *mets* is the energy cost of the activity expressed as kilocalories expended per kilogram body weight per hour of activity. A met was considered as corresponding to 1 $kcal \cdot kg^{-1} \cdot h$ of $activity^{-1}$ and the *mets* value for each activity was established by a group of experts on the basis of the exercise and work physiology literature (13).

To determine the effect of exercise intensity on adiposity, subjects of each sex were divided into four subgroups on the basis of the *mets* value of their leisure-time activities by use of the following criteria: group A, subjects not reporting activities of ≥ 5 METS ≤ 6 mo in the past year; group B, subjects reporting activities of ≥ 5 METS but < 7 METS for ≥ 6 mo in the past year; group C, subjects reporting activities of ≥ 7 METS but < 9 METS for ≥ 6 mo in the past year; and group D, subjects reporting activities of ≥ 9 METS for ≥ 6 mo in the past year. When a subject could be classified in more than one group, he or she was assigned to the highest relevant intensity group. The mean age (±SD) and number of women in each subgroup were as follows: group A, 31.9 ± 8.2 y, $n = 848$; group B, 29.9 ± 8.1 y, $n = 252$; group C, 28.2 ± 7.0 y, $n = 112$; and group D, 28.5 ± 6.8 y, $n = 154$. The corresponding values for men were group A, 31.9 ± 8.2 y, $n = 552$; group B, 30.2 ± 8.2 y, $n = 224$; group C, 29.5 ± 7.4 y, $n = 161$; and group D, 29.7 ± 7.7 y, $n = 320$.

The protocol used for measuring fitness variables, which, like the questionnaire, were administered in the home, was the Canadian Standardized Fitness Test (14). Heart rate response to a standardized, multistage, submaximal step test was measured for the estimation of $\dot{V}O_2max$. This battery of field tests also included the measurement of waist and hip circumferences as well as skinfold thicknesses at the following sites: suprailiac, subscapular, calf, biceps, and triceps.

Statistical procedures

A one-way analysis of variance (ANOVA) was used to compare values of the four intensity subgroups of subjects for each dependent variable (15). Moreover, we performed the same comparison after adjustment by covariance analysis for the contribution of total energy expenditure of leisure-time activities on the intergroup differences (15). The differences between activity-intensity groups in skinfold thicknesses and waist-to-hip-circumference ratio (WHR) were also studied by use of a covariance analysis controlling for the contribution of total subcutaneous fat (sum of five skinfold thicknesses).

Results

Tables 1 and 2 present values of total energy expenditure of leisure-time physical activities, $\dot{V}O_2max$, and anthropometric characteristics in women and men, respectively. In general, subjects reporting vigorous physical activities in their leisure time were also characterized by higher levels of energy expenditure of activities except for women categorized in the highest exercise-intensity group, whose values were similar to those of the lowest-intensity group. All these variations were not statistically significant, however, probably because of the large intra-

TABLE 2
Energy expenditure of activities (EEA), $\dot{V}O_2$max, and anthropometric characteristics in men categorized by intensity of usual daily leisure-time activities*

	Activity intensity				Statistical analysis	
Variable	A ($x < 5$ METS) ($n = 552$)	B ($5 \leq x < 7$ METS) ($n = 224$)	C ($7 \leq x < 9$ METS) ($n = 161$)	D ($x \geq 9$ METS) ($n = 320$)	ANOVA	ANCOVA†
EEA ($kcal \cdot kg^{-1} \cdot y^{-1}$)	376 ± 1062	373 ± 802	523 ± 1387	493 ± 1116	NS	—
$\dot{V}O_2$max ($mL \cdot kg^{-1} \cdot min^{-1}$)	42.2 ± 7.1	44.6 ± 8.0	44.2 ± 7.5	46.4 ± 7.6	A ≠ B, C, D; B, C ≠ D	A ≠ B, C, D; B, C≠ D
Body weight (kg)	76.2 ± 11.5	76.6 ± 11.2	75.8 ± 10.8	76.8 ± 9.9	NS	NS
BMI (kg/m^2)	24.7 ± 3.3	24.9 ± 3.3	24.7 ± 3.3	24.5 ± 2.8	NS	NS
Waist-to-hip ratio	0.88 ± 0.06	0.87 ± 0.06	0.87 ± 0.06	0.86 ± 0.06	A, B, C ≠ D	A, B, C ≠ D
Circumferences (cm)						
Waist	85.8 ± 9.0	85.2 ± 9.0	84.9 ± 8.8	83.9 ± 8.0	A ≠ D	A ≠ D
Hip	97.7 ± 7.1	97.5 ± 5.9	97.0 ± 6.4	97.8 ± 5.8	NS	NS

