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ORIGINAL RESEARCH

Level of physical activity and anthropometric characteristics in old age—results from a national health survey

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Abstract
Advanced age is associated with degenerative changes in body composition. There is evidence suggesting that changes may vary upon differences in lifestyle, environment, or gender. Physical activity engagement is considered an important component of lifestyle definition. There are suggestions that engaging in physical activity might alleviate degenerative body compositional changes. The objective is to assess the relationship between adherence to recommended guidelines of physical activity and anthropometric parameters in Israeli older adults. Anthropometric measures, including height, weight, and waist circumference, were taken, and BMI was calculated, from a random sample of 1,663 elderly adults (799 men and 864 women), aged 74.31 (±6.05) years old. Participants reported their physical activity habits and, based on official guidelines recommendations, they were divided into sufficiently active, insufficiently active, and inactive groups. One-way ANOVA (level of physical activity) for both genders was conducted for each anthropometric variable. In both genders, an association between level of physical activity and weight, waist circumference, and BMI was found, with lower values among the sufficiently active. In addition, a relationship between level of physical activity and height was indicated among women, implying that the more active women were taller than the less active. In addition to the already known health benefits of physical activity in old age, it is possible that adherence to recommended guidelines of physical activity is associated with favorable anthropometric characteristics.

Keywords Anthropometrics · Physical activity · Aging · Health · Guidelines

Declaration of original work The authors declare that the submitted manuscript has not been published before (neither in English or in any other language), and it is not under consideration for publication elsewhere.

Contribution to the paper A. Dunsky—designed the research, analyzed the data, and wrote the paper
S. Zach—contributed her ideas to the analysis of the data
A. Zeev—formulated the statistical design, analyzed the data, and reviewed the Results section
U. Goldbourt—contributed his ideas and expertise to the analysis of the data
T. Shimony—prepared the data for statistical analysis
R. Goldsmith—helped in obtaining the Ethics Committee approval and coordinated the collection of the data
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Introduction

Anthropometric parameters reflect body size and composition. In advanced age, anthropometric parameters are exposed to degenerative processes, leading to body composition changes. With regard to height, there is a longitudinal decrease as a result of vertebral compression, change in height and shape of disks, loss of muscle tone, and postural changes [6, 25]. Regarding weight, until the age of 75, people tend to gain weight, and in very old age, there is a decrease in weight [2, 25]. As a consequence, body mass index (BMI), calculated based on weight and height, tends to increase in middle age and then stabilizes between 50 and 70 years old [8, 23]. Both genders show a decrease in average BMI after the age of 75 [23].

Several factors such as genetics and diseases, may affect anthropometric parameters. For example, increases in weight, BMI, and waist circumference are correlated with increased incidence of illnesses, such as cardiovascular disease and obesity-related metabolic risk [3, 7, 10], as well as various kinds of cancer [9, 20].

A lifestyle factor known to be correlated with anthropometric parameters such as BMI, waist circumference, and weight is engagement in regular physical activity [4, 6, 8, 12, 13, 22, 24]. On the other hand, habitual physical activity is also known to be negatively correlated with some diseases [2, 20].

Simoes et al. [21] provided insight into the association between leisure-time physical activity and obesity-related dependency on activities of daily living among older adults. They suggested that obese older adults who are also inactive are candidates for public health programs, as most of them become disabled older adults. Another study indicated that in obese individuals who remained physically active, the risk of morbidity and mortality were lower than in normal-weight individuals who were sedentary [2].

Recently, two different longitudinal studies followed physical activity habits of twins, and their association with high-risk fat [13] and with two anthropometric parameters (waist circumference and weight gain) [24]. Both studies point to the positive association between physical activity and more favorable body composition and anthropometric characteristics.

The evidence in the literature on the relationship between anthropometric parameters and various types of diseases in advanced age on one hand, and between physical activity and these diseases on the other, led us to pursue the third segment of the triangle, namely the relationship between anthropometric parameters and physical activity. Although both of these are considered predictors of health in advanced age, evidence on the relationship between them is scarce and is reported mainly in relation to incidence of various diseases. Our assumption was that people who adhere to recommended guidelines of activity for preserving health have more favorable anthropometric parameters than those who do not follow the recommended guidelines.

