Optimizing Fitness in Obesity: A Program Combining Various Exercise Techniques

Optimisation de la condition physique dans l'obésité : Un programme combinant différentes techniques d'exercice

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Abstract

Introduction : Obesity, indicated by a high body mass index (BMI), is linked to a potential decline in functional capacity and muscle strength, especially within weight-bearing joints. However, up to now, no study has managed to demonstrate a relationship between these factors that is sufficiently strong.

Aim: This study aims to present a mixed physical activity regimen for obese individuals.

Methods: Data were gathered from 20 obese participants (12 females, 8 males) and 13 controls (9 females, 4 males). The «obese» group had a BMI ≥ 25.0 kg/m2, while the «control» group had a BMI < 25.0 kg/m2. The exercise program consisted of walking, running, and muscle stretching, with 2 sessions weekly. Training began at the fat oxidation threshold, gradually extending sessions. From the ninth session, the program alternated between fat and anaerobic threshold sessions, aiming for 4 periods of 12 minutes at the anaerobic threshold.

Results: Significant body composition changes were observed in obese individuals, not controls. Obese women lost 1.7±0.6 kg (p=0.006), while obese men lost 5.8±2.1 kg (p=0.02). Fat mass reduction was 2.6±0.6 kg (p<0.001) for women and 4.9±1.1 kg (p=0.003) for men. Exercise tolerance improved in obese subjects, reaching higher fat and anaerobic thresholds post-training. Performance increased by +14.3% (p=0.03) at the fat threshold and +12.1% at the anaerobic threshold (p=0.02), with minimal change in heart rate (3.9-4.3%, p>0.05).

Conclusion: This study demonstrates two outcomes: a tailored exercise regimen for obese individuals enhances body composition, surpassing prior studies. Additionally, the program elevates performance at fat and anaerobic thresholds, accompanied by slightly increased heart rates. This suggests improved fat oxidation capacity in obese individuals.

Keys words : Obesity, BMI, physical activity, program.

Résumé

Introduction : L'obésité, caractérisée par un indice de masse corporelle (IMC) élevé, engendre un risque de diminution de la capacité fonctionnelle et de la force musculaire, en particulier au niveau des articulations porteuses de poids. Toutefois, jusqu'à présent, aucune étude n'a réussi à établir une corrélation suffisamment robuste entre ces facteurs.

Objectif : Cette étude vise à présenter un programme d'activité physique mixte pour les personnes obèses.

Méthodes : Les données ont été recueillies auprès de 20 participants obèses (12 femmes, 8 hommes) et 13 témoins (9 femmes, 4 hommes). Le groupe «obèse» avait un IMC ≥ 25,0 kg/m2, tandis que le groupe «témoin» avait un IMC < 25,0 kg/m2. Le programme d'exercice comprenait de la marche, de la course et des étirements musculaires, avec 2 séances par semaine. L'entraînement a débuté au seuil d'oxydation des graisses, avec une extension progressive des séances. À partir de la neuvième séance, le programme alternait entre des séances au seuil des graisses et des séances plus intenses au seuil anaérobie, visant 4 périodes de 12 minutes au seuil anaérobie.

Résultats : Des changements significatifs de la composition corporelle ont été observés chez les personnes obèses, mais pas chez les témoins. Les femmes obèses ont perdu 1,7±0,6 kg (p=0,006), tandis que les hommes obèses ont perdu 5,8±2,1 kg (p=0,02). La réduction de la masse grasse était de 2,6±0,6 kg (p<0,001) pour les femmes et de 4,9±1,1 kg (p=0,003) pour les hommes. La tolérance à l'exercice s'est améliorée chez les sujets obèses, atteignant des seuils de graisse et anaérobies plus élevés après l'entraînement. Les performances ont augmenté de +14,3 % (p=0,03) au seuil des graisses et de +12,1 % au seuil anaérobie (p=0,02), avec un changement minimal de la fréquence cardiaque (3,9-4,3 %, p>0,05).

Conclusion : Cette étude met en évidence deux résultats significatifs : un programme d'exercice adapté aux personnes obèses améliore considérablement leur composition corporelle, dépassant les études antérieures. De plus, le programme accroît les performances aux seuils des graisses et anaérobies, avec une légère augmentation de la fréquence cardiaque. Cela suggère une meilleure capacité d'oxydation des graisses chez les personnes obèses.

Mots clés : Obésité, IMC, activité physique, programme.

