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Differences in fat distribution and body composition in women with anorexia: a comparative study with active and sedentary controls

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RESUMEN

El objetivo de este estudio fue analizar la distribución regional de grasa en pacientes con anorexia (AN) en comparación con controles sedentarios y activos. Se realizaron mediciones antropométricas (pliegues cutáneos, diámetros, circunferencias y masa corporal) en un grupo de 66 mujeres, dividido en 3 grupos (AN, control sedentario y control activo) emparejados por edad. Se verificó la normalidad de los datos y se utilizó un ANOVA de una vía con pruebas post hoc t para comparar los grupos. Los tamaños del efecto se calcularon utilizando d de Cohen (p<0.05). Se encontraron diferencias significativas entre los grupos de anorexia (AN), control activo (AC) y control sedentario (SC) para la mayoría de las variables antropométricas. El grupo AN mostró valores más bajos de pliegues cutáneos, circunferencias y masa en comparación con AC y SC (p<0.001, d>0.8). Los diámetros biliocrestal y torácico mostraron diferencias significativas entre grupos. El análisis de masa confirmó menores valores de masa grasa, muscular y residual en AN. En cuanto a los somatotipos, AN presentó menor mesomorfia que AC (p=0.018) y mayor ectomorfia que AC y SC (p<0.001). Estos resultados destacan las diferencias en la composición corporal entre los grupos, destacando la importancia de comparar a sujetos con enfermedades crónicas con aquellos que se ejercitan regularmente.

Palabras clave:

Trastornos alimentarios
Masa magra
Medidas antropométricas
Distribución regional de la grasa
Ejercicio

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ABSTRACT

The aim of this study was to analyze the regional fat distribution in patients with anorexia (AN) compared with sedentary and active controls. Anthropometric measurements (skinfolds, diameters, circumferences and mass measurements) were taken in a group of 66 women divided into 3 groups (AN, sedentary control and active control) matched by age. Data normality was verified, and a one-way ANOVA with post-hoc t-tests was used to compare groups. Effect sizes were calculated using Cohen's d (p<0.05). Significant differences were found among the anorexia (AN), active control (AC), and sedentary control (SC) groups for most anthropometric variables. The AN group exhibited lower skinfolds, circumferences, and mass values than AC and SC (p<0.001, d>0.8). Biliocrestal and thorax diameters showed significant differences across groups. Mass analysis confirmed lower fat, muscle, and residual mass in AN. Regarding somatotypes, AN showed lower mesomorphy than AC (p=0.018) and higher ectomorphy than both AC and SC (p<0.001). These results highlight the distinct body composition differences across groups, highlighting the importance of comparing chronically ill subjects with those who exercise regularly.

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Introduction

Anorexia nervosa (AN) is one of the most common chronic diseases among adolescents (ages between 15 and 19) in Western countries (Lucas et al., 1991) that very often persists into adulthood (Mattar et al., 2011). It is an eating disorder (ED) characterized by a low bone mineral content (BMC), poor body composition (Hübel et al., 2019) and image perception (Esposito et al., 2018), and low weight (Haas et al., 2018). These alterations are usually accompanied by elevated cholesterol (Hussain et al., 2019), increased sensitivity to insulin (Ilyas et al., 2019), depleted fat stores and reduced body protein (Russell et al., 1994), therefore, suggesting that these and other biophysiological factors play a key role in the disease prognosis (Watson et al., 2019). In an effort to better define the nutritional status of AN patients, investigators have examined body composition – including fat mass and lean mass – through anthropometric measurements (Nicholls et al., 2002). Although improvement in nutritional intake and weight regain remain the goal of all AN patients, the altered body composition, especially regional fat distribution, has been detrimental for psychological and physical recovery in this population (Misra et al., 2003). Different studies focusing on regional fat distribution in AN have shown: First, the total fat mass and lean mass is reduced compared to controls (Kerruish et al., 2002); second, there is a disproportionate decrease of fat content in the extremities at the onset of the disease (Bredella et al., 2014); and third, weight recovery is accompanied by an altered fat redistribution where fat accumulates mainly in the trunk, therefore, increasing central fat deposition (El Ghoch et al., 2014). This evident accumulation in the trunk region is a potential risk factor and contributor to relapse of the psychiatric condition (Esposito et al., 2018).