The recommended dose of physical activity in advanced age has been determined and disseminated by several official health bodies in the last decade [1, 16]. Our purpose in the current study was to examine whether adopting the prescription of physical activity as recommended by these health bodies is associated with better anthropometric characteristics.

Methods

The data presented on the current study are part of the data taken from a survey carried out by the Israel Ministry of Health, over an 18-month period, between July 2005 and December 2006.

Survey population

The target population included Israeli citizens aged 65 and above, living in the community (in their own homes or sheltered housing), who have resided in the country for at least 1 year.

Exclusion criteria

Adults not living in their own homes in the community for the following reasons: being out of the country for 6 months or more, hospitalization for more than 6 months, hospitalization in a psychiatric institution, hospitalization in a long-term care institution or an institution for the mentally fragile or older adults with significant cognitive reduction according to the Mini Mental State Examination (MMSE) score adjusted for age and education, and immigrants who arrived in Israel after December 31, 2003. In total, after the exclusion procedure (which is detailed in Netz et al. [17]), 1,663 individuals, aged 74.31 (±6.05) years old, took part in the study—799 men and 864 women.

The survey was approved by the Ethics Committee of the Chaim Sheba Medical Center and the Ministry of Health. Each interviewee signed an informed consent form for the questionnaire and for the measurement of anthropometric parameters.

Survey tools and organization

A personal, face-to-face interview was conducted in the interviewee's home using a structured questionnaire and a 24-h recall questionnaire. The questionnaire included demographic details and questions on health status, functional status, cognitive state, use of medications and nutritional supplements, physical activity, smoking status, and eating and dieting patterns. Health status was determined based on reported chronic illnesses. The chronic illnesses list included nine illnesses/

conditions: heart disease, lung disease, stroke, renal disease, cancer, diabetes, hypercholesterolemia, hypertension, and osteoporosis. The number of illnesses/conditions was recorded. Smoking status was determined based on three options: currently smoking, smoked in the past, and never smoked. Eating and dieting patterns were based on nutrient data collected, and nutrient intakes, including calcium, were calculated using the Tzameret dietary analysis program, which contains the "BINAT" nutrient database. This program was developed by the Nutrition Department of the Ministry of Health. At the end of the interview, measurements of anthropometric parameters were taken.

Anthropometric measurements

The measurements were carried out twice (and the average was calculated) according to a protocol and included standing height, weight, and waist circumference. All measurements were carried out in light clothing. Weight and height were measured without shoes, although if the interviewee refused to remove his/her shoes, this was noted, and then 2 cm were subtracted from the height measurement.

Weight
Weight measurement was carried out using an analog scale suitable for weighing up to 130 kg, with accuracy to 0.5 kg. The scales were placed on an uncarpeted floor and calibrated before weighing. If the measurements differed by more than 1.0 kg, a third measurement was carried out.

Waist circumference
This was measured using a flexible tape that could measure up to 150 cm, at the narrowest part of the torso, where a *fold* is created when bending sideways. If the two measurements differed by more than 5 mm, a third measurement was carried out.

Height
This was measured using a spring-coil measuring tape. A rigid aluminum angle was used to determine the meeting point of the top of the skull with the wall/door, and stickers were used to mark the height. If the two measurements differed by more than 5 mm, a third measurement was carried out.

BMI
BMI was calculated by the formula: weight (kg)/height (m)^2.

Assessment of physical activity

The physical activity questionnaire used in the current study was based on a standard questionnaire used previously in an adult (aged 25–64) population study by the Israel Center for Disease Control performed together with the Food and Nutrition Services. Participants were asked about their physical activity habits in two sets of questions; one set referred to intensive activity (participation in energetic physical activity that "makes you breathe harder or puff and pant"), and the other to leisure-type physical activity. Participants reported the frequency, duration (months or years), and average length of activity sessions. In addition, they were asked to report the time devoted to specific activities (walking outside or on a treadmill, jogging, swimming, bike riding or stationary cycling, light exercise such as yoga, body shaping, and strength training in a fitness room). Based on recommendations from the American Heart Association [16], the ACSM [1] and the DHHS [5], regarding aerobic exercise, participants were divided into three groups according to level of physical activity (for further details see Netz et al. [17]):

Group 1
: Sufficiently active—those who were involved in moderate leisure-type physical activity for at least 150 min a week or in intensive activity for at least 75 min a week, or a combination of the two.

