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Predictors of 6-minute walk test results in lean, obese and morbidly obese women

M. Hulens[1], G. Vansant[2], A. L. Claessens[3], R. Lysens[1], E. Muls[2]

[1]Department of Rehabilitation Sciences, Faculty of Physical Education and Physiotherapy, [2]Department of Endocrinology, Metabolism and Nutrition, Faculty of Medicine, UZ Gasthuisberg, [3]Department of Sport and Movement Sciences, Faculty of Physical Education and Physiotherapy, Katholieke Universiteit Leuven, B-3000, Belgium
Corresponding author: Maria Hulens, Faculty of Physical Education and Physiotherapy, Tervuursevest 101, B-3001- Leuven, Belgium. Tel: +32 16 32 91 14, Fax: +32 16 32 91 97, E-mail: maria.hulens@flok.kuleuven.ac.be

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The aim of this study was first, to assess the presence of medical conditions that might interfere with walking; second, to assess the differences in walking capacity, perceived exertion and physical complaints between lean, obese and morbidly obese women; and third, to identify anthropometric, physical fitness and physical activity variables that contribute to the variability in the distance achieved during a 6-minute walk test in lean and obese women.

A total of 85 overweight and obese females (18–65 years, body mass index (BMI) $\geq$ 27.5 kg m^{-2}), 133 morbidly obese females (BMI $\geq$ 35 kg m^{-2}) and 82 age-matched sedentary lean female volunteers (BMI $\leq$ 26 kg m^{-2}) were recruited. Patients suffering from severe musculoskeletal and cardiopulmonary disease were excluded from the study. Prior to the test, conditions that might interfere with walking and hours of TV watching were asked for. Physical activity pattern was assessed using the Baecke questionnaire. Weight, height, body composition (bioelectrical impedance method), isokinetic concentric quadriceps strength (Cybex) and peak oxygen uptake (peakVO$_2$__bicycle ergometer) were measured. A 6-minute walk test was performed and heart rate, walking distance, Borg rating scale of perceived exertion (RPE) and physical complaints at the end of the test were recorded.

In obese and particularly in morbidly obese women suffering from skin friction, urinary stress incontinence, varicose veins, foot static problems and pain, wearing insoles, suffering from knee pain, low back pain or hip arthritis were significantly more prevalent than in lean women ($P < 0.05$). Morbidly obese women (BMI > 35 kg m^{-2} $N = 133$) walked significantly slower (5.4 km h^{-1}) than obese (5.9 km h^{-1}) and lean women (7.2 km h^{-1}, $P < 0.05$), were more exerted (RPE 13.3, 12.8 and 12.4, respectively, $P < 0.05$) and complained more frequently of dyspnea (9.1%, 4.7% and 0% resp., $P < 0.05$) and musculoskeletal pain (34.9%, 17.7% and 11.4% resp., $P < 0.05$) at the end of the walk. In a multiple regression analysis, 75% of the variance in walking distance could be explained by BMI, peakVO$_2$, quadriceps muscle strength age, and hours TV watching or sports participation.

These data suggest that in contrast with lean women, walking ability of obese women is hampered not only by overweight, reduced aerobic capacity and a sedentary life style, but also by perceived discomfort and pain. Advice or programs aimed at increasing walking for exercise also need to address the conditions that interfere with walking, as well as perceived symptoms and walking difficulties in order to improve participation and compliance.