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INTRODUCTION

The phenomenon of obesity is reaching alarming proportions in Morocco. 25.2% of the Moroccan population is overweight, and 10.3% suffer from obesity(1). Nearly one-third of the population in Morocco, approximately 10.3 million people, experience overweight issues, which have become a public health concern that has been increasing over the past ten years, as highlighted in a study by the High Commission for Planning (HCP) of Morocco in 2011. According to this survey conducted by the HCP among 2426 households, Morocco has made significant progress in combating undernutrition. In children under the age of five, underweight rates decreased from 9.3% in 2004 to 3.1% in 2011, placing the Kingdom in a very favorable position compared to the global average (16%). For adults over 20 years old, the prevalence of underweight is now only 3.3%, compared to 3.9% in 2001. However, Morocco is facing serious obesity problems. In total, 10.3 million adult Moroccans, 63.1% of whom are women, are affected by obesity or pre-obesity, according to the report. Among these individuals, 3.6 million, which is nearly one in five Moroccan adults, are affected by severe and morbid obesity. Women are the most affected (26.8%), particularly in urban areas. Severe and morbid obesity has increased at an average rate of 7.3% per year over the past 10 years, alarming the HCP, which notes that inactivity, as well as living standards and education levels, influence this phenomenon. Indeed, the frequency of overweight and obesity is increasing rapidly, especially among children, making it a major global health problem(2). Morocco does not appear to be spared from the phenomenon of childhood obesity, the prevalence of which is alarmingly increasing. Childhood obesity is a major risk factor for cardiovascular diseases and can lead to joint, respiratory, metabolic, endocrine, and even orthopedic problems. Beyond the somatic consequences, childhood obesity can cause numerous psychosocial disorders. Furthermore, obesity in children presents a significant risk of persisting into adulthood. These multiple complications of obesity emphasize the importance of effective preventive approaches that should be implemented from childhood(3). Indeed, there is an association between excess weight in early childhood and numerous complications, and this excess weight is also linked to an increased risk of morbidity and premature death in adulthood (3). These consequences on physical health add to the psychological and social repercussions related to the altered body image caused by obesity in children. Considering its rapid progression worldwide, childhood obesity is becoming an increasingly worrying health phenomenon. It represents one of the consequences of the nutrition transition and sedentary lifestyles that have emerged in many countries, particularly in urban areas (4). In 2002, the World Health Organization (WHO) considered that 60 to 85% of the global population had a sedentary lifestyle, including two-thirds of children, and attributed two million deaths per year to it. It is, therefore, one of the most serious public health problems of our time, and although it is not yet receiving sufficient attention, some refer to it as an epidemic of physical inactivity (5).

Regular and moderate physical activity has beneficial effects on longevity by reducing overall mortality, particularly cardiovascular mortality. The initial epidemiological data presented in the 1980s on Harvard alumni (6) have been extensively confirmed by several studies conducted in large and diverse populations of men and women of varying ages (7). It is well accepted that physical activity plays a protective role against obesity. However, the combination of a suitable hypocaloric diet is necessary (8). Additionally, physical activity has a beneficial effect on fat distribution, particularly visceral fat, and increases muscle mass.

METHODS

Type and Study Method

This is a cross-sectional descriptive research study that was conducted on a representative sample of obese individuals in the Fes-Meknes region. This means that the study aimed to describe the characteristics of the sample of obese individuals in the region at a specific point in time. The study took place from September 06 to November 11, 2022.

Study populations

Inclusion criteria : Our study focused on obese individuals aged 18 to 40 years.

Exclusion criteria **:** In our study, participants with uncontrolled cardiovascular diseases, endocrine dysfunction, musculoskeletal impairment preventing them from continuing their training, as well as those with diabetes and/or osteoarticular disorders were excluded. This allowed us to focus on the effect of intense exercise on functional capacity and muscle power among obese individuals without these conditions.

All participants were randomly selected from different sports clubs and sportive institutions.

Description of medical intervention

We collected data from 20 obese subjects (12 women and 8 men) and 12 control subjects (7 women and 5 men). We included in the "obese" group all subjects with a BMI ≥ 25.0 kg/m2, and in the "control" group all subjects with a BMI < 25.0 kg/m2. The subjects participated in the physical activity program either on medical recommendation or on their own initiative. Excluded from the study were subjects under the age of 17 or over 65, subjects who had undergone or were undergoing weight-loss surgery (such as gastric bypass or gastric banding), and subjects who did not participate in the exercise program for at least 6 weeks. The subjects did not receive any specific dietary instruction at any time.

METHODS

Anthropometric measurements

The body mass (BM) was measured using an electronic scale (Balance NRBF701-17) (Accuracy: 0.1 kg). The participants were lightly clothed.

The triangular exercise tests was used to determine the fat and anaerobic thresholds for each subject. We defined the fat threshold as the point where the Respiratory Quotient (RQ) ranged from 0.88 to 0.90, and the anaerobic threshold as the point where the RQ ranged from 0.96 to 1.00.

During the triangular exercise test, the subjects were accompanied by an experienced sports monitor to collect data while running on a variable-speed and incline treadmill (Technogym, Italy). Heart rate was recorded using a Polar Tempo system. Measurement of the Respiratory Quotient (RQ) was conducted using an Altitrainer 200 facial mask, which measured oxygen consumption, carbon dioxide production, and ventilation.