Group 2
: Insufficiently active—those who were involved in physical activity but for a lesser amount of time than the above.

Group 3
: Inactive—those who reported no activity or activity less than once a week.

Statistical analysis

As there are anthropometric differences between men and women, all analyses were conducted separately for each gender. Analyses were performed in three phases:

1. One-way ANOVAs were conducted for assessing differences between the activity groups on the following demographic and health variables, which are known to relate to anthropometric parameters: age, number of illnesses, number of medications, and calcium intake [2, 3, 6, 7, 9, 10, 20, 25]. A chi-square analysis was conducted on percent of smokers in each group.
2. One-way ANOVAs were conducted for assessing differences between the activity groups on the following anthropometric measurements: weight, waist circumference, height, and BMI. Bonferroni post hoc procedure was used

Table 1 Variables related to anthropometric parameters in the three levels of physical activity among Israeli men (means and standard deviations), 2005–2006

Variable	Sufficiently active n=322	Insufficiently active n=201	Inactive n=276
Age (years)	74.0 (±6.0)	75.6 (±6.3)	75.3 (±6.8)
Illness status (number of illnesses per participant)	2.1 (±1.4)	2.3 (±1.5)	2.5 (±1.6)
Percent of smokers (%)	10.2	12.4	19.4
Calcium intake by food (mg/dl)	615 (±309)	590 (±288)	534 (±321)

for assessing the differences between the activity groups (alpha=0.05).

3. Two-step regressions were conducted to assess the contribution of demographic and health variables (step 1) and physical activity (step 2) to the variability of each anthropometric parameter (step 1).

Results

Descriptive statistics of demographic and health variables for the three levels of physical activity are presented in Table 1 (men) and Table 2 (women). As demonstrated, there is a trend of association between most variables and physical activity. Among men, the sufficiently active group had fewer chronic illnesses ($F_{2,796}$=5.07, p<.01), had a smaller percentage of smokers ($\chi^2_{2,796}$=10.85, p<.01), and was younger ($F_{2,796}$= 4.94, p<.01) than the other two groups. For both men and women, the sufficiently active group had a higher daily intake of calcium ($F_{2,789}$=5.23, p<.01 among men, and $F_{2,854}$=12.1, p<.01 among women) than the other two groups.

Differences between the three physical activity groups on anthropometric parameters are presented in Fig. 1 (men) and Fig. 2 (women).

Significant group differences among men appear on weight ($F_{2,742}$=6.39, p<.01). The inactive group was significantly heavier than the sufficiently active group (p<.01) and had a significantly larger waist circumference ($F_{2,733}$=16.56, p<.01) than the sufficiently and insufficiently active groups (p<.05). In addition, the insufficiently active group had a larger waist circumference than the sufficiently active group (p<.05). The inactive group had a significantly higher BMI ($F_{2,\ 726}$=8.87, p<.01) than the sufficiently active group (p<.01).

Among women, the inactive group was significantly heavier ($F_{2,797}$=11.35, p<.01) than the sufficiently active group (p<.01) and the insufficiently active group (p<.01), and had a significantly larger waist circumference ($F_{2,790}$=23.15, p<.01) than the sufficiently active group (p<.01) and the insufficiently active group (p<.01). The inactive group also had a significantly higher BMI ($F_{2,777}$=18.11, p<.01) than the sufficiently active group (p<.01) and the insufficiently active group (p<.01). In addition, among women (Fig. 2), significant group differences appear on height ($F_{2,791}$=5.22, p<.01). The sufficiently active group was significantly taller than the insufficiently group (p<.05) and the inactive group (p<.05).