Walking is a convenient and beneficial exercise mode to improve energy balance, aerobic fitness, metabolic fitness and well being in obese women (Donnelly, Jacobsen, Heelan, Seip, Smith, 2000; Duncan, Gordon, Scott, 1991; Williford, Scharff-Olsen, Blessing, 1993; Jurimae, Jurimae, Pihl, 2000). Walk tests performed either in the field (Donnelly et al., 1992; Laukkanen, Oja, Pasanen, Vuori, 1992; Mattson, Larsson, Rössner, 1996) or on a treadmill (Donnelly, Jakicic, Roscoe, Jacobsen, Israel, 1990; Babb, Korzick, Meador, Hodgson, Buskirk, 1991; McInnis, Bader, Pierce, Balady, 1999) have been used to estimate exercise capacity in obese subjects. Walking is an activity of daily living, which is often impaired as a direct consequence of obesity, through excess weight bearing (Mattson et al., 1996). But walking capacity can also be reduced as an indirect consequence, particularly due to mechanical complications: osteoarthritis or pain in the feet or ankles (Holmes & Mann, 1992; Messier, Davies, Moore, Davis, Pack, Kazmar, 1994), the knees (Messier, 1994), the hip or in the low back (Hart & Spector, 1993; Oliveria, Felson, Cirillo, Reed, Walker, 1999), friction of the skin (Biaunie & Kalis, 1993) and perhaps varicose veins (Seidell, de Groot, van Sonsbeek, Deurenberg, Hautvast, 1986) or urinary incontinence (Mommsen & Foldspang, 1994). Little is known, however, about variables that influence walking capacity in obese compared to lean subjects. Previously identified variables in obese subjects are BMI or weight, age and VO$_2$max, (Donnelly et al., 1992; Laukkanen, Oja, Pasanen, Vuori, 1992) and in non-obese subjects also extension torque of the quadriceps muscle (Mikesky, Meyer, Thompson, 2000). The influence of physical activity level on walking ability in obese subjects has not been studied yet.

The first aim of this study was to assess the presence of co-morbid conditions that might interfere with walking in lean (body mass index—BMI $\leq 26\,kg\,m^{-2}$) and obese (BMI $\geq 27.5\,kg\,m^{-2}$) to morbidly obese (BMI $\geq 35\,kg\,m^{-2}$) women. Secondly, to assess the magnitude of differences in walking capacity and perceived symptoms between obese and non-obese women, using a 6-minute walk field test. The third aim was to identify predictors that contribute to the variability in the distance achieved during a 6-minute walk test in obese women.

Materials and methods

A total of 218 overweight women with a body mass index (BMI) $\geq 27.5\,kg\,m^{-2}$, aged between 18 and 65 years, who were seeking medical help in order to achieve weight loss were recruited from the Outpatient Clinic of Endocrinology Department of the University Hospital Gasthuisberg in Leuven. In addition, 82 lean but sedentary, healthy female volunteers in the same age range and with a BMI $\leq 26\,kg\,m^{-2}$ were recruited from the University staff, hospital staff, kitchen employees, family and friends. Subjects with well-controlled hypertension, dislipidemia and type II diabetes were included. Patients suffering from discus herniation, lumbar spondylosis, severe orthopedic pain, acute sprain or strain, or from symptomatic cardiopulmonary disease were excluded from the study.

Weight was measured to the nearest 0.1 kg on a Seca beam balance scale, with the subjects wearing no shoes and only light clothing. Height was measured to the nearest 0.5 cm with a wall-mounted stadiometer. Weight and height were then used to calculate BMI. Body composition was measured using the bio-electrical impedance method (Bodystat 1500). Whole body measurements were taken with the subject lying down and the stretched legs and arms slightly abducted from the side. Standard locations were used with one electrode pair placed on the posterior surface of hand and wrist and the other pair on the anterior surface of the foot. (Baumgartner, Ross, Heymsfield, 1999) The participants had an overnight fast and had taken no medication that could affect body water content.

To estimate physical activity pattern, the Baecke questionnaire was used (Baecke, Burema, Frijters, 1982). This inventory quantifies work, sport and leisure physical activity, using a 5-point scale with descriptors ranging from never (1 point) to always (5 points). A sport activity index was calculated as the sum of intensity multiplied by time engaged, and the proportion of yearly participation. By adding the scores on the three items of the Baecke questionnaire, a global activity score was calculated. This score ranges from 3–15. In addition, mean time spent watching TV each day was asked for.

Prior to the test, patients were asked for conditions that might interfere with walking capacity. They were asked whether they suffered intermittently from friction of the skin, urinary stress incontinence, visible varicose veins, known hip arthritis, foot or ankle static problems or pain; or if they owned or were wearing insoles. Furthermore, they were asked to state if never—seldom—sometimes—frequently or always they suffered from knee or low back pain.