After the triangular exercise test, the subjects began a training program twice a week. The first eight sessions aimed to develop endurance at the fat threshold. During the initial sessions, subjects were encouraged to brisk walk or lightly jog (according to their abilities) for 10 to 20 minutes, monitoring their heart rate to not exceed the level corresponding to an RQ of 0.90 during the initial triangular exercise test. This exercise period was followed by 10 minutes of muscle stretching, then 1 to 2 additional exercise periods of 10 to 20 minutes, identical to the first one. Each session concluded with 10 minutes of muscle stretching. As the sessions progressed, subjects were encouraged to extend the duration of their first exercise period, gradually reaching 60 minutes of continuous exercise

From the fifth week, starting from the ninth training session, one of the two weekly sessions focused on resistance training at the anaerobic threshold. The goal was to achieve a higher heart rate that corresponded to an RQ ranging from 0.96 to 1.00.

The resistance training sessions were conducted as follows: the subject began with a period of brisk walking or light jogging for 10 to 20 minutes, similar to the first 8 sessions. Then, the subject performed 4 sets of 5-minute runs each, reaching a heart rate compatible with the anaerobic threshold. The 4 sets were separated by 2-minute rest intervals. Afterwards, the subject engaged in a 5 to 10-minute walking period to lower the heart rate to a level compatible with an RQ below 0.90. Finally, the subject performed 10 minutes of muscle stretching. The objective after 16 or more sessions of this type was to complete 4 periods of 12 minutes each at the anaerobic threshold.

Statistical analysis: The analysis of the results was conducted using three statistical software programs, SPSS 18.0 (IBM, Inc., Chicago, IL), Graph Pad Prism (version 6.0, Inc., CA), and WHO Anthro Plus.

Ethical considerations: The participants in the survey were informed about the reasons for the study. Those who were literate were all asked to fill out a personal identification form. For those who had no formal education, oral consent was obtained. They then agreed to have their parameters measured. Their informed and voluntary consent was obtained prior to the start of the research. They were free to withdraw from the survey at any time without any negative consequences. The data was collected anonymously.

RESULTS

Table 1 presents the basic characteristics and average training duration of the four groups.

On average, participants of all genders have an age of 42.2±1.9 years. There is no significant difference in terms of age between the groups of women and the groups of men.

Table 1. Basic characteristics and average training duration of the four groups.

	Obese		Controls		P (Obese Vs Controls)	
	W	M	W	M	W	M
Number	12	08	07	05		
Age	41,6 ±1,6	40,6 ±2,8	41,8 ±3,5	42,1 ±2,1	0,97	0,82
Weight	88.1±2.2	98±6.6	64.2±1.6	66.3±3.1	< 0.0001	0.03
BMI	31.0±0.8	32.3±2.7	23.3±0.6	24.1±0.6	< 0.0001	0.02
Body fat (%)	42.3±0.9	29.5±1.8	32.0±1.9	24.4±1.8	< 0.0001	0.09
Waist circumference	99.2±2.0	117.8±4.8 (n=6)	85.7±2.1 (n=6)	82.1±3.5 (n=4)	0.006	0.006
Hip circumference	114.5±1.9	117.8±4.8 (n=6)	85.7±2.1 (n=6)	82.1±3.5 (n=4)	0.006	0.006
Waist-to-Hip ratio	0.84±0.01	1.01±0.02 (n=6)	0.84±0.02 (n=6)	0.88±0.02 (n=4)	0.998	0.03
Duration (weeks)	23.9±2.8	30.1±5.3	22.7±5.4	43.7±6.3	0.69	0.19

The results show a significant difference between the two groups in terms of weight. Obese women have an average weight of 88.1±2.2 kg, while control women have an average weight of 64.2±1.6 kg (p<0.0001). For men, obese individuals have an average weight of 98±6.6 kg, while controls have an average weight of 66.3±3.1 kg (p=0.03).

There is a highly significant difference between obese women and control women in terms of body fat percentage (42.3±0.9% and 32.0±1.9%, respectively, p<0.0001). However, there is no significant difference between obese men and control men in terms of body fat percentage (29.5±1.8% and 24.4±1.8%, respectively, p=0.08).

Finally, according to table 1, it can be observed that the average durations of training periods do not show statistically significant differences between the different groups. Thus, the average training duration for obese women is 23.9±2.8 weeks, while it is 22.7±5.4 weeks for control women (p=0.69). For the two respective groups of men, the average training duration is 30.1±5.3 and 43.7±6.3 weeks, but there is no statistically significant difference between them (p=0.19).

