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Original Article

Aerobic Steps As Measured by Pedometry and Their Relation to Central Obesity

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Abstract

Background: The purpose of this study was to examine the relation between daily steps and aerobic steps, and anthropometric variables, using the waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR).

Methods: The participants in this cross-sectional study were taken the measurements of by a trained anthropologist and then instructed to wear an Omron pedometer for seven consecutive days. A series of statistical tests (Mann-Whitney U test, Kruskal-Wallis ANOVA, multiple comparisons of z' values and contingency tables) was performed in order to assess the relation between daily steps and aerobic steps, and anthropometric variables.

Results: A total of 507 individuals (380 females and 127 males) participated in the study. The average daily number of steps and aerobic steps was significantly lower in the individuals with risky WHR and WHtR as compared to the individuals with normal WHR (P=0.005) and WHtR (P=0.000). A comparison of age and anthropometric variables across aerobic steps activity categories was statistically significant for all the studied parameters. According to the contingency tables for normal steps, there is a 5.75x higher risk in the low-activity category of having WHtR>0.50 as compared to the high-activity category.

Conclusions: Both normal and aerobic steps are significantly associated with central obesity and other body composition variables. This result is important for older people, who are more likely to perform low-intensity activities rather than moderate- or high-intensity activities. Our results also indicate that risk of having WHtR>0.50 can be reduced by almost 6x by increasing daily steps over 8985 steps per day.

Keywords: Pedometer, Physical activity, Omron, WHR, WHtR

Introduction

Obesity, and in particular excessive visceral fat, is associated with a number of health problems, including an increased risk of cardiovascular diseases, type-2 diabetes, some types of cancer and premature death (1-4). The number of overweight and/or obese individuals has been on the rise in Euro-American society, but also in developing countries such as Mexico or China (5-7). According to a report from the World Health Organisation, approximately 2.3 billion adults will become overweight, and more than 700 million will become obese by 2015. Thus, prevention of overweight and obesity has become an important field of research (8).

The primary cause of obesity is an energy imbalance between the calories that are consumed and the calories that are expended. Recent systematic reviews show that obese and overweight individuals could reduce their body weight by increasing their physical activity (9-15). As a result of increasing interest in objective monitoring of daily physical activity, several assessments of physical activity have been developed. Of these methods, the pedometer provides a low-cost and user-friendly assessment of physical activity in terms of the number of steps (16-19). Until recently, however, there has been a limitation of pedometers in that they are not able to record the intensity of the physical activity. Since physical activity recommendations require the physical activity to be of at least moderate intensity for the prevention and treatment of obesity, pedometers should also provide information about the intensity of physical activity (8, 20-22). On the basis of recent studies we may assume that moderate-intensity walking (walking at 3 METs) appears approximately equal to at least 100 step.min^{-1} (8, 21).

The aim of our study was to observe the relations between the number of daily steps and aerobic steps, and anthropometric variables, using the waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR). The main reason for choosing the Omron pedometer with the 'aerobic steps' function to conduct this study was its widespread use at the present time. However, there is no researched evidence that would support the claim that stepping rate of minimum 60 steps per minute in a period of over 10 minutes leads to improved health and that it has significant connection to health indicators. Of health indicators, we focused on the WHR and WHtR, because these variables are identified with a number of health problems and are outside the scope of most of the studies dealing with physical activity.

Methods

Subjects

The present study involved 507 adults (380 females and 127 males) native to the Czech Republic, all of them between 16 and 73 years of age (the average age in females being 45.8±13.14 years and 44.4±13.52 years in males). The subjects were recruited via advertisements placed in mass media (radio, television, www pages) in the city of Brno and neighbouring regions in the year 2006. All the subjects had signed a written consent which was archived. The study was approved by the Ethical Committee of the Faculty of Medicine, Masaryk University, Brno.

Anthropometric measurement

All the anthropometric measurements contained in this study were obtained by trained examiners from the subjects when barefoot and in underwear. Body height and body weight were measured to the nearest 0.5 cm and 0.1 kg respectively, using a digital scale (SECA 764, SECA gmbh&co., Hamburg, Germany). The waist and hip circumferences (cW, cH) were measured to the nearest 0.5 cm. The waist circumference was measured at the level of the umbilicus. The waist-to-hip ratio (WHR) was calculated as the circumference of the waist divided by the circumference of the hips, the waist-to-height ratio (WHtR) was calculated as the circumference of the waist divided by body height. The percentage of body fat (%BF) was determined using a Bodystat 1500 MDD body composition analyser.