A 6-minute walk test was performed in a hospital circular corridor, i.e., with no turning point. The 6-minute walk is a commonly used test to estimate functional capacity in subjects with low exercise capacity, such as heart failure (Cahalin, 1996), pulmonary disease (Roomi, Johnson, Waters, Yohannes, 1996) and fibromyalgia (Pankoff, Overend, Lucy, White, 2000). The women were asked to "walk as fast as possible while maintaining a comfortable walking pace" (Ekblom, William, Hartley, Moore, Wear, 1979). At the end of the test, heart rate (palpated at the wrist within 15 s after the end of the test), walking distance, Borg Rating Scale of perceived exertion (RPE)(Jakicic, Donnelly, Pronk, Jawad, Jacobsen, 1995) and physical complaints or discomforts were recorded. Only the heart rates of the women taking no betablockers were considered ($n = 247$).

The isokinetic dynamometer Cybex 350 was used to measure isokinetic concentric quadriceps muscle strength. This is the extension force of the knee executed against a lever arm, maintaining a constant angular velocity of $60^{\circ -1}$. Positioning of the subjects was standardized according to the manual (Cybex 350 User Guide, Lumex Inc., Ronkonkoma, NY), as subjects were tested in the seated position with the back fully supported and with trunk, thigh and ankle straps in position. Both legs were tested, but since walking capacity is assumed to be limited by the worst performing knee, only the strength of that knee (expressed as peak torque in Newton-meters—Nm) was reported. Peak oxygen uptake (peakVO_2) was assessed during a graded maximal ergometer bicycle test with the subjects cycling at 60 rounds per minute. The load was increased with 10 W. every minute until exhaustion. At this stage all subjects had a respiratory quotient (RQ) $\geq$ 1.0. Gas exchange was measured using the computerized standard open circuit technique (Sensormedics Vmax 29, Yorba Linda, California).

Statistical procedures

For each variable, mean and standard deviation were calculated in the lean, obese and morbidly obese women. Each variable was tested for whether it follows the normal distribution. The latter was done for the global physical activity score on the Baecke questionnaire and for VO_2max. To assess the differences between groups, a one-way ANOVA for the normal distributed variables and a non-parametric ANOVA for the other variables was performed. One-way frequency tables were computed for symptoms that might interfere with walking capacity and for the physical complaints after the walk test in the three groups. To test correlations between the results of the 6-minute-walk and other variables, Pearson correlations were computed. The significance level was set at $P < 0.05$. Next, a stepwise multiple regression was performed, including age, BMI, peakVO_2, physical activity level, knee extension peak torque of the worst performing knee, sports index or hours of daily TV-viewing as independent variables, and distance achieved in the 6-minute-walk as the dependant variable. For inclusion of variables entered into the expression, significance level was set at $P < 0.15$.

Results

Descriptive characteristics of the participants are presented in Table 1. Weight, fat-free mass (FFM), fat mass (FM) and BMI were significantly different in the three BMI categories. Global physical activity score on the Baecke questionnaire was lower in the obese groups compared to the lean group, especially for sports; whereas leisure time and work scores did not differ between groups. In addition, the obese subjects spent more time watching TV each day.

Table 1. Physical characteristics, physical activity and exercise capacity in the lean, obese and morbidly obese women. Data are given as mean ± standard deviation