Table 2. Comparison of performance and physiological characteristics of obese subjects and control subjects before the training period

	Obese		Controls		P (Obese Vs Controls)	
	W	M	W	M	W	M
Threshold fat speed (km/h)	5.2±0.5 (n=10)	4.5±0.4 (n=6)	4.8±0.2 (n=6)	6.3±0.8 (n=4)	0.35	0.10
Anaerobic threshold speed (km/h)	5.5±0.4 (n=09)	6.5±0.5 (n=7)	6.9±0.2 (n=5)	8.5±0.4 (n=5)	0.01	0.02
Heart rate at the fat threshold (bpm)	118.0±3.5 (n=12)	114±3.9 (n=7)	119.6±4.9 (n=6)	121±17.2 (n=5)	0.97	0.33
Heart rate at the anaerobic threshold (bpm)	139±4.1 (n=12)	130.1±4.5 (n=7)	145±5.3 (n=6)	156.3±10.5 (n=4)	0.22	0.04
Oxygen consumption at the fat threshold (ml/kg/min)	16.2±0.5 (n=12)	18.4±2.1 (n=7)	17.8±0.6 (n=6)	25.6±6.1 (n=4)	0.19	0.19
Oxygen consumption at the anaerobic threshold (ml/kg/min)	19.8±1.1 (n=12)	23.5±2.3 (n=7)	24.3±1.3 (n=6)	32.1±4.3 (n=4)	0.004	0.10
Ventilation at the fat threshold (l/min)	34.8±1.5 (n=12)	44.7±2.9 (n=7)	24.7±1.4 (n=6)	41.3±13.3 (n=4)	0.001	0.72
Ventilation at the anaerobic threshold (l/min)	48.6±3.1 (n=12)	61.4±4.8 (n=7)	42.3±2.9 (n=6)	62.3±13.1 (n=4)	0.23	0.76

The speeds reached at the fat threshold do not show significant differences between the groups of women and the groups of men. For obese women, the average speed at the fat threshold is 5.2±0.5 kilometers per hour (km/h), while control women have a speed of 4.8±0.2 km/h (p = 0.35). Men, on the other hand, reach speeds of 4.5±0.4 km/h and 6.3±0.8 km/h (p = 0.10), respectively.

The speeds reached at the anaerobic threshold differ significantly between the groups, unlike the speeds at the fat threshold. Obese women reach a speed of only 5.5±0.4 km/h, while control women reach 6.9±0.2 km/h (p=0.01). In men, the speeds are 6.5±0.5 km/h for the obese and 8.5±0.4 km/h for the controls (p=0.02).

The results show that the heart rates of obese subjects and control subjects do not differ significantly, either at the fat threshold or at the anaerobic threshold. However, it is important to note that a slight difference approaching the threshold of significance was observed in men at the anaerobic threshold. For women, the average heart rate at the fat threshold is 118.0±3.5 beats per minute (bpm) for the obese and 119.6±4.9 bpm for the controls (p=0.97).

At the anaerobic threshold, the mean values are 139±4.1 bpm and 145±5.3 bpm, respectively (p=0.22). For men, the mean values at the fat threshold are 114±3.9 bpm for the obese and 121±17.2 bpm for the controls (p=0.33). At the anaerobic threshold, the mean values are 130.1±4.5 bpm and 156.3±10.5 bpm, respectively (p=0.04).

Finally, a comparison of the ventilatory efforts provided by the different groups was also conducted. These data are expressed in liters per minute (l/min). At the fat threshold, obese women have a ventilation of 48.6±3.1 l/min, while control women have a ventilation of 24.7±1.4 l/min (p=0.001). Although this difference is highly significant, it is not significant in men, who have values of 44.7±2.9 l/min for the obese and 41.3±13.3 l/min for the controls (p=0.72). At the anaerobic threshold, no significant difference was observed in both sexes. Obese and control women have values of 48.6±3.1 l/min and 42.3±2.9 l/min, respectively (p=0.23). In obese and control men, ventilation was 61.4±4.8 l/min and 62.3±13.1 l/min, respectively (p=0.76).

Impact of the physical exercise program on body composition

Effect of exercise on weight

The weight data was available for all subjects in the study. A significant decrease in weight was observed in both obese women and obese men. Obese women went from 87.5±2.7 kg before exercise to 85.8±2.7 kg after exercise, corresponding to a decrease of -1.9% or a weight loss of -0.09±0.16 kg/week (p=0.006). Obese men, on the other hand, went from 104.0±7.4 kg before to 98.2±6.4 kg after exercise, representing a decrease of -5.6% or -0.26±0.26 kg/week (p=0.02).

However, neither the control women nor the control men showed a significant variation in their weight. Control women went from 61.6±1.3 kg to 60.7±1.5 kg (-1.5%; -0.03 kg/week; p=0.35), while control men went from 68.1±3.9 kg to 67.4±4.7 kg (-1.0%; -0.02 kg/week; p=0.73).