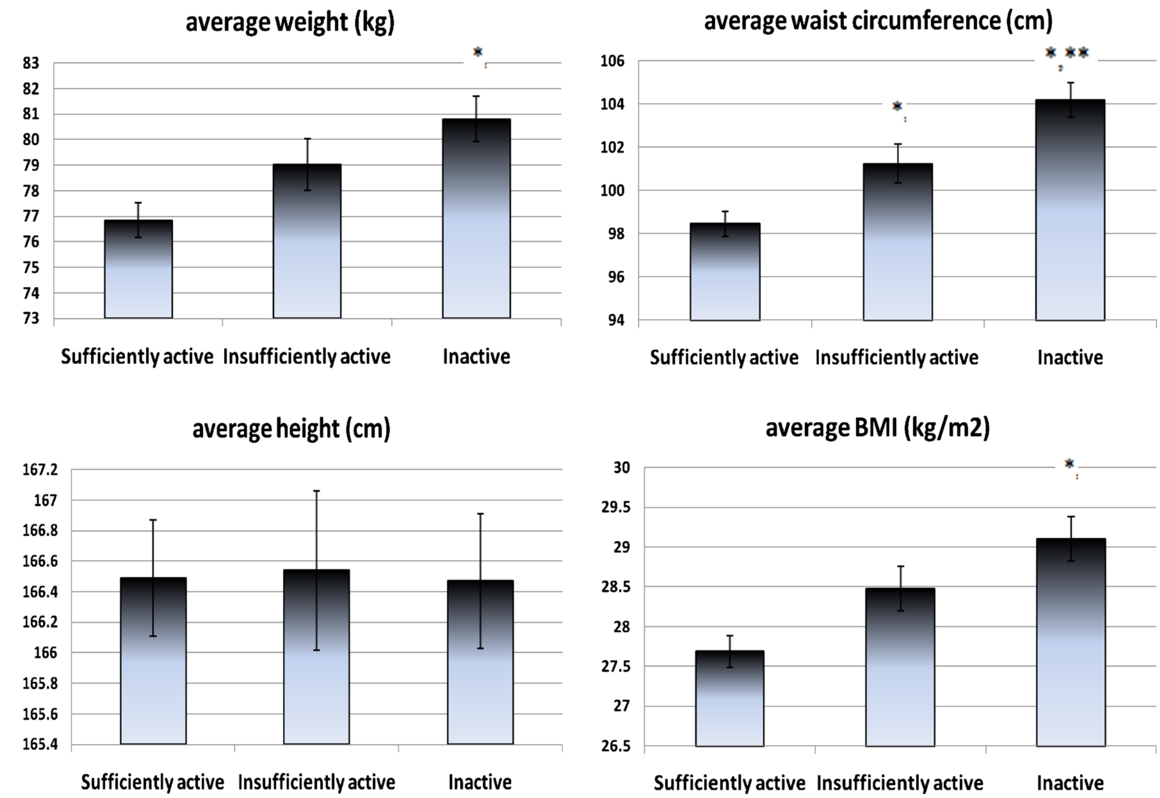
Results of the regressions for men are shown in Table 3. As demonstrated, level of physical activity contributed to the explanation of the variance of three anthropometric variables (weight, waist circumference, and BMI) in addition to demographic and health variables (age, illness status, number of medications, smoking status, and calcium intake).

Results of the regressions for the women (Table 4) are similar to those of the men. In addition, among women, the level of physical activity significantly contributed to the explanation of the variance of height, independent of demographic, and health variables (age, illness status, smoking status, and calcium intake).

In order to examine robustness, a cross-validation procedure was performed. Two separate regressions, each for 50 % of the participants chosen at random, produced the same trend of results.