	Lean ($N = 82$)	Obese ($N = 85$)	Morbidly obese ($N = 133$)	P
Age (yr)	39.0 ± 11.8	39.5 ± 11.4	38.9 ± 12.4	NS
Anthropometry				
Weight (kg)	60.9 ± 7.6	88.2 ± 8.8	108.7 ± 14.0	0.0001
BMI (kg/m^2)	22.1 ± 2.1	32.3 ± 1.9	40.7 ± 4.4	0.0001
FFM (%)	72.9 ± 4.9	57.3 ± 3.5	51.3 ± 3.7	0.0001
FM (kg)	16.7 ± 4.1	42.7 ± 3.4	53.2 ± 9.7	0.0001
Baecke				
SSS	1.7 ± 1.7	1.2 ± 1.8	0.8 ± 1.4	0.0001
Work Index	2.5 ± 0.7	2.6 ± 0.7	2.7 ± 0.7	0.02
Sports Index	2.5 ± 0.7	2.1 ± 0.7	1.9 ± 0.7	0.0001
Leisure time Index	2.9 ± 0.6	2.6 ± 0.7	2.6 ± 0.7	0.004
Global PA Index	7.9 ± 1.2	7.3 ± 1.3	7.2 ± 1.3	0.0002
TV/viewing (hours/day)	1.1 ± 0.8	2.5 ± 1.8	2.6 ± 1.4	0.0001
Exercise capacity				
PeakVO$_2$ (ml min^{-1})	1627.9 ± 457.0	1566.0 ± 3723.0	1661.8 ± 372.3	NS
PeakVO$_2$/kg body weight	26.3 ± 6.3	17.7 ± 3.9	15.4 ± 3.6	0.0001
Muscle strength				
Flexion best knee	71.9 ± 23.1	66.4 ± 18.5	66.9 ± 18.4	NS
Extension best knee	123.1 ± 28.9	132.0 ± 26.9	136.4 ± 29.8	0.005
Flexion least knee	71.4 ± 21.2	63.0 ± 16.2	64.1 ± 18.7	0.008
Extension least knee	113.9 ± 24.7	123.8 ± 24.3	124.4 ± 29.9	0.002
6-min walk				
Distance (m)	722.3 ± 64.3	591.3 ± 54.2	538.9 ± 67.6	0.0001
Speed (km/h)	7.2 ± 0.6	5.9 ± 5.4	5.4 ± 6.8	0.0001
RPE	12.4 ± 2.0	12.8 ± 1.7	13.3 ± 1.9	0.007
HR (beats min^{-1})	127.3 ± 17.6	124.43 ± 17.2	126.4 ± 17.1	NS

BMI = Body Mass Index; FFM = fat-free mass; FM = fat mass; HR = heart rate; RPE = Borg Rating Scale for perceived exertion; SSS = Simple Sports Score.

Table 2. Conditions that might interfere with walking capacity

	Lean ($N = 82$)	Obese ($N = 85$)	Morbidly obese ($N = 133$)	χ^2
Friction of the skin	1 (1.2%)	29 (34.5%)	76 (57.1%)	0.001
Foot static problems or pain	8 (9.9%)	25 (29.4%)	50 (37.6%)	0.001
Insoles	4 (4.9%)	14 (16.7%)	29 (21.8%)	0.01
Knee pain	15 (18.5%)	41 (48.2%)	72 (54.1%)	0.001
Low back pain	38 (46.9%)	67 (78.8%)	95 (71.4%)	0.001
Hip arthritis	0 (0%)	6 (7.1%)	10 (7.5%)	0.04
Varicose veins	18 (22.2%)	31 (37.4%)	45 (34.1%)	0.09
Urinary stress incontinence	16 (19.8%)	32 (38.6%)	50 (37.6%)	0.01

Peak aerobic performance, indicated by absolute peak oxygen uptake (peakVO$_2$) during the bicycle ergometer test, was similar in the groups. Yet, peak oxygen uptake per kilogram body mass (peakVO$_2$/kg) was lower in the morbidly obese ($15.4 \pm 3.6\,\mathrm{mL\,min^{-1}\,kg^{-1}}$) and in the obese ($17.7 \pm 3.9\,\mathrm{mL\,min^{-1}\,kg^{-1}}$) than in the lean women ($26.3 \pm 6.3\,\mathrm{mL\,min^{-1}\,kg^{-1}}$, $P = 0.0001$). Absolute knee extension peak torque of both knees, on the other hand, was significantly higher in the obese and morbidly obese subjects compared to the lean, whereas flexion strength of the worst performing knee was lower in the obese subjects ($P < 0.01$).

The distance achieved by obese women during the 6-minute walk was on average 131.0 m less and even as much as 183.4 m less in the morbidly obese women, than the distance achieved by lean controls. This means that the obese walked on average only 81.9% and the morbidly obese only 74.6% of the distance of the lean women. Obese subjects also rated exertion slightly but significantly higher than their lean counterparts, whereas heart rates at the end of the walk were not different.