Table 3. Effect of exercise on ventilation at the fat threshold

	Weight (kg) before exercise	Weight (kg) after exercise Average	weight difference (kg) per week	Difference between before and after	P
Obese women (12)	87.5±2.7	85.8±2.7	-0.09±0.16	- 1.9%	0.006
Obese men (08)	104.0±7.4	98.2±6.4	-0.26±0.26	- 5.6%	
Obese women (07)	61.6±1.3	60.7±1.5	-0.03±0.12	- 1.5%	0.35
Obese men (05)	68.1±3.9	67.4±4.7	-0.02±0.07	- 1.0%	

Effect of exercise on body fat quantity

Body fat was measured in a group of 12 obese women, 8 obese men, 7 control women, and 5 control men.

Among all obese subjects, there was a significant decrease in body fat, while no significant decrease was observed in the control subjects.

Obese women reduced their body fat percentage from 42.3±0.9% to 37.2±0.8% after exercise, which corresponds to a decrease of 6.6% or a fat loss of -2.0±0.4 kg (p<0.001). Obese men decreased their body fat percentage from 29.5±1.7% to 24.7±2.9%, resulting in a decrease of 11.7% or a fat loss of -6.5±2.4 kg (p=0.004).

The results for the control subjects are as follows: control women decreased their body fat percentage from 32.0±1.9% to 28.2±2.7%, and control men reduced their body fat percentage from 24.4±1.8% to 21.3±1.8%.

Table 4. Effect of exercise on body fat

	Body fat before exercise		Body fat after exercise		difference (%) between before and after	
	In %	In kg	In %	In kg		
Obese women (12)	42,3±0,9	36.6±1.8	37.2±0.8	34.6±1.6	- 6.6 %	< 0.001
Obese men (08)	29.5±1.8	31,2±3,8	23.7±1.5	24.7±2.9	- 11.7 %	0,004
Obese women (07)	32.0±1.9	19.4±1.4	28.2±2.7	18.6±1.9	- 7.5 %	0.09
Obese men (05)	24.4±1.8	16.3±0.6	21.3±1.8	14.3±1.7	- 15.1%	0,30

Effect of exercise on waist circumference

The waist circumference was measured in 12 obese women, 08 obese men, 07 control women, and 05 control men. Significant changes are observed in this parameter for both obese women and men, as well as control women. Only control men show no significant variation.

Before exercise, the waist circumference of obese women is 99.2±2.0 cm, while after exercise, it decreases to 95.1±2.0 cm. For obese men, it changes from 117.8±4.8 cm to 112.6±5.7 cm.

In control women, a decrease of -3.6% is observed, with a circumference of 85.7±2.1 cm before exercise and 83.1±2.6 cm after exercise (p=0.03). Finally, in control men, the circumference changes from 82.1±3.3 cm before to 81.4±1.6 cm after exercise.

Table 5. Effect of exercise on waist circumference (W)

	W (cm) before exercise	W (cm) after exercise	Difference between before and after	p
Obese women	99.2±2.0	95.1±2.0	- 1.9 %	0.001
Obese men	117.8±4.8	112.6±5.7	- 4.8 %	0.02
Obese women	85.7±2.1	83.1±2.6	- 3.6 %	0.03
Obese men	82.1±3.5	81.4±1.6	- 0.4 %	0,76

Effect of the physical exercise program on performance and physiological characteristics at the fat and anaerobic thresholds

The data were available for 20 obese subjects (12 women; 8 men) and 12 control subjects (7 women; 5 men). It is observed that obese subjects reach a fat threshold at a speed of 4.8±0.2 km/h before exercise and 5.3±0.2 km/h after exercise, which represents a significant increase of 13.8%. When we divide the data by gender (not shown), the changes are no longer significant. Obese women achieve an average speed of 5.2±0.5 km/h before exercise and 5.9±0.5 km/h after exercise, while obese men go from 4.5±0.4 km/h to 5.4±0.4 km/h. As for the control subjects, their performance at the fat threshold does not show significant variation. The speed reached before exercise is 4.9±0.4 km/h, and after exercise, it is 5.2±0.6 km/h. When we separate women and men, we obtain a speed of 4.8±0.2 km/h before and after exercise for women; men, on the other hand, go from 6.3±0.8 km/h to 6.6±0.8 km/h.

Table 6. Effect of exercise on performance at the fat threshold

	Speed achieved before exercise (km/h)	Speed achieved after exercise (km/h)	Difference between before and after exercise	p
Obese Women (n=12)	5.2±0.5	5.9±0.5	+ 11.1%	0.14
Obese Men (n=8)	4.5±0.4	5.4±0.4	+ 18.4%	0,13
Obese Women and Men (n=20)	4.8±0.2	5.3± 0.2	+ 13.8 %	0,03
Obese Women (n=07)	1.8 ± 0.2	4.8±0.2	± 0.0	1.0
Obese Men (n=05)	6.3±0.8	6.6±0.8	+ 10.2%	0.40
Obese Women and Men (n=12)	4.9±0.4	5.2±0.6	+4.8 %	0.49