* $\bar{x}$ ± SD. NS, $p > 0.05$.
† Covariance analysis, controlling for the statistical effect of the total energy expenditure of activities.

group variations in energy expenditure of activities. As expected, $\dot{V}O_2$max was significantly higher in subjects reporting activities of moderate-to-high intensity in comparison with subjects not performing these activities. This difference was also revealed by the covariance analysis, which removed the contribution of total energy expenditure of activities on variations in $\dot{V}O_2$max.

Tables 1 and 2 also indicate that body weight was comparable in each activity-intensity group for both sexes. On the other hand, female and male subjects categorized in the highest activity-intensity group were characterized by a reduced WHR ($p < 0.05$), which was mainly explained by lower waist circumferences. The intergroup differences in WHR and waist circumference persisted when statistical controls were performed for the effect of energy expenditure of activities (Tables 1 and 2).

As shown in **Table 3,** women performing moderate-to-high-intensity leisure-time activities had significantly lower amounts of subcutaneous fat than did subjects not practicing such activities, except for the calf skinfold thickness. Furthermore, this table shows that these differences persisted when the contribution of total energy expenditure of activities was removed by covariance analysis.

Table 4 indicates that men practicing vigorous activities also tended to have a reduced subcutaneous adiposity. The intergroup differences for women revealed by the ANOVA were essentially unchanged when the contribution of total energy expenditure of activities to variations in adiposity was removed.

The effect of exercise intensity on skinfold thicknesses and WHR adjusted for the effect of the sum of skinfold thicknesses is presented in **Table 5.** In both sexes none of the differences between activity-intensity groups in skinfold thicknesses persisted after the effect of total subcutaneous adiposity was controlled for. On the other hand, after the statistical correction for the role of subcutaneous fat, the WHR

TABLE 3
Subcutaneous fat in women categorized by the intensity of usual daily leisure-time activities*

	Activity intensity				Statistical analysis	
Variable	A ($x < 5$ METS) ($n = 848$)	B ($5 \leq x < 7$ METS) ($n = 252$)	C ($7 \leq x < 9$ METS) ($n = 112$)	D ($x \geq 9$ METS) ($n = 154$)	ANOVA	ANCOVA†
Skinfold thickness (mm)						
Suprailiac	13.4 ± 7.5	12.2 ± 6.3	11.0 ± 5.8	11.4 ± 5.4	A ≠ C, D	A ≠ C, D
Subscapular	14.6 ± 6.7	13.2 ± 5.6	12.9 ± 5.7	12.3 ± 4.3	A ≠ C, D	A ≠ C, D
Calf	16.5 ± 6.8	15.3 ± 5.8	15.0 ± 5.2	15.4 ± 5.9	NS	NS
Biceps	8.5 ± 4.6	7.8 ± 4.1	7.7 ± 4.4	7.1 ± 3.1	A ≠ D	A ≠ D
Triceps	18.1 ± 6.7	16.9 ± 5.6	16.4 ± 5.1	16.5 ± 5.1	A ≠ C, D	A ≠ C, D
Σ 5 skinfold thicknesses (mm)	70.5 ± 28.4	65.3 ± 24.0	62.0 ± 21.0	62.6 ± 20.2	A ≠ C, D	A ≠ C, D
Σ Trunk skinfold thicknesses (T) (mm)	27.9 ± 13.6	25.4 ± 11.5	23.9 ± 11.2	23.7 ± 9.0	A ≠ C, D	A ≠ C, D
Σ Extremity skinfold thicknesses (E) (mm)	42.9 ± 16.6	39.9 ± 13.8	38.7 ± 12.2	38.9 ± 12.8	A ≠ C, D	A ≠ C, D
ΣT/ΣE	0.66 ± 0.19	0.63 ± 0.16	0.61 ± 0.16	0.62 ± 0.17	A ≠ C, D	A ≠ C