Existing conditions that might interfere with walking capacity are presented in Table 2. One third of the obese and more than half of the morbidly obese women state

Table 3. Physical complaints or discomforts reported following the 6-minute walk

	Lean ($N=82$)	Obese ($N=85$)	Morbidly obese ($N=133$)	P
No complaints	54 (68.4%)	51 (60.0%)	55 (41.7%)	0.001
Musculoskeletal pain	9 (11.4%)	15 (17.7%)	46 (34.9%)	0.01
Dyspnea	0 (0%)	4 (4.7%)	12 (9.1%)	0.02
Muscular fatigue	1 (1.3%)	1 (1.2%)	5 (3.8%)	0.3
Tibia pain	9 (11.4%)	13 (15.3%)	17 (12.9%)	0.5
Minor complaints	9 (7.5%)	1 (1.1%)	3 (2.3%)	0.02

Table 4. Pearson correlation coefficients between the 6-minute walk test variables and anthropometric parameters

	Distance	HR beats min^{-1}	RPE
Age (yr)	– 0.27****	– 0.46****	– 0.22****
Anthropometry			
Weight	– 0.68****	NS	0.22****
BMI	– 0.77****	NS	0.22***
FFM (%)	0.80****	NS	– 0.18**
FM (kg)	– 0.74****	NS	0.21***
Physical activity			
Sports index	0.42****	NS	NS
Global index	0.26****	NS	NS
TV-watching	– 0.44****	NS	NS
Maximal bicycle ergometer test			
PeakVO$_2$	0.26****	0.20**	NS
PeakVO$_2$/kg BW	0.75****	0.20**	NS
Worst performing knee			
Extension torque	0.15**	0.25****	0.14**
Flexion torque	0.40****	0.22***	0.11*

****$P \leq 0.0001$, ***$P \leq 0.001$, **$P \leq 0.01$, *$P \leq = 0.05$. NS = not significant; RPE = Rating of Perceived Exertion as assessed by the Borg Rating Scale; BW = Body weight.

to suffer intermittently from friction of the skin, whereas this is only one percent of the lean women. Foot or ankle static problems or pain, wearing or owning insoles and known hip arthritis were significantly more prevalent in obese than in lean subjects. About half of the obese subjects stated to suffer sometimes to always from knee pain vs. about only 1/5 in lean subjects. Having sometimes, frequently or always low back pain was reported in about $\frac{3}{4}$ of the obese subjects, whereas this was less than $\frac{1}{2}$ in lean women. These differences were statistically significant.

Physical complaints or discomforts reported following the 6-minute walk are presented in Table 3. Obese women experienced significantly more musculoskeletal pain and dyspnea than lean. In the morbidly obese women, the prevalence of pain symptoms was even twice as much as in the obese and three times more than in the lean women. The pain was mainly localized in the knees and much less in the low back, the thigh and the feet, or the ankles. Some of the morbidly obese patients had more than one symptom, e.g., dyspnea plus musculoskeletal pain. The occurrence of leg fatigue and of pain localized on the ventral surface of the tibia was similar in the three groups. The lean subjects showed minor complaints more frequently than the obese subjects. In fact, only 41.7% of the morbidly obese women had no complaints when walking, as opposed to 60% of the obese and 68.4% of the lean women. These differences were statistically significant.

Pearson correlation coefficients between the parameters of the 6-minute walk and other variables are presented in Table 4. The distance achieved was negatively associated with weight, BMI and FM and positively with FFM. The sports index showed a moderate positive, and TV watching a negative relationship with walking performance. Physical activity, especially sports participation was positively related, whereas TV-watching was negatively related to walking distance. Peak aerobic capacity and quadriceps strength were positively associated with a better walking capacity. Perceived exertion at the end of the walk was weakly related with obesity parameters and with leg muscle strength, and negatively with age. In this study, heart rate at the end of the 6-minute walk was weakly positively related to aerobic capacity and to leg muscle strength. Distance achieved was related to heart rate ($r = 0.32$, $P = 0.0001$), but not to RPE and RPE was related to heart rate ($r = 0.16$, $P = 0.01$).