The data were available for 20 obese subjects (12 women and 8 men) and 12 control subjects (7 men and 5 women). Before exercise, obese subjects reached the anaerobic threshold at a speed of 6.1±0.3 km/h. After exercise, this speed significantly increased to 7.2±0.3 km/h. When we divide the data by gender (not shown), there is a trend towards significance in women: a speed of 5.5±0.4 km/h before exercise and 6.2±0.3 km/h after exercise. However, for men, the variation is not significant: a speed of 6.5±0.5 km/h before exercise and 7.4±0.5 km/h after exercise. Let's now turn to the control subjects. When considering all 12 subjects as a whole, their speed at the anaerobic threshold changes from 7.6±0.4 km/h to 8.2±0.5 km/h, which is not a significant modification. For women observed individually, the speed changes from 6.9±0.2 km/h to 7.2±0.2 km/h, and for men, it changes from 8.5±0.4 km/h to 9.2±1.0 km/h. Thus, there is a variation that tends towards significance in the latter. A significant decrease in heart rate is observed in obese men.

Table 7. Effect of exercise on performance at the anaerobic threshold

	Speed reached before exercise (km/h)	Speed reached after exercise (km/h	Difference between before and after exercise	p
Obese Women (n=12)	5.5±0.4	6.2±0.3	+ 12.9%	0.06
Obese Men (n=8)	6.5±0.5	7.4±0.5	+ 8.3 %	0.21
Obese Women and Men (n=20)	6.1±0.3	7.2±0.3	+ 11.8 %	0.02
Obese Women (n=07)	6.9±0.2	7.2±0.2	+2.1%	0.69
Obese Men (n=05)	8.5±0.4	9.2±1.0	+ 9.0 %	0.06
Obese Women and Men (n=12)	7.6±0.4	8.2±0.5	+ 5.2 %	0.21

Effect of physical exercise on physiological characteristics at a speed of 6 km/h

The data were collected from 20 obese subjects (12 females and 8 males) and 12 control subjects (7 females and 5 males). Prior to exercise, obese subjects had a heart rate of 133.8±3.6 bpm, which decreased to 132.1±3.8 bpm after exercise, representing a non-significant decrease of -1.5% (p=0.43). When examining the sexes separately, it was observed that obese women experienced a slight decrease from 139.1 ±3.9 bpm to 138.8±3.8 bpm, while obese men experienced a significant decrease from 128.2±7.4 bpm to 120.8±7.2 bpm. Thus, a significant decrease in heart rate was only observed in obese men. Regarding the control subjects, when considering both sexes, their heart rate decreased from 123.1±5.2 bpm to 120.8±4.4 bpm, also indicating a non-significant variation. When examining the sexes separately, a decrease in heart rate was observed in female controls from 128.2±5.5 bpm to 124.4±3.5 bpm, while male controls experienced a slight increase from 109.3±5.7 bpm to 111.1±13.1 bpm. Therefore, a significant decrease in heart rate was only observed in obese men.

Table 8. Effect of physical exercise on heart rate at the 6 km/h threshold

	HR before exercise (heartbeats per minute)	HR after exercise (heartbeats per minute)	Difference between before and after	p
Obese Women (n=12)	139.1±3.9	138.8±3.8	- 0.3 %	0.91
Obese Men (n=8)	128.2±7.4	120.8±7.2	- 5.6 %	0.05
Obese Women and Men (n=20)	133.8±3.6	132.1±3.8	- 1.5 %	0.43
Obese Women (n=07)	128.2±5.5	124.4±3.5	- 2.6 %	0.54
Obese Men (n=05)	109.3±5.7	111.1±13.1	+ 0.6 %	0.96
Obese Women and Men (n=12)	123.1±5.2	120.8±4.4	- 1.8 %	0.56

Table 9. Effect of exercise on oxygen consumption at a 6 km/h threshold

	VO2 before exercise (in ml/kg/min)	VO2 after exercise (in ml/kg/min)	Difference between before and after	p
Obese Women (n=12)	19.8±0.6	20.8±0.8	+ 6.1 %	0.20
Obese Men (n=8)	20.8±1.8	22.4±1.2	+ 5.2 %	0.52
Obese Women and Men (n=20)	20.1±0.5	21.7±0.6	+ 5.3 %	0.05
Obese Women (n=07)	19.8±0.4	21.8±0.5	+ 9.2 %	0.33
Obese Men (n=05)	19.8±1.9	17.9±2.5	- 11.1 %	0.49
Obese Women and Men (n=12)	19.8±0.4	21.6±0.9	+ 4.1 %	0.44

Obese subjects had an oxygen consumption of 20.1±0.5 ml/kg/min before exercise, which increased to 21.7±0.6 ml/kg/min after exercise. This indicates a clear tendency towards a significant variation. When examining the sexes separately, obese women had an oxygen consumption of 19.8±0.6 ml/kg/min before exercise, which increased to 20.8±0.8 ml/kg/min after exercise, while obese men had an oxygen consumption of 20.8±1.8 ml/kg/min before exercise, which increased to 22.4±1.2 ml/kg/min after exercise. Regarding the control subjects, regardless of sex, their oxygen consumption increased from 19.8±0.4 ml/kg/min to 21.6±0.9 ml/kg/min. When separating women from men, the following results were obtained: control women had an oxygen consumption of 19.8±0.4 ml/kg/min before exercise, which increased to 21.8±0.5 ml/kg/min after exercise, while men had an oxygen consumption of 19.8±1.9 ml/kg/min before exercise, which decreased to 17.9±2.5 ml/kg/min after exercise.