On the other hand, bone loss and increased risk of fractures are complications of the weight loss associated with AN (Visser et al., 1999). Evidence suggests that the decline in bone mineral density is primarily influenced by the reduction in muscle mass and strength, rather than by intrinsic alterations in bone tissue (Soyka et al., 2002). These effects on body composition, resulting from extreme weight loss, vary depending on whether this occurs solely through starvation or is accompanied by excessive physical exercise (Görner and Reineke, 2020). In this context, various studies indicate that individuals with AN predominantly lose fat mass; however, the extent of lean mass and muscle strength loss is closely related to unhealthy exercise behaviors (Jendrysek et al., 2015; Gravina et al., 2018). It is well known that regular participation in sports reduces the amount of body fat and increases lean body mass, consequently, improving insulin sensitivity which has been shown to disease (Wolfe, 2006). The importance of muscle mass, strength, and metabolic function are recognized as key elements for the prevention of many pathological conditions and chronic diseases (Buchholz et al., 2013). In this sense, muscle has shown to be critical in the recovery from illness or severe trauma (e.g. survival from a severe burn injury is lower in individuals with reduced lean mass) (Evans, 1995), while muscle loss is known to be detrimental to cancer survival (Hadigan et al., 1999). It appears, therefore, that in addition to fat content, the assessment of lean mass recovery is of great importance to provide meaningful information of both physical health status and the effectiveness of weight regain programs in patients with AN.

Previous research in patients with AN has demonstrated that gains in muscle function can be achieved when exercise programs are incorporated into the treatment (Vancampfort et al., 2014). where resistance training has shown to be particularly effective (Ortega et al., 2008). However, gains are not permanent, as muscle mass and strength tend to regress to previous levels when programs are discontinued. This is crucial when assessing progress in AN patients compared with sedentary controls, as muscle strength, mass, and overall body composition will not reach levels considered "healthy". Therefore, it is necessary to include more appropriate control groups that are comparable to a truly healthy (active) profiles, rather than relying on sedentary individuals who may not reflect the ongoing physiological adaptations associated with a healthy active lifestyle (e.g. improved muscle mass, fat distribution, etc.). Therefore, the objective of this study was to analyze the regional fat distribution in patients with AN compared sedentary and active but otherwise healthy controls.

Methodology

This study complies with the Declaration of Helsinki for research involving human subjects. Informed consent was obtained from all participants (and their legal tutors if they were under 18 years of age) by signing a written document prior to data collection but after the protocol was reviewed by Hospital de San Rafael (Mendoza) and approved on April 2020 7th as per document 2018/0502.

Sample

The sample consisted of a total of 22 women diagnosed with anorexia nervosa and 44 healthy women. AN patients (n=22) were diagnosed by health professionals specialized in eating disorders following the criteria established by the DSM-5 (American Psychiatric Association, 2013). All participants were under medical treatment at the time of their inclusion in the study, which included nutritional therapy and psychotherapy adapted to each case and were in a recovery phase, not yet reached the target body weight as defined by the clinical guidelines for AN (American Psychiatric Association, 2013). Patients with AN recruited for the study included both those who were physically active and those who were not prior to the start of treatment. However, during treatment, no physical activity was permitted, in accordance with the center's treatment standards. Additionally, healthy controls (n=44) were age-matched with AN participants, and allocated to either one group of women (n=22) who were sedentary (SC) or a group of women (n=22) who were physically active (AC). Physical activities were recorded through a brief interview. The type of exercises performed by AC were skating (31.82%), judo (40.91%), handball (13.64%), badminton (4.54%), athletics (4.54%) and canoeing (4.54%). The control group was selected from a sample taken from schoolchildren, university students, and recreational women.