Physical activity assessment

The subjects involved in the study were instructed to wear a pedometer (Omron HJ-113W-E; Omron Healthcare Co., Ltd., Kyoto, Japan) and to record the total number of steps taken each day. The pedometer was placed either in their trouser pocket or attached to the waistband. The subjects wore the pedometer all day, for seven days, except when sleeping or bathing. The participants were encouraged not to alter their usual physical activity. The pattern of physical activity was based on the number of steps and aerobic steps taken. The pedometer stored the number of aerobic steps in its memory when a step rate of minimum 60 steps per minute in a period of over 10 minutes was performed.

Data treatment and statistical analysis

The walking activity (steps per day) and anthropometrical data were evaluated as continuous and categorical variables using the Statistica for Windows software (version 9.0). A *P*-value of <0.05 was considered to be statistically significant for all the analyses. The data obtained by the pedometer were averaged over seven days. Continuous variables were tested for normality by the Shapiro-Wilk's test of normality. A non-parametric Mann-Whitney U test was performed to examine the walking activity (averaged steps and aerobic steps per day) in the WHR and WHtR categories. The individuals were divided into the WHR and WHtR categories on the basis of the WHO report. The categories were defined as 'normal WHR' (N; WHR<0.90 for men and WHR<0.85 for women) and 'risky WHR' (R; WHR>0.90 for men and WHR>0.85 for women) (23), and 'normal WHtR' (N; WHtR <0.50) and 'risky WHtR' (R; WHtR >0.50) (24). A non-parametric Kruskal-Wallis ANOVA and multiple comparisons of z' values were performed in order to examine the body composition variables in the three groups of physical activity level. The individuals were categorised into three different groups of physical activity level using the 25th and 75th percentiles for the distribution. In the low-activity level category, the individuals took fewer than 5101 steps per day, in the moderate-activity level category 5101-8985 steps per day and in the high-activity level more than 8985 steps per day. In aerobic steps, the individuals taking fewer than 140 aerobic steps per day were placed in the low-activity level category, the individuals taking 140-1500 aerobic steps per day in the moderate-activity level category, and the individuals taking more than 1500 aerobic steps per day in the high-activity level. The data in the text and in the tables are presented as the mean and standard deviations (mean±sd). The contingency tables were used to visualise the relative amount of individuals across the created categories.

Results

Table I. shows the daily number of steps and aerobic steps in the WHR and WHtR categories. The average daily number of steps and aerobic steps was 6758±2874 and 966±1399 respectively for the subjects with risky WHR, which is significantly less than 7809±2942 steps and 1337±1612 aerobic steps performed by the subjects with normal WHR (*P*=0.00). Similarly, the participants with risky WHtR took 6877±2788 steps and 977±1351 aerobic steps per day, which is significantly less than 8804±3139 steps and 1824±1930 aerobic steps for the subjects with normal WHtR (*P*=0.00).

Table 1: Daily number of steps and aerobic steps across WHR and WHtR categories with results of non-parameric Mann-Whitney U test

Variable	WHR						WHtR					
	Normal (n=228)		Risky (n=279)		Mann-Whitney U test		Normal (n=93)		Risky (n=414)		Mann-Whitney U test	
	Mean	sd	Mean	sd	U	*P* value	Mean	sd	Mean	sd	U	*P* value
Steps/day	7809	2942	6758	2874	25050	0.00	8804	3139	6877	2788	12268	0.00
Aerobic steps/day	1337	1612	966	1399	26080	0.00	1824	1930	977	1351	13271	0.00

Mann-Whitney U test performed to examine walking activity among the WHR and WHtR categories. WHR categories - Normal (WHR<0.90 for men and WHR<0.85 for women) and Risky (WHR>0.90 for men and WHR>0.85 for women) (23), WHtR categories - Normal (WHtR <0.50) and Risky (WHtR >0.50) (24)

A comparison of age and anthropometric variables across physical activity categories is shown in Table 2 and a related statistical analysis is shown in Table 3. A multiple comparison of z' values revealed that with regard to the age of the participants, there are significant differences between low-activity and high-activity categories both in normal and aerobic steps. For normal steps the individuals in the high-activity category are on average six years younger than the individuals in the low-activity category, and for aerobic steps the individuals in the high-activity category are on average five years younger as compared to the low-activity category. The individuals in the high-activity category of normal steps have on average 34% body fat and weight of 84 kg, a mean BMI of

30 kg/m^2, a mean WHR of 0.86 and a mean WHtR of 0.57, which are significantly lower values in comparison with the average of 40% body fat, weight of 101 kg, a mean BMI of 36 kg/m^2, a mean WHR of 0.92 and a mean WHtR of 0.66 in the low-activity category (P<0.05). The only parameter that gives no statistically significant result across the normal steps activity categories is body height.