Results of the stepwise multiple regression analysis are presented in Table 5. Fifty-nine percent of the variance in walking distance in the obese women could be explained by BMI alone. An additional 11% was explained by entering peakVO$_2$ and 2% more by entering extension torque of the worst performing knee into the model. Entering age and hours of TV-viewing, each explained 1% more of the variance. When replacing TV viewing by sports index, the partial R^2 was 0.5% instead of 1%. All variables in the model were significant. Thus 75% of the variance in walking performance of obese women could be explained by the combination of all these variables. A multiple regression analysis with FFM% instead of BMI revealed R^2 of 73% and a SEE of 37.4, and age was no longer significant.

Discussion

Walking ability is hampered in obese and especially in morbidly obese subjects, when compared to their lean counterparts. This was demonstrated in this study in

Table 5. Stepwise multiple regression analysis including age, fat mass, weight, BMI, peakVO_2, knee extension peak torque and sports index or hours of daily TV-viewing as independent variables and distance achieved in the 6-minute walk as the dependant variable

Variable	BMI	VO_2 max	Knee torque	Age	Sports index	Hours TV	interc.	R^2	F	*P*	SEE
Distance	− 9.0						905.3	0.59	375.2	0.0001	74.6
	9.4	0.08					783.1	0.70	306.0	0.0001	23.7
	9.8	0.06	0.8				742.4	0.73	238.7	0.0001	12.2
	9.8	0.05	0.7	− 1.0			810.4	0.74	188.5	0.0001	4.7
	9.5	0.04	0.7	− 1.0	10.4		786.4	0.75	154.2	0.0001	4.6
	9.1	0.04	0.62	− 1.0		− 7.3	818.6	0.75	148.7	0.0001	6.5

interc. = intercept.

lean and obese women, using the 6-minute walk test. Not only anthropometric, but also physical activity and physical fitness parameters, as well as present medical conditions were found to interfere with walking in the obese women.

In the obese women (Table 1) global physical activity scores were lower compared to the lean subjects, and this was mainly due to the lower sports score and the larger proportion of sedentary activities such as TV-viewing. This is in accordance with previous data showing an association of a higher BMI with lower physical activity level and more time spent watching TV (Fitzgerald, Kriska, Pareira, de Courten, 1997; Coakley, Kawachi, Manson, Speizer, Willet, Colditz, 1998).

The lower aerobic exercise capacity per unit body weight (peakVO_2/kg) in obese subjects compared to the lean, has been shown in previous studies (Salvadori, Fanari, Fontana, Buontempi, Saezza, Buado, Miserocchi, 1999). The larger quadriceps strength in the obese subjects is evident since moving the larger body weight causes a training effect of these muscles. (Hulens, Vansant, Lysens, Claessens, Muls, Brumagne, 2001)

The lean women in this study walked on average with a higher speed (7.2 km h^{-1}) than the obese (5.9 km h^{-1}) and morbidly obese (4.4 km h^{-1}) subjects. This seems evident, since obese women transport a larger body mass. In a study of Laukkanen et al. (1992) using a 1-km walk test, speed in obese women aged 20–65 years (mean BMI 32.0 kg m^{-2}) was on average 6.7 km h^{-1}. This is faster than the obese women in our study, but the instruction given was to “walk as fast as you can, but do not risk your health”, whereas in our study we asked to “maintain a comfortable walking pace”. In another study of Mattson et al. (1996), morbidly obese women (mean BMI 37.1 kg m^{-2}) were asked to walk at least 4 min in a 70 m corridor. They walked on average 4.3 km h^{-1}. This is slower than the morbidly obese women in our study, but here the instruction was to “walk at a self-selected comfortable walking pace”.