Anthropometric assessment

Anthropometric measurements were carried out in accordance with the protocol developed by the International Society for Advances in Kinanthropometry (ISAK) (Marfell-Jones and Reilly, 2005) by a Level 2 anthropometrist. Body weight was measured with a CAM type scale (ISO 90200). Standing height was measured with a stadiometer, and a 40-centimeter-high wooden box was used for sitting height. For large and small diameters, a long branch gauge and a short branch gauge were used, respectively. The circumferences were assessed with a non-extensible Lufkin metal tape (Rosscraft Innovations Inc, Vancouver, Canada) and the skin folds were measured with a Harpenden caliper (British Indicators, West Sussex, UK).

Body composition evaluation

Body composition was evaluated using the 5-component model that divides the body into anatomically defined masses (adipose tissue, muscle tissue, residual tissue, bone tissue and skin) using the formulas described by Ross and Kerr (2004). Fractionation of mass was adjusted in its calculation according to Holway and Garavaglia (2009). Specifically for this work, muscle mass and adipose mass were considered. Body mass index (BMI) was calculated by dividing the body weight in kilograms by the square of the height in meters (kg/m^2). The formulas used for the evaluation of body composition can be found in Annex I.

Statistical analysis

Tests of normal distribution and homogeneity were conducted on all data before analysis using the Shapiro-Wilk test, respectively, and all data were found to be suitable for parametric testing. Descriptive data for the sample and variables were reported in means and standard deviations (SD). A one-way analysis of variance (ANOVA) was performed to assess the differences between the groups (AN, AC and SC) on each variable. Following a significant ANOVA result, a post hoc analysis was conducted using t-tests for independent samples to compare the specific group means. Data were analyzed using IBM SPSS Statistics 29.0 and the significance level was set at $p<0.05$. Additionally, effect sizes for group differences were expressed as Cohen's d (Cohen, 2013); effect sizes are reported as: trivial (<0.2), small (0.2-0.49), medium (0.5-0.79), and large (≥0.8) (Cohen, 2013).

Results

Table 1 shows age, weight, height, and height seated for each group. No differences were found at baseline except for body weight [t(42)= -5.091; p=0.000; d=1.53] and height [t(42)=2.84; p=0.007; d=0.86] between the AN and AC groups. And for body weight [t(42)= -7.493; p=0.000; d=2.26] between the AN and SC groups. The comparisons of skinfolds, diameters, circumferences, and mass between AN, AC, and SC are presented as means and SD in Table 2. A one-way ANOVA indicated that there was a significant difference between the groups for all variables, except for the biacromial, anteroposterior thorax, humerus and femur diameter, and for head circumference, total bone mass and skin mass. Post-hoc comparisons using t-tests for independent samples revealed that skinfold measurements were significantly different between the AN and AC groups [d>0.8] and between the AN and SC groups for all skinfolds [d>0.8]. The AN group had significantly lower values compared to the AC and SC groups. When comparing AC and SC groups, only tricipital skinfold [t(42)= -2.566; d=0.77] and calf skinfold [t(42)= -2.322; d=0.7] were significantly smaller for AC.

Table 1. Descriptive parameters of the sample. All values are represented as mean and standard deviation (in parentheses).