Table 2 Variables related to anthropometric parameters in the three levels of physical activity among Israeli women (means and standard deviations), 2005–2006

Variable	Sufficiently active n=233	Insufficiently active n=251	Inactive n=380
Age (years)	73.6 (±5.6)	73.8 (±5.2)	74.0 (±6.0)
Illness status (number of illnesses per participant)	2.5 (±1.4)	2.6 (±1.5)	2.7 (±1.5)
Percent of smokers (%)	7.3	8.0	9.0
Calcium intake by food (mg/dl)	603 (±302)	561 (±333)	485 (±272)



*significantly different from sufficiently active, p<.05
**significantly different from insufficiently active, p<.05

Fig. 1 Anthropometric parameters at three levels of physical activity among Israeli men (means and standard errors), 2005–2006. *$p<.05$, significantly different from sufficiently active; **$p<.05$, significantly different from insufficiently active

Discussion

The purpose of this study was to examine the relationship between levels of physical activity, in terms of the recommended guidelines for preserving health, and anthropometric measurements in a population study of Israeli older adults. The results, which corroborated previous studies [4, 6, 8, 12, 13, 22, 24], indicated a clear negative association between level of physical activity and weight, and waist circumference and BMI values, in both genders. The more active a person was, the lower the values of these parameters. Furthermore, even after controlling for age, calcium consumption, health status (number of illnesses and number of medications), and smoking status, this trend still appeared.

Lower values of BMI, weight, and hip circumference are usually considered beneficial in terms of risk for a number of diseases [3, 7, 9, 10, 20]. However, it should be noted that lower values of weight as well as of BMI at age 75 and over may indicate muscular atrophy caused by smoking and bad eating habits, or by genetic, environmental, and social variables [25]. In the current study, muscular mass was not assessed; however, we assessed the relationship between BMI and physical activity separately for participants younger than age 75 (age 65–75); again, significant group differences were found among both men ($F_{2,429}$=8.82, p<.01) and women ($F_{2,516}$=16.18, p<.01). In addition, we do know that the active participants in the present study predominantly reported aerobic exercise as their preferred activity [17]. It is well known that aerobic exercise leads to weight reduction and a decrease in BMI [15], and therefore, the negative association between weight and BMI and physical activity in the present study is probably a result of reduced fat, which is obviously more desirable than reduced muscle mass.

Regarding height, the findings of the current study indicate that for women, height preservation is associated with physical activity. These results support the findings of Dey et al. [6] on Swedish older adults (inactive subjects were shorter than active subjects) and of Sagiv et al. [18] on Belgian older adults. Sagiv et al. followed changes of height as a function of physical activity patterns over 30 years. Based on that study, while significant height loss was observed over the years, the rate of height loss among subjects who were physically active was significantly lower. Since aging is associated with bone loss and fragility, mostly due to the lack of sexual hormones, it may affect the length of bones and, as a