The heart rates at the end of the test, in the women taking no betablokkers in our study were similar in the three groups. In the study of Laukkanen et al. (1992) heart rates in the obese subjects were about 174 beats min^{-1}, which is much higher than the 124 beats min^{-1} in our study. This is possibly due to the larger distance and the higher speed of that walk, since average age (42.4 $\pm$ 8.8 years) was comparable to our study group. Moreover, in our study, pulse rate was recorded at the wrist within 15 s after the end of the test, which might already have caused a modest recovery of the heart rate. But in the study of Mattson et al. (1996) in the slower 4-minute walk in morbidly obese women, heart rate was on average 107 beats min^{-1}, which is lower than the 126 beats min^{-1} in our morbidly obese women. Moreover, the women in our study were also on average 5.2 years younger.

Perceived exertion and dyspnea after walking were more pronounced in the obese subjects compared to the lean. (Table 3) In a study of Jakicic et al. (1995) in morbidly obese women (BMI 37.6 kg m^{-2}), a link was found between perceived exertion (RPE) and both percentage peakVO_2 and percentage heart rate reserve. The increased exertion in the obese women might be due to the transportation of the larger body weight, demanding a larger percentage of peak oxygen consumption. In the study of Mattson et al. (1996) oxygen cost of walking was estimated at 56% of peakVO_2 in morbidly obese subjects, whereas in lean subjects this was only 36%. Moreover, obesity has been found to be associated with changing gait pattern, especially in the presence of osteoarthritis of the knees (Messier, 1994). These changes might cause an additional increase of oxygen cost of walking. In our study dyspnee occurred in 5% of the obese and 9% of the morbidly obese women, which is comparable to the 9% breathlessness symptoms in the obese women of the 1-km walk study of Laukkanen et al. (1992). Dyspnea in obese subjects is also due to the deposition of the fat mass under the diaphragm and on the chest wall, reducing lung volumes and decreasing compliance of the chest (Zerah, Harf, Perlemuter, Lorino, Lorino, Atlan, 1993).

Furthermore, musculoskeletal pain was a common complaint after the 6-minute walk in the obese subjects in our study. In fact, musculoskeletal conditions and symptoms were prevalent before the walk test in the obese and especially in the morbidly obese sample: foot or ankle static problems or pain, having to wear insoles, knee pain, low back pain and to a lesser extend hip arthritis. In a recent study, it has been found that increases in weight increased plantar foot pressures for the first metatarsal, lesser metatarsal, midfoot, and heel regions leading to overuse in these structures (Vela, Lavery, Armstrong, Anaim, 1998). Furthermore, ankle pain such as posterial tibial tendinitis is more common in obese subjects, especially in those with mal-alignment (*calcaneus valgus*). (Aboukrat, 1997) Similarly, osteoarthritis of the knees is more prevalent in obesity. (Hart & Spector, 1993) In a recent systematic review of the literature (Leboeuf-Yde, 2000), body weight was found to be commonly associated with low back pain. In some studies obesity was also associated with hip arthritis (Cooper et al., 1998), whereas other studies found no association (Sturmer, Gunther, Brenner, 2001). Thus, in our study musculoskeletal pain was reported in 1/5 of the obese and in 1/3 of the morbidly obese women, whereas this was only reported in 1/10 of the lean. The prevalence of pain symptoms in the lean women is probably due to the normal aging process. In a study of Lamb et al. (Lamb et al., 2000) in older women with recent knee pain and a high pain severity score, obesity and inactivity were very important factors in limiting fast paced walking. In our study, also another type of leg pain occurred, e.g., pain on the ventral surface of the tibia. It is most likely due to walking fast on the solid surface of the hospital corridor, stressing the tibia. (Batt, 2001) Whereas the lean women walked faster carrying a smaller body mass, obese women walked slower carrying a larger body mass. This might explain why tibia pain is equally common in the three BMI groups. Leg fatigue was not commonly reported in our study, but in the study of Laukkanen et al. (1992) in obese women performing a 1-km-walk, mild leg symptoms were the most common limiting factors in 58% of them. These also included leg fatigue.