Thus, we observe an increase close to the threshold of significance only in obese subjects regarding oxygen consumption.

DISCUSSION

This study reveals that our participants significantly improved after the program in terms of heart rate, aerobic fitness, functional capacity, exercise tolerance, total body fat, strength, and muscle mass.

When comparing the pre-exercise fitness characteristics, such as speed, heart rate, and oxygen consumption at the fat and anaerobic thresholds, between our obese subjects and control subjects, we observed non-significant differences at the fat threshold, except for ventilation in women. However, at the anaerobic threshold, we observed significant differences in both speed (in both sexes) and oxygen consumption (only in women). Additionally, in men, there is a trend towards a significant difference in heart rates.

In other words, our results indicate that obese subjects reach the anaerobic threshold with less effort than control subjects, which means they oxidize fats for a shorter duration. These observations are consistent with the hypothesis put forward by Wade et al. (9) that body composition influences the preference for oxidized substrates. According to this hypothesis, obese subjects, who have a higher percentage of body fat and a lower proportion of slow-twitch muscle fibers (type 1), would be less efficient in fat oxidation. However, it is worth mentioning that other studies, including the one by Geerling et al. (10), have questioned this notion. Furthermore, it is important to note that the initial training level may also play a role in the observed differences, as it influences the combustion of energy substrates, and it is possible that the control subjects had a higher initial training level.

Effect of Physical Exercise on Body Composition

One of the most notable and remarkable conclusions of this study is that the examined physical exercise program leads to a significant reduction in weight, body fat, and abdominal circumference.

Our results demonstrate an average weight loss of -0.14±0.03 kg per week for our obese subjects, regardless of gender. This weight loss is nearly twice as high as that reported by Wilmore in an analysis of 46 studies (11,12), where the average duration of exercise was 16.3 weeks. Furthermore, the weight loss in our subjects is 11 times higher than that in the HERITAGE study (13), which is one of the most significant and recent studies in the field of weight management through physical activity. In this 20-week study, subjects underwent progressive endurance training. When considering both genders separately, we observe a weight loss of -0.08±0.03 kg per week in the women of our study, whereas the HERITAGE study showed a weight loss of only -0.005 kg per week in women. For men, the weight loss in our cohort is -0.19±0.06 kg per week, nearly three times higher than that in the HERITAGE study. Furthermore, our study is also consistent with a meta-analysis of 28 studies conducted by Garrow and Summerbell (14), which found slightly lower weight loss in our obese female subjects compared to their study (0.09 kg/week versus 0.12 kg/week after excluding two studies), while our male participants lost nearly three times more

weight (0.26 kg/week versus 0.09 kg/week).

Additionally, it is important to highlight the significant reduction in abdominal circumference that we observed in obese women and men. This observation is particularly interesting as studies have demonstrated that high values of abdominal circumference, reflecting significant accumulation of abdominal fat, are associated with an increased risk of metabolic complications such as insulin resistance, diabetes, lipid disorders, and atherosclerosis (15).

Although our sample size is modest compared to large-scale studies like HERITAGE, it is important to note that our physical activity program led to significant improvements in body composition that have not yet been observed in previous studies.

Effects of Physical Activity on Performance and Physiological Characteristics

In addition to its effects on body composition, our physical activity program also has beneficial effects on the performance of obese subjects at the fat and anaerobic thresholds. After completing the program, obese subjects require significantly greater effort to reach these thresholds. In other words, they spend more time at the fat threshold. This results in increased fat oxidation, thus promoting fat loss. Conversely, these changes were not observed in the control subjects, or at least to a lesser extent.

We also examined physiological characteristics (heart rate, oxygen consumption, and ventilation) measured before and after exercise at the fat and anaerobic thresholds. Except for oxygen consumption at the anaerobic threshold, none of the other parameters showed significant changes, despite a significant improvement in performance achieved after exercise, as mentioned earlier. Although we did not observe a significant variation in the measured parameters at a given speed (we chose 6 km/h), we can conclude that obese subjects become, at least in terms of their physiological characteristics, more exercise-tolerant: heart rate increases less rapidly, and ventilatory effort is reduced.