As regards aerobic steps, the results were statistically significant in all the studied parameters. The individuals in the high-activity category have on average 33% body fat, their mean height is 170 cm and mean weight 87 kg, they have a mean BMI of 30 kg/m^2, a mean WHR of 0.87 and a mean WHtR of 0.57. These values are significantly lower when compared with the average of 40% body fat, height of 167 cm, weight of 99 kg, a mean BMI of 35 kg/m^2, a mean WHR of 0.90 and a mean WHtR of 0.65 in the low-activity category (P<0.05).

Table 2: Body composition parameters across physical activity categories defined by 25th and 75th percentiles for the distribution of normal and aerobic steps count

Variable	Steps					
	Low (n=126)		**Moderate (n=254)**		**High (n=127)**	
	Mean	**sd**	**Mean**	**sd**	**Mean**	**sd**
Age	49	13	45	13	43	13
%BF	40.5	10.9	37.5	10.4	34.0	10.6
Height	167.3	10.2	167.3	8.6	168.0	8.4
Weight	100.9	26.6	91.3	21.5	84.0	20.0
BMI	36.1	9.0	32.6	7.2	29.7	6.5
WHR	0.92	0.10	0.88	0.10	0.86	0.10
WHtR	0.66	0.12	0.60	0.11	0.57	0.11
Variable	**Aerobic steps**					
	Low (n=126)		**Moderate (n=254)**		**High (n=127)**	
	Mean	**sd**	**Mean**	**sd**	**Mean**	**sd**
Age	47	13	47	13	42	14
%BF	40.0	10.8	38.1	10.1	33.3	11.1
Height	167.2	9.9	166.5	8.5	169.6	8.7
Weight	99.1	27.3	90.8	20.7	86.8	22.0
BMI	35.4	8.8	32.8	7.3	30.1	7.1
WHR	0.90	0.10	0.88	0.10	0.87	0.10
WHtR	0.65	0.12	0.61	0.11	0.57	0.10

Categorization into three groups of activity level; low = low-activity level category (< 5101 steps per day; < 140 aerobic steps per day), moderate = moderate-activity level category (5101-8985 steps per day; 140-1500 aerobic steps per day), high = high-activity level category (> 8985 steps per day; > 1500 aerobic steps per day)

The distribution of the participants across all the categories (physical activity, WHR, WHtR) is shown in the contingency table (Table 4). This table shows that in the group with low-activity in daily steps, the ratio between the individuals with normal WHR and those with risky WHR is 1:2.07, in the group with moderate-activity this ratio is 1:1.15 and in the group with high-activity it is 1:0.84. The risk of centralised obesity increases indirectly with the amount of steps taken. In the number-of-steps categories [>8985], [8985-5101], [<5101] the risk of central obesity is 0.84:1.15:2.07, based on the relative frequencies of the participants with normal and risky WHR, which means that the risk is 2.5 times higher in the low-activity category as compared to the high-activity category.

Table 3: Non-parametric Kruskal-Wallis ANOVA and multiple comparisons of z´ values of body composition variables among the three groups of physical activity level

Variable		**Steps**			**Aerobic Steps**	
		Low	**Moderate**		**Low**	**Moderate**
Age	Moderate	2.47*		Moderate	0.09	
	High	3.69*	1.79	High	2.69*	3.20*
%BF	Moderate	2.40*		Moderate	1.72	
	High	4.74*	3.08*	High	4.84*	3.87*
Height	Moderate	0.01		Moderate	0.15	
	High	0.7	0.81	High	2.41*	2.94*
Weight	Moderate	3.13*		Moderate	2.43*	
	High	5.46*	3.18*	High	3.87*	2.3
BMI	Moderate	3.34*		Moderate	2.47*	
	High	6.27*	3.90*	High	5.21*	3.55*
WHR	Moderate	3.35*		Moderate	2.23	
	High	4.05*	1.33	High	2.85*	1.6
WHtR	Moderate	3.98*		Moderate	2.79*	
	High	6.29*	3.29*	High	5.34*	3.38*