* $\bar{x}$ ± SD. NS, $p > 0.05$.
† Covariance analysis, controlling for the statistical effect of the total energy expenditure of activities.

TABLE 4
Subcutaneous fat in men categorized by the intensity of usual daily leisure-time activities*

	Activity intensity				Statistical analysis	
Variable	A ($x < 5$ METS) ($n = 552$)	B ($5 \leq x < 7$ METS) ($n = 224$)	C ($7 \leq x < 9$ METS) ($n = 161$)	D ($x \geq 9$ METS) ($n = 320$)	ANOVA	ANCOVA†
Skinfold thickness (mm)						
Suprailiac	16.7 ± 7.8	16.3 ± 8.0	15.9 ± 8.3	15.1 ± 7.3	A ≠ D	A ≠ D
Subscapular	13.8 ± 5.8	13.4 ± 5.8	13.3 ± 6.0	12.8 ± 5.0	NS	NS
Calf	8.9 ± 4.3	8.1 ± 3.2	8.2 ± 3.9	8.0 ± 3.4	A ≠ B, D	A ≠ B, D
Biceps	5.0 ± 2.2	4.8 ± 2.0	4.8 ± 2.6	4.6 ± 1.7	A ≠ D	A ≠ D
Triceps	10.6 ± 4.3	10.3 ± 4.1	9.9 ± 4.2	9.8 ± 3.9	NS	NS
Σ Five skinfold thicknesses (mm)	54.9 ± 21.3	52.8 ± 20.0	52.1 ± 21.7	50.1 ± 18.0	A ≠ D	A ≠ D
Σ Trunk skinfold thicknesses (T) (mm)	30.4 ± 12.7	29.7 ± 12.8	29.1 ± 13.6	27.9 ± 11.7	NS	NS
Σ Extremity skinfold thicknesses (E) (mm)	24.5 ± 9.9	23.1 ± 8.5	22.9 ± 9.8	22.3 ± 7.8	A ≠ D	A ≠ D
ΣT/ΣE	1.27 ± 0.34	1.30 ± 0.35	1.29 ± 0.38	1.27 ± 0.34	NS	NS

* $\bar{x}$ ± SD. NS, $p > 0.05$.

† Covariance analysis, controlling for the statistical effect of the total energy expenditure of activities.

remained significantly lower in subjects who performed high-intensity exercise.

Discussion

The effect of exercise on body weight and fat loss has been investigated frequently and, despite the large amount of data accumulated, uncertainty still persists concerning what may constitute the prescription that will maximize caloric deficit. Evidence supports the concept that morphological changes are more pronounced when a large amount of exercise is performed. On the other hand, the available experimental data do not allow us to address the question of the level of exercise intensity that will favor a maximal postexercise negative energy balance (16). Thus, the primary goal of the present study was to look at morphological characteristics of people performing or not performing vigorous physical activities in their leisure time on a regular basis. The data of the 1981 Canada Fitness Survey were particularly appropriate for investigating this effect because energy expenditure of activities that accounts for frequency, intensity, and duration as well as subcutanous fat and anthropometric characteristics were measured in a large national sample.