In addition, it is possible that in our study other conditions might have limited walking performance in obese women, such as the friction of the skin through fat deposition on the thighs (Mattson et al., 1996) and in the deep skin folds through excessive sweating (Biaunie et al., 1993). Varicose veins, which might cause oedema or the perception of 'heavy legs', might interfere with walking, but we observed no statistical difference in reported prevalence in the three groups. Self-reported varicose veins though, have been reported to be more prevalent in severely obese women (Seidell et al., 1986). Furthermore, urinary stress incontinence was twice as prevalent in the obese subjects compared to lean. Incontinent patients report leaking at sneezing, coughing, exercises, laughing and bending, but also when walking. (Papa Petros & Ulmsten, 1992) Our subjects however, did not mention these symptoms spontaneously, following the 6-minute walk.

Pearson correlation coefficients (Table 4) of the distance achieved after the 6-minute walk were related to anthropometry, physical activity and performance variables investigated in this study. The larger BMI and percentage fat mass in lean and obese women, the slower they walked. This is in agreement with previous studies on walking capacity in obese women. (Donnelly et al., 1992; Laukkanen et al., 1992; Mattson et al., 1996) In our study, the lesser hours of TV-watching and the higher sports participation the women reported, the larger the distance achieved. Correlation was weak, but significant. It is possible that there was underreporting of the hours of TV-watching, both in lean and obese subjects. TV-viewing is a typical sedentary behavior which has been shown to be associated with a higher BMI in previous studies (Fitzgerald et al., 1997; Crawford, Jeffery, French, 1999). Our findings suggest that sedentary behavior might be associated with impaired functionality, such as walking ability in lean and obese women. Thus, when increasing sports participation and decreasing watching TV, walking ability might be improved. Walking distance in this study was related to both flexion and extension torque of the knee. Trough weight bearing quadriceps muscles are more trained for walking in obese subjects than hamstrings. (Hulens et al., 2001) But on the other hand, these muscles are weakened more easily, due to the consequent osteoarthritis of the knees (Wessel, 1996).

Heart rates after walking were positively related to walking distance and consequently to walking speed. In the study of Laukkanen et al. (1992), where obese subjects were walking faster than in our study, heart rates were also higher. However, heart rates at the end of the test were similar in lean and obese women. This might be due to the poorer aerobic fitness of the obese and morbidly obese women walking slower, but at a larger percentage of their heart rate reserve. Heart rates in our study were also related to perceived exertion. This is in agreement with the study of Jakicic et al. (1995), where heart rate expressed as a percentage of peak heart rate was related to perceived exertion in obese women performing a walk test. Perceived exertion in our study was negatively related to age. This could mean that older women have other limiting symptoms, such as osteoarthritis or pain in the knees. In addition, perceived exertion increased as weight and BMI increased. This is most likely due to the excess weight they have to move about. Fat free mass (and thus muscle mass), however, was negatively associated with RPE.

The stepwise multiple regression (Table 5) identified BMI as the most important predictor of walking distance in lean and obese women, explaining 59% of the variance. Including fitness parameters, such as aerobic capacity (peakVO_2) explained another 11% and extension torque of the worst performing knee explained another three percent. When entering age, another one percent was explained, up to 74%. TV-viewing or sports index each independently increased R^2. Thus walking ability is influenced, not only by excess weight, aerobic fitness and leg muscle strength, but also by sedentary behavior, such as spending time watching TV or low sports participation or both.

Perspectives

The aims of this study were to assess the presence of medical conditions that might interfere with walking, to assess the differences in walking capacity, perceived exertion and physical complaints between lean, obese and morbidly obese women, and to identify anthropometric, physical fitness and physical activity variables that contribute to the variability in the distance achieved during a 6-minute walk test in lean and obese women. In obese women, more co-morbid conditions existed that might interfere with walking. Obese and particularly morbidly obese women walked slower, were more exerted and complained more frequently of dyspnea and musculoskeletal pain at the end of the walk. The variables that contribute to the variability in the distance achieved in the 6-minute walk test in obese and lean women were BMI, peakVO_2, quadriceps strength, age and TV-viewing or sports participation. These results suggest that losing weight, as well as exercise programs or sports participation combining both aerobic and leg strength training in women might improve walking ability, especially in obese and morbidly women. Moreover, advice or programs aimed at increasing walking for exercise need to address the co-morbid conditions that interfere with walking, as well as perceived symptoms and walking difficulties in order to improve participation and compliance.

Key words: 6-minute walk; obesity; women.

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