	AN (n=22)	AC (n=22)	SC (n=22)
Age (years)	20.70 (4.93)	20.65 (5.16)	20.69 (4.98)
Weight (kg)	45.16 (4.1)	53.02 (5.96)	56.51 (5.79)
Height (cm)	162.02 (6.37)	157.27 (4.58)	158.81 (4.80)
Height seated (cm)	83.64 (3.52)	84.25 (2.76)	84.96 (3.33)

AN: Anorexia; **AC:** Active control; **SC:** Sedentary control

Regarding diameters, significant differences were observed between the AN and AC groups for biliocrestal diameter and thorax diameter. For biliocrestal diameter, the AN group had significantly higher values compared to the AC group [t(42) =3.137; d=0.95]; the thorax diameter was significantly lower in AN group compared to the AC group [t(42)= -0.446; d=1.58]. The same was found among the AC group and SC group [biliocrestal diameter: t(42)= -3.782; d=1.14; thorax diameter: t(42)=2.057; d=0.62]. No significant differences were found between the AN and SC groups for all these variables, except for the thorax diameter values [t(42)= -3.838; d=1.16], which were lower for the AN group.

In relation to the circumferences, significant differences were observed between the AN and AC groups [d>0.8] and between the AN and SC groups [d>0.8] for all these variables, except for the head diameter. The AN group had significantly lower values compared to the AC and SC groups. Additionally, significant differences were observed between the AC and SC groups for thoracic [t(42)= -2.542; d=0.77], abdominal [t(42)= -2.393; d=0.72], forearm [t(42)= -9.872; d=2.97], thigh [t(42)=2.874; d=0.87], contracted arm [t(42)= -2.460; d=0.75] and hip [t(42)= -2.477; d=0.75] circumferences. For all the significant variables, the AC group had lower values compared to the SC group.

Lastly, regarding mass measurements, significant differences were observed between the AN and AC groups for fat [t(42)= -3.489; d=1.05], muscle [t(42)= -4.923; d=1.49] and residual mass [t(42)= -3.749; d=1.12]. And between the AN and SC groups for fat [t(42)= -4.889; d=1.47], muscle [t(42)= -7.093; d=2.14] and residual mass [t(42)= -4.443; d=1.34]. The AN group had significantly lower values compared to the AC and SC groups. However, no significant differences were found between the AC and SC groups.

Table 2. One-way ANOVA comparing skinfolds, diameters, circumferences and mass for anorexia, active control, and sedentary control groups.

	AN		AC		SC		ANOVA	AN vs. AC	AN vs. SC	AC vs. SC
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p**	**p**	**p**	**p**
Skinfolds (mm)										
Tricipital	10.11	3.52	14.05	4.24	17.17	3.81	**<0.001****	**0.002****	**0.000****	**0.014***
Subscapular	6.52	1.69	10.39	3.21	11.58	3.43	**<0.001****	**0.000****	**0.000****	0.243
Supraspinal	6.05	2.65	11.27	5.10	13.05	4.13	**<0.001****	**0.000****	**0.000****	0.210
Abdominal	10.30	4.31	16.49	6.68	19.01	5.69	**<0.001****	**0.001****	**0.000****	0.186
Thigh	13.56	4.01	21.01	6.23	24.02	7.54	**<0.001****	**0.000****	**0.000****	0.157
Gemelus	9.38	3.49	14.13	4.23	17.30	4.81	**<0.001****	**0.000****	**0.000****	**0.025***
Diameters (cm)										
Biacromial	34.39	1.47	35.11	1.26	34.66	1.87	0.222	0.087	0.587	0.359
Biliocrestal	26.15	1.63	24.74	1.32	26.31	1.43	**<0.001****	**0.003****	0.718	**0.000****
Anteroposterior thorax	16.30	1.59	16.58	2.56	17.09	1.06	0.156	0.658	0.059	0.397
Thorax	22.93	1.44	25.35	1.62	24.47	1.21	**<0.001****	**0.000****	**0.000****	**0.046***
Humerus	5.84	0.25	5.89	0.33	5.81	0.31	0.734	0.631	0.691	0.431
Femur	8.63	0.35	8.65	0.40	8.88	0.50	0.145	0.889	0.060	0.093
Circumferences (cm)										
Head	54.35	1.39	53.63	1.21	54.24	0.94	0.121	0.074	0.763	0.068
Thoracic	76.30	3.06	81.56	4.22	84.34	2.92	**<0.001****	**0.000****	**0.000****	**0.015***
Abdominal	59.35	3.85	65.56	4.80	68.83	4.24	**<0.001****	**0.000****	**0.000****	**0.021***
Arm	21.79	2.05	24.95	2.13	26.03	1.74	**<0.001****	**0.000****	**0.000****	0.072
Forearm	20.69	0.96	21.98	1.08	26.48	1.85	**<0.001****	**0.000****	**0.000****	**0.000****
Thigh	45.66	3.46	54.78	6.84	53.56	3.63	**<0.001****	**0.000****	**0.000****	**0.006****
Calf	30.72	2.15	52.31	4.18	54.29	4.88	**<0.001****	**0.000****	**0.000****	0.157
Contracted arm	23.68	2.32	32.54	1.89	34.05	2.15	**<0.001****	**0.000****	**0.000****	**0.018***
Hip	83.18	3.61	90.02	5.59	94.25	5.73	**<0.001****	**0.000****	**0.000****	**0.017***
Mass (kg)										
Fat	14.81	2.44	17.95	3.45	19.69	4.00	**<0.001****	**0.001****	**0.000****	0.129
Total bone	6.18	0.88	5.90	0.52	5.91	0.65	0.410	0.205	0.250	0.959
Skin	3.19	0.31	3.21	0.20	3.14	0.28	0.736	0.735	0.609	0.328
Muscle	17.18	2.51	21.17	2.85	22.87	2.80	**<0.001****	**0.000****	**0.000****	0.052
Residual	3.80	0.81	4.78	0.93	4.89	0.82	**<0.001****	**0.001****	**0.000****	0.693