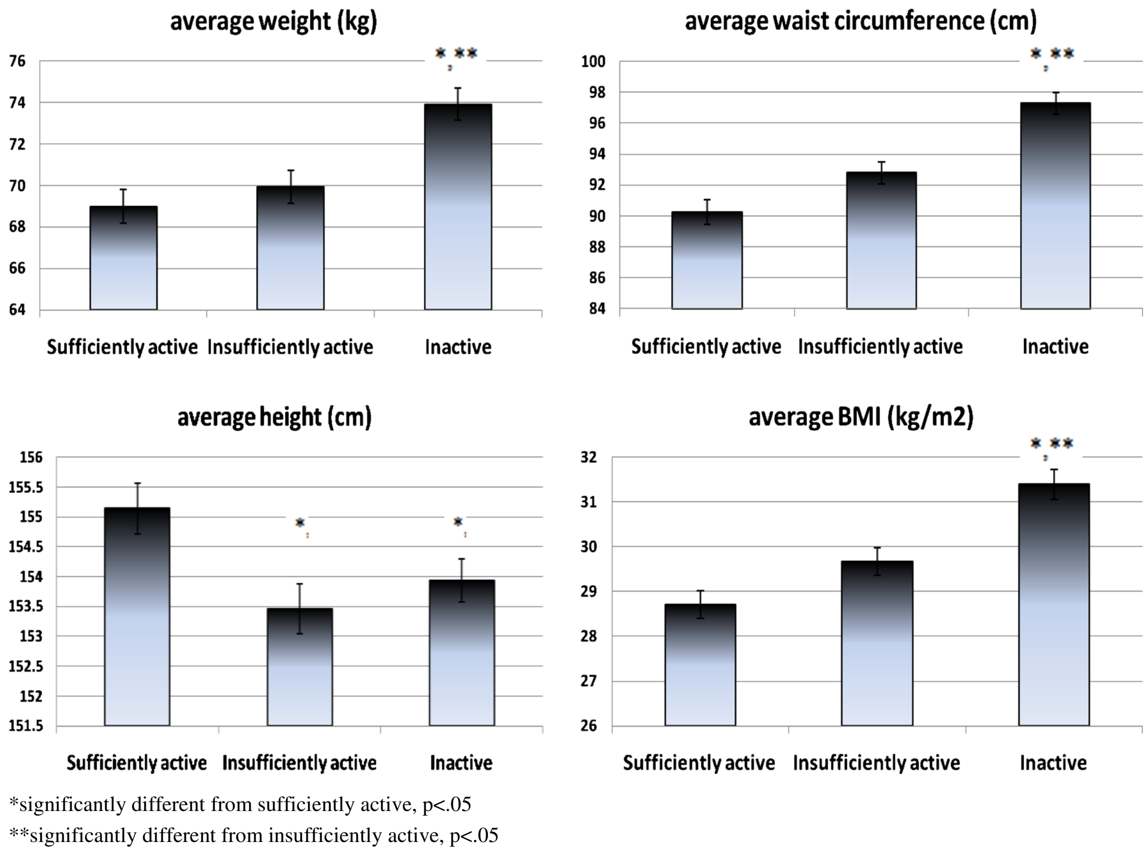


Fig. 2 Anthropometric parameters at three levels of physical activity among Israeli women (means and standard errors), 2005–2006. *$p<.05$, significantly different from sufficiently active; **$p<.05$, significantly different from insufficiently active

consequence, affect the height of the person. Indeed, there is evidence of loss of height in men and women during aging, with a greater decline among women [19].

Although bone growth and loss is strongly determined by genetic factors, physical activity has been commonly considered as an essential stimulus for bone remodeling, which strengthens the bone. The skeletal tissues adapt and respond to mechanical strains such as weight bearing and muscular forces, which occur during engagement in physical activity [14]. That is, physical activity might increase bone density and thus prevent height loss during the aging process [18, 19].

As most daily physical activities involve weight bearing (such as walking, stair climbing, etc.), these activities affect mainly the strength of the weight-bearing bones (such as the lumbar vertebrae and the hip) [11]. Based on this assumption, stronger lumbar vertebrae would maintain their height during the aging process, and this would prevent general height loss. This assumption can explain the association between physical activity and height in women reported in the present study, and may be a reason for encouraging women to engage in weight-bearing physical activity. It should be noted that the differences found in our study between activity levels, although significant, are small in terms of absolute values, and thus are not relevant in clinical terms. However, the positive association between level of physical activity and height may point to the potential contribution of physical activity to the reduction of the skeletal degenerative process typical to aging.

In addition to the physical activity-anthropometric parameters relationship, our study also provides support for the well-evidenced physical activity-health relationship. As indicated in Tables 1 and 2, the active people had fewer chronic illnesses and had a smaller percentage of smokers among them than the inactive people. Our study, then, indicates that those who adhere to the recommended guidelines of physical activity in old age are both healthier and have more favorable anthropometric parameters than those who do not meet the guidelines. Obviously, our study is unable to determine that adherence to physical activity guidelines is the cause of more favorable anthropometric characteristics. It is possible that pre-exercising anthropometric characteristics were responsible for a certain physical activity pattern. However, our study provides additional support for the well-evidenced correlation of physical activity and anthropometric parameters on one hand, and of physical activity and health on the other

Table 3 Two-step regressions explaining the variance of the anthropometric parameters among Israeli men, 2005–2006