Categorization into three groups of activity level; low = low-activity level category (< 5101 steps per day; < 140 aerobic steps per), moderate = moderate-activity level category (5101-8985 steps per day; 140-1500 aerobic steps per day), high = high-activity level category (> 8985 steps per day; > 1500 aerobic steps per day). * *P*<0.05

The ratio between individuals with normal WHtR and individuals with risky WHtR in the group with low-activity in daily steps is 1:13, in the group with moderate-activity the ratio is 1:4.64 and in the group with high-activity it is 1:2.26.

The risk of centralised obesity increases indirectly with the amount of steps taken. In the number-of-steps categories [>8985], [8985-5101], [<5101], the risk of central obesity is 2.26:4.64:13, based on the relative frequencies of the participants with normal and risky WHtR, which means that the risk is 5.8 times higher in the low-activity category as compared to the high-activity category.

The situation in the aerobic steps category is similar. In the low-activity group, the ratio between the individuals with normal WHR and the individuals with risky WHR is 1:1.86, in the moderate-activity group this ratio is 1:1.21 and in the high-activity group it is 1:0.84. The risk of centralised obesity increases indirectly with the amount of aerobic steps taken. In the number-of-aerobic steps categories [>1500], [1500-140] [<140], the risk of central obesity is 0.84:1.21:1.86, based on the relative frequencies of the participants with normal and risky WHR, which means that the risk is 2.21 times higher in the low-activity category as compared to the high-activity category.

The ratio between the individuals with normal WHtR and the individuals with risky WHtR in the group with low-activity in daily aerobic steps is 1:8.69, in the group with moderate-activity the ratio is 1:4.91, and in the group with high-activity it is 1:2.43.

The risk of centralised obesity increases indirectly with the amount of aerobic steps taken. In the number-of-aerobic-steps categories [>1500], [1500-140] [<140], the risk of central obesity is 2.43:4.91:8.69, based on the relative frequencies of the participants with normal and risky WHtR, which means that the risk is 3.58 times higher in the low-activity category as compared to the high-activity category.

Table 4: The distribution of the participants across all the categories (physical activity, WHR, WHtR)

Variable	WHR			Variable	WHR		
Steps	Normal	Risky	Total	Aerobic Steps	Normal	Risky	Total
Low	41	85	126	Low	44	82	126
Moderate	118	136	254	Moderate	115	139	254
High	69	58	127	High	69	58	127
Total	228	279	507	Total	228	279	507
Variable		WHtR		Variable		WHtR	
Steps	Normal	Risky	Total	Aerobic Steps	Normal	Risky	Total
Low	9	117	126	Low	13	113	126
Moderate	45	209	254	Moderate	43	211	254
High	39	88	127	High	37	90	127
Total	93	414	507	Total	93	414	507

Categorization into three groups of activity level; low = low-activity level category (< 5101 steps per day; < 140 aerobic steps per day), moderate = moderate-activity level category (5101-8985 steps per day; 140-1500 aerobic steps per day), high = high-activity level category (> 8985 steps per day; > 1500 aerobic steps per day).WHR and WHtR categories defined as; WHR categories - Normal (WHR<0.90 for men and WHR<0.85 for women), Risky (WHR>0.90 for men and WHR>0.85 for women) (23), WHtR categories - Normal (WHtR <0.50) and Risky (WHtR >0.50) (24)

Discussion

In this study we examined the relation between daily steps and aerobic steps, and anthropometric variables, using the waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR). We found out that normal and aerobic steps are significantly associated with central obesity and other body composition variables.

The relation between BMI categories and daily steps has been examined in a number of studies to date (25-28). Recently, the stepping rate has been the subject of studies attempting to 'translate' moderate physical activity into a number of steps. The aim of this study was to establish whether aerobic steps (as defined by the Omron pedometer) have a biological merit. Another purpose of this study was to determine the relation between the WHR and WHtR categories and the number of steps taken, as these very important indices of central obesity have been outside the scope of most of the studies dealing with physical activity.