*p: differences between active control and sedentary control, p<0.05; **p: differences between anorexia group and active control, p<0.01.

AN: Anorexia; **AC:** Active control; **SC:** Sedentary control; **SD:** standard deviation.

The comparisons of somatotypes between AN, AC, and SC are presented as means and SD in Table 3. A one-way ANOVA indicated that there was a significant difference between the groups for all variables. For endomorphy, significant differences were observed between the AN and AC groups [t(42)= -4.70; d=1.42] and between the AN and SC groups [t(42 = -7.84; d=2.36], with the AN group showing significantly lower values compared to both AC and SC. No significant differences were found between the

AC and SC groups [t(42)= -2.00; p> =0.086]. For mesomorphy, significantly lower values are observed for the AN group compared to the AC group [t(42)= -2.906; d= -2.906]. No significant differences were found between the other groups. In relation to ectomorphy, significant differences were observed between the AN and AC groups [t(42)=9.272; d=2.77] and between the AN and SC groups [t(42)=12.297; d=3.67]. The AN group had significantly higher values compared to the AC and SC groups.

Table 3. One-way ANOVA of somatotype components for anorexia, active control and sedentary control groups.

	AN		AC		SC		ANOVA	AN vs. AC	AN vs. SC	AC vs. SC
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p**	**p**	**p**	**p**
Endomorphy	2.21	0.79	3.60	1.14	4.22	0.91	**<0.001****	**.000****	**.000****	0.086
Mesomorphy	1.80	1.00	2.69	1.02	2.09	0.94	**0.018***	**0.006****	0.330	0.051
Ectomorphy	3.45	0.49	1.81	0.68	1.56	0.54	**<0.001****	**0.000****	**0.000****	0.181

*p: significant differences, p<0.05; **p: significant differences, p<0.01

AN: Anorexia; **AC:** Active control; **SC:** Sedentary control. **SD:** standard deviation.

Discussion

The objective of this study was to analyze the anthropometric characteristics in patients with AN under treatment compared to sedentary controls and physically active controls. Skinfold analyses showed significant differences among AN, AC, and SC, with consistently lower values in the women with AN. These data were in agreement with the results published in previous studies, indicating that the reduction in body mass in people with AN involves both adipose and lean tissue, with the loss of the former being to a greater extent and, therefore, one of the most frequent symptoms in this population (Orphanidou et al., 1997; Abbaspour et al., 2021; Dos Reis et al., 2022; Hurtado et al., 2023). For this reason, skinfold measurement may be one of the best biomarkers for measuring fat stores in these individuals (Loucks, 2007).