Variable	Model and predictors	Standardized predictors' coefficients	r^2	r^2 change	Significant F change
Weight	1: Age	−0.26	0.096	0.022	0.00
	Calcium intake	0.01			
	Smoking	−0.12			
	Illness	0.00			
	Medications	0.19			
	2: Age	−0.27	0.118		0.00
	Calcium intake	0.02			
	Smoking	−0.14			
	Illness	−0.01			
	Medications	0.18			
	Insufficiently active	0.09			
	Inactive	0.17			
Waist circumference	1: Age	−0.11	0.052		0.00
	Calcium intake	−0.03–0.12			
	Smoking	0.05			
	Illness	0.15			
	Medications	−0.13			
	2: Age	−0.01	0.097	0.045	0.00
	Calcium intake	−0.15			
	Smoking	0.03			
	Illness	0.13			
	Medications	0.11			
	Insufficiently active	0.24			
	Inactive				
Height	1: Age	−0.29	0.085		0.00
	Calcium intake	0.08			
	Smoking	−0.04			
	Illness	−0.02			
	Medications	0.05			
	2: Age	−0.29	0.087	0.002	0.54
	Calcium intake	0.08			
	Smoking	−0.04			
	Illness	−0.02			
	Medications	0.04			
	Insufficiently active	0.04			
	Inactive	0.04			
BMI	1: Age	−0.14	0.064		0.00
	Calcium intake	−0.04			
	Smoking	−0.10			
	Illness	0.04			
	Medications	0.18			
	2: Age	−0.16	0.087	0.023	0.00
	Calcium intake	−0.03			
	Smoking	−0.12			
	Illness	0.02			
	Medications	0.17			
	Insufficiently active	0.09			
	Inactive	0.17			

Table 4 Two-step regressions explaining the variance of the anthropometric parameters among Israeli women, 2005–2006

Variable	Model and predictors	Standardized predictors' coefficients	r^2	r^2 change	Significant F change
Weight	1: Age	−0.24	0.076		0.00
	Calcium intake	−0.08			
	Smoking	−0.03			
	Illness	0.04			
	Medications	0.10			
	2: Age	−0.25	0.099	0.023	0.00
	Calcium intake	−0.05			
	Smoking	−0.04			
	Illness	0.03			
	Medications	0.09			
	Insufficiently active	0.03			
	Inactive	0.17			
Waist circumference	1: Age	−0.11	0.050		0.00
	Calcium intake	−0.12			
	Smoking	−0.02			
	Illness	0.09			
	Medications	0.09			
	2: Age	−0.11	0.093	0.043	0.00
	Calcium intake	−0.09			
	Smoking	−0.03			
	Illness	0.08			
	Medications	0.08			
	Insufficiently active	0.09			
	Inactive	0.25			
Height	1: Age	−0.20	0.051		0.00
	Calcium intake	0.11			
	Smoking	0.02			
	Illness	−0.08			
	Medications	0.10			
	2: Age	−0.19	0.061	0.010	0.02
	Calcium intake	0.10			
	Smoking	0.02			
	Illness	−0.08			
	Medications	0.10			
	Insufficiently active	−0.11			
	Inactive	−0.11			
BMI	1: Age	−0.17	0.062		0.00
	Calcium intake	−0.14			
	Smoking	−0.03			
	Illness	0.06			
	Medications	0.07			
	2: Age	−0.18	0.097	0.035	0.00
	Calcium intake	−0.11			
	Smoking	−0.03			
	Illness	0.06			
	Medications	0.06			
	Insufficiently active	0.08			
	Inactive	0.22			

[1–3, 7, 9, 10, 16, 20], implying that active people who have favorable anthropometric parameters are healthier than those who are inactive. Alternatively, it is possible that anthropometric parameters serve as mediators between physical activity and health in advanced age.

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Conflict of interest disclosure
Ayelet Dunsky, Sima Zach, Aviva Zeev, Uri Goldbourt, Tal Shimony, Rebecca Goldsmith, and Yael Netz declare that they have no conflict of interest.

Informed consent
All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (the Chaim Sheba Medical Center and the Ministry of Health, Israel) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all patients for being included in the study.

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