The findings of the present study demonstrate that the number of steps and aerobic steps is significantly higher in individuals classified as having 'normal' WHR and WHtR (WHR<0.90 for men, WHR<0.85 for women and WHtR <0.50) than in individuals classified as having 'risky' WHR and WHtR (WHR>0.90 for men, WHR>0.85 for women and WHtR >0.50) (23-24). Because the results were similar (in regard of statistical significance values) in both normal- and aerobic-steps categories, it can be suggested that aerobic steps have the same predictive value as normal steps. The individuals, whose body parameters fit into the risk categories, should be encouraged to increase their physical activity regardless of the intensity of the activity. However, this result runs contrary to the study of Yoshioka et al. whose study has shown that the amount of vigorous physical activity is an important predictor of normal weight conditions rather than the moderate-intensity physical activity. In their study, the individuals who performed moderate physical activity for more than 30 minutes per day showed a significantly lower BMI (22.4±0.2) than the rest (23.0±0.1). Moreover, the individuals who were in the 4th and 5th quintile of moderate PA and 5th quintile of vigorous PA showed a lower BMI than the rest (29). This finding was additionally confirmed by the study of Ayabe et al. in which the overweight/obese individuals spent a significantly shorter time performing physical activity at >100 steps min^{-1}, especially at >130 steps min^{-1}, as compared to the normal-weight individuals (8). It seems that a stepping rate higher than 60 steps per minute for a minimum of ten minutes is necessary to demonstrate the importance of intensity of physical activity in the prediction of obesity.

The studies mentioned above assessed obesity in terms of the BMI. However, it is in particular excessive visceral fat and central obesity that is associated with an increased risk of cardiovascular diseases and mortality (30-32). Relative fat distribution, as measured by the ratio of waist circumference to hip circumference (WHR), was popular for many years and still is a good predictor of health risk (33-37). Nevertheless, based on recent studies, it is the waist-to-height ratio (WHtR) which seems to have a closer relation to health outcomes (38). In this study we have proven that both the WHR and WHtR have statistically significant relations to the pedometer data. An important connection between the WHR and daily steps has been described in middle-aged women. Women classified as inactive (<6000 steps d^{-1}) or somewhat active (6000–9999 steps d^{-1}) had more total fat and more centrally located fat (WHR=0.87 in inactive and WHR=0.80 in somewhat active) than those who averaged 10,000 or more steps each day (average WHR=0.75) (39). In this study, the individuals in the low-activity category have a mean WHR of 0.92, those in the moderate-activity category 0.88 and in the high-activity category the mean WHR is 0.86. This tendency is identical with that found in the study by Thompson et al., although the WHR is higher in all the physical activity categories. This is probably caused by the fact that in the present study the average step count is lower across all the physical activity categories (low<5101 steps d^{-1}, moderate=5101-8985 steps d^{-1} and high>8985 steps d^{-1}). In addition, the present study also included males, who generally have a higher WHR than women (40).

Based on the contingency tables, it could be said that the best discriminating variables are the WHtR and daily steps. The risk of central obesity, defined as WHtR>0.50, was 5.8 times higher in the low-activity category as compared to the high-activity category of normal steps. For example, in the WHR category the risk of central obesity was 2.5 times higher in the low-activity category as compared to the high-activity category of normal steps, which is half of that found in the WHtR category.

The present study has certain limitations, however. It is based on a cross-sectional design, and therefore it is unclear whether the increase in daily steps improves the degree of obesity. Because pedometers were used, it was not possible to evaluate either upper-arm or water-related physical activity. The stepping rate was not recorded either. The steps taken by the participants were evaluated by the pedometer either as normal or aerobic. Another problem is that the stepping rate is affected by step length (22). Thus, in individuals of lower height, as well as in children, a faster stepping rate might be required to achieve significant differences.

Conclusion

The findings of this study demonstrate that aerobic steps as defined by the Omron pedometer have the same predictive value as normal steps. Both normal and aerobic steps are significantly associated with central obesity and other body composition variables. These findings are particularly important for older people, who are more likely to perform low-intensity physical activities rather than moderate- or high-intensity physical activities. In addition, the WHtR was identified as a suitable variable for further research. According to the contingency tables for normal steps, there is a 5.75 times higher risk of having WHtR>0.50 in the low-activity category as compared to the high-activity category. Basically it means that risk of having WHtR>0.50, which is associated with number of health problems, can be reduced by almost 6x by increasing daily steps over 8985 steps per day.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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