When comparing the data of the skinfolds between the control groups (sedentary and active women), we only found significant differences in the triceps and calf, with both being smaller in active women. As is well known, physical exercise, contributes to healthier body composition, as reflected by lower body fat content (Westerterp, 2018). Given the differences were only found in triceps and calf skinfolds, we could take into consideration the age range of the sample is still young, so these differences could be more accentuated in the future, enabling additional medical problems in the future such as hypertension, hypercholesterolemia, type II diabetes, hyperuricemia, hypertriglyceridemia, impaired lung function, hepatic steatosis, osteoarthritis, body pain and problems related to the loss of balance and coordination , as demonstrated in a study by Tsai et al. (2004) in which overweight and obese people were compared with people with normal body mass indices.

Regarding diameter measurements, our data show significant differences in biliocrestal diameter with higher values in women with AN compared to the group of active women. In addition to the reduced total body mass of people with AN compared to control groups, weight regain in AN is often accompanied by altered redistribution of fat, increasing the central deposition of fat (Folsom et al., 2000). This can be detrimental to the psychological and physical recovery of this population (Krahn et al., 1993) and is also associated with greater insulin resistance (Probst et al., 1996), thus having potentially negative metabolic consequences, as observed in other pathologies such as obesity (Folsom et al., 2000). The same occurs when comparing the control groups, where we also found significant differences in the biliocrestal diameter measurements, these being greater among the sedentary groups suggesting an increased gynoid-like fat deposition. The consequences derived from the accumulation of fat inflict considerable damage and it is considered one of the most important risk factors for metabolic and cardiovascular disease. However, there is evidence that shows that the improvement in health and the decrease in abdominal fat percentage is proportional to the increase in physical activity (McLaughlin, Lamendola and Liu, 2011).

Regarding the diameter of the thorax, the results show significant differences in this measurement, these values being higher in the control group of active women compared to both the women with AN and the control group of sedentary women. The measurements of the bone diameters are used to obtain the width of the bone, in addition to representing the bone, muscle and visceral development of the thorax (Albaladejo Vaquero-Cristobal and Esparza-Ros, 2019). Misra et al. (2003) point out that the dietary restriction typical of people with AN, in addition to biological changes, couples a series of important physical changes. Among them, the possibility of leading to cachectic states stands out, due to the progressive malnutrition that manifests itself in most cases (Vahia, 2013). These anthropometric parameters can vary with lifestyle, in such a way that sports practice or inadequate nutrition could induce changes in anthropometric variables (Rivera-Sosa, 2016). In addition, malnutrition has several adverse effects on the respiratory system, decreasing, among others, the strength of the inspiratory muscles (Ryan, Whittaker and Road, 1992). Something similar occurs in patients with chronic obstructive pulmonary disease, where reduced diffusing capacity and weight loss are associated with severe impairment of diaphragmatic function (Murciano et al., 2012); in the mentioned study, the diaphragmatic strength of a group of women with AN, measured through spirometric values, was markedly affected before refeeding. As was the case with a study by Pieters et al. (2000) who showed that the function of the respiratory muscles is clearly altered in anorexia nervosa. This decrease in inspiratory muscle strength, a possible symptom in people with AN and sedentary people, may be related to a smaller chest diameter and the aforementioned state of cachexia. On the contrary, among the different adaptations to which people who perform physical exercise are subjected, one of the most important is the one produced in the ventilatory system (Courteix et al., 1997). In a study carried out by Santibáñez et al. (2017), whose objective was to correlate chest diameters and perimeters with lung function between a group of swimmers and another control group, it was shown that the anthropometric measurements taken from the former, together with their spirometric values, were higher. Therefore, although in our study significant differences were also found in the diameter of the thorax between the group of sedentary women and women with AN, we might think that using a sample of sedentary controls as healthy people would not be the most ideal when it comes to compare populations with pathologies.