As expected, participation in activities of increasing levels of intensity was associated with increases in $\dot{V}O_2$max. This is in agreement with results reported by Taylor et al (10) who observed the same phenomenon with the Minnesota Leisure Time Activity Questionnaire. These observations suggest that the type of questionnaire used in the present study is valid for discriminating between individuals with respect to the intensity of usual leisure-time activities.

The major finding of this study is that subcutaneous fat was generally lower in subjects who regularly practiced vigorous physical activities. Moreover, when statistical controls were performed to remove the effect of energy expenditure of activities, a significant difference persisted between subjects practicing or not practicing vigorous activities on a regular basis. This indicates that the effect of exercise intensity on body fat and its distribution was not due to the energy cost of activities but to an effect on other components of energy balance. In this sense, experimental evidence suggests that the intensity of exercise might influence energy intake. Thus, according to Stevenson et al (7), vigorous exercise might exert a suppressing effect on postexercise energy intake. This hypothesis is supported by recent data that indicate that there is a significant association between the exercise-induced increase in catecholamines and food-intake inhibition (17).

The reduction in body fat observed in individuals performing vigorous exercise may also be explained by an increase in postexercise RMR. Indeed, Lennon et al (8) recently reported data suggesting that the increase in RMR induced by training might depend on the level of exercise intensity.

Results presented in Table 5 indicate that the effect of exercise intensity on individual skinfold thicknesses was no longer observed after adjustment for the concomittant effect of exercise intensity on total subcutaneous fat. This suggests that the response of each skinfold was proportional to the overall response of subcutaneous fat. On the other hand, results indicate

TABLE 5
Effect of exercise intensity on waist-to-hip ratio and individual skinfold thicknesses corrected for the sum of skinfold thicknesses*

Variable	Men	Women
Waist-to-hip ratio	A, B, C ≠ D‡	A, C ≠ D
Skinfold thickness (mm)		
Suprailiac	NS	NS
Subscapular	NS	NS
Calf	NS	NS
Biceps	NS	NS
Triceps	NS	NS

* NS, $p > 0.05$. Intergroup differences were determined by a covariance analysis controlling for the statistical effect of the sum of skinfold thicknesses.

‡ *See* Tables 1–4 for characteristics of groups A, B, C, and D.

that the WHR remained significantly lower in individuals who practiced high-intensity exercise even after the effect on subcutaneous fat was controlled for. This result suggests that high-intensity exercise is associated with a preferential mobilization of abdominal fat. To our knowledge, it is the first time that such a preferential regional mobilization of fat is reported. These results are concordant with earlier reports from our laboratory (18, 19) indicating a trend for a greater reduction of abdominal fat during exercise-induced fat loss. The present report further addresses this issue by controlling for the reduction in total fat, which is important considering the well-established positive relationship between obesity and the proportion of abdominal fat (20–23).

We acknowledge that our study reports cross-sectional observations that warrant further investigation in a longitudinal exercise-training study. Considering the importance of abdominal fat as a correlate of the metabolic complications of obesity (20–23), the effect of exercise intensity on the proportion of abdominal fat could have beneficial effects on the health profile of sedentary individuals. Such an issue also deserves further investigations.

Results presented in Tables 3 and 4 showed that statistically significant effects of exercise intensity on subcutaneous fat were observed more systematically in women than in men. This is likely explained by the fact that the criterion of exercise intensity that could be used from the questionnaire represented a greater relative stress for women than for men. Therefore, these data should not be used to speculate about the existence of sex differences in the ability to adapt to exercise training.

In summary, the results of this study show that individuals performing vigorous activities are characterized by reduced levels of subcutaneous adiposity and WHR. This phenomenon is also observed when the statistical effect of total energy expenditure of leisure-time activities on subcutaneous fat is removed. The effect of exercise intensity on fat distribution also seems to be independent of variations in total subcutaneous fat.

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