Correlation between Weight Loss and Improvement in Physical Performance

Surprisingly, we did not observe a significant correlation between the magnitude of weight loss and the improvement in performance or changes in physiological characteristics. Thus, these parameters appear to be relatively independent of weight variation. This finding leads us to hypothesize that the changes induced by physical exercise (particularly the shift in the fat threshold in obese individuals) cannot be solely explained by weight loss but may result from mechanisms that are still poorly understood. It is possible that the development of slow-twitch muscle fibers, mentioned earlier, may play a role in promoting better fat oxidation.

CONCLUSION

In this study, despite its limitations, we were able to demonstrate significant changes in both body composition and physiological characteristics in obese subjects exposed to a physical exercise program tailored to their needs, alternating efforts at the fat threshold with efforts at the anaerobic threshold. It is very likely that this combination of moderate and intense efforts, which has been scarcely investigated in previous studies, confers superiority to our program compared to those that only focus on a single aspect of physical exertion.

With these observations, we can now consider that physical exercise, even when practiced without a strict hypocaloric diet, can be highly beneficial for obese individuals. However, it is crucial that this physical exercise precisely meets the demands of obese subjects, which are likely different from those of normal-weight individuals. The combination of varied intensity efforts indeed promotes a significantly higher compliance among subjects who may struggle with sustained intense efforts in the long term.

Many questions regarding physical activity in obese patients in general, and in our subjects in particular, still remain unanswered. What are the repercussions of a physical activity program that leads to significant weight loss on the quality of life of an obese individual? To what degree of compliance can we expect if such a program is applied in the long term? Do the effects on weight and physiological characteristics from our program persist after the training period ends, and if so, for how long and to what extent?

Although these questions remain open, we can no longer ignore the importance of physical activity in obese individuals, whether it is to achieve weight loss or simply improve physical fitness.

REFERENCES

1. Schuch, F. B., Vasconcelos-Moreno, M. P., Borowsky, C., Zimmermann, A. B., Rocha, N. S., & Fleck, M. P. Exercise and severe major depression: effect on symptom severity and quality of life at discharge in an inpatient cohort. Journal of psychiatric research. 2015;61, 25-32.
2. Carneiro LSF, Fonseca AM, Vieira-Coelho MA, Mota MP, Vasconcelos-Raposo J. Effects of structured exercise and pharmacotherapy vs. pharmacotherapy for adults with depressive symptoms: A randomized clinical trial. J Psychiatr Res. déc 2015;71:48-55.
3. Rahim S, Baali A. Étude de l`obésité et quelques facteurs associes chez un groupe de femmes marocaines résidentes de la ville de Smara (sud du Maroc). Antropo. 2011;(24):43-53.
4. Gupta N, Goel K, Shah P, Misra A. Childhood obesity in developing countries: epidemiology, determinants, and prevention. Endocr Rev. 2012;33(1): 48-70.
5. World Health Organization. Rapport sur la santé dans le monde : 2002 : réduire les risques et promouvoir une vie saine [Internet]. Organisation mondiale de la Santé; 2002 [cité 17 févr 2023]. Disponible sur: https://apps.who.int/iris/handle/10665/42522
6. Paffenbarger RS, Hyde RT, Wing AL, Hsieh CC. Physical activity, all-cause mortality, and longevity of college alumni. N Engl J Med . 1986;314(10): 605-613.
7. Andersen RM. Revisiting the behavioral model and access to medical care: does it matter? J Health Soc Behav. mars 1995;36(1):1-10.
8. Shephard RJ, Balady GJ. Exercise as cardiovascular therapy. Circulation. 1999;99(7): 963-972.
9. Wade AJ, Marbut MM, Round JM. Muscle fibre type and aetiology of obesity. Lancet. 7 avr 1990;335(8693):805-8.
10. Krassas GE, Tzotzas T, Tsametis C, Konstantinidis T. Prevalence and trends in overweight and obesity among children and adolescents in Thessaloniki, Greece. J Pediatr Endocrinol Metab. 2001;14 Suppl 5:1319-26; discussion 1365.
11. Wilmore JH. Variations in physical activity habits and body composition. Int J Obes Relat Metab Disord. oct 1995;19 Suppl 4:S107-112.
12. Wilmore JH. Increasing physical activity: alterations in body mass and composition. Am J Clin Nutr. mars 1996;63(3 Suppl):456S-460S.
13. Wilmore JH, Després JP, Stanforth PR, Mandel S, Rice T, Gagnon J, et al. Alterations in body weight and composition consequent to 20 wk of endurance training: the HERITAGE Family Study. Am J Clin Nutr. sept 1999;70(3):346-52.
14. Garrow JS, Summerbell CD. Meta-analysis: effect of exercise, with or without dieting, on the body composition of overweight subjects. Eur J Clin Nutr. janv 1995;49(1):1-10.
15. Adults (US) NOEIEP on the I Evaluation, and Treatment of Obesity in. Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults. National Heart, Lung, and Blood Institute; 1998.