After measuring the circumferences in the three groups, we found significant differences in all the variables analyzed in both the upper and lower body. The group of women with AN presents lower values compared to both control groups. Caloric restriction, characteristic of AN, may lead to a decrease in the size of muscle and adipose tissue throughout the body, which would be reflected in smaller total circumferences, especially in the thorax and legs, where they lose most of their mass (Couturier and Lock, 2006). In this research, DXA was used to measure body composition in adolescent women with anorexia nervosa, finding a significantly lower percentage of fat in the trunk compared to the healthy control group, although in this case, the percentage of fat in the extremities did not differ between the two groups. Furthermore, it should be noted that, in the treatment of AN, the measurement of thigh circumference (relating it to BMI) should be an indicator to pay attention to, since reaching this measurement at 50 cm after the first treatment cycle is related to a favorable long-term prognosis (Buchholz et al., 2013).

In the same way, significant differences were found between the control groups, with the circumferences of the thorax, abdomen, arm, contracted arm and hip being lower in the group of active women and higher in the thigh circumference. First of all, as the existing scientific literature demonstrates, waist circumference can be a great indicator when estimating a person's abdominal fat (Janssen et al., 2004). Second, it is also well known that physical exercise is associated with significant reductions in total fat mass and waist circumference itself (Andersson et al., 1991). Finally, the decrease in total body mass and waist circumference after carrying out a physical exercise program attenuates the risk of having health problems, since both are clear determinants of metabolic risk (Bernardoni et al., 2020). Therefore, after analyzing these data, we can reconsider the hypothesis that using control groups that do not engage in physical exercise is not the best way to compare populations with chronic pathologies.

Regarding mass measurements, we found significant differences between all groups in the variables of fat, muscle and visceral mass. Whether we compare the women with AN to the active control group or the sedentary control group, we can see that women with AN have less fat, less muscle, and less visceral fat. In this sense, we must make special emphasis that having a total, muscular and visceral body mass below a minimum is also a problem to be considered. Body composition abnormalities, such as low muscle mass, are a predictor of morbidity and mortality, particularly in settings where the disease itself can lead to this condition (Cruz-Jentoft et al., 2010), as occurs with the AN. This low muscle mass, in the hospital setting, is associated with aspects such as a longer duration of hospital stay, lower physical function and poorer quality of life for patients (Cruz-Jentoft et al., 2010), since skeletal muscle it is involved in people's mobility, strength, and balance (Studenski et al., 2014), as well as being related to hormonal regulation and other metabolic abnormalities (Cruz-Jentoft et al., 2010). In addition, bone loss and increased risk of fractures are also among the complications associated with weight loss in AN (Legroux-Gerot et al., 2005), relating to loss of muscle mass and reduced muscle strength more than with decreased bone mineral density itself (Bulik et al., 2006). In the light of the substantial evidence provided on the maintenance of muscle mass, strength and physical function in people with chronic pathologies, health professionals should incorporate techniques for the detection and treatment of this problem.

Although there are numerous problems associated with high adiposity, having very low levels of fat mass is also associated with health problems, including elevated cortisol and reduced immune function (Cunha, Ribeiro and De Oliveira, 2006). These problems can be increased in women with AN with a low percentage of fat mass, and may also present amenorrhea, an important indicator of the state of physical health in women with AN, with possible consequences in bone mineral density deficits and/or biological abnormalities (Dalle-Grave, Calugi and Marchesini, 2008). According to the classification of centile scores a body mass index below 17% is among the criteria for having AN and is attributed to the reduction of dietary intake below the amounts recommended for it to be healthy (Fried et al., 2007). In this sense, in a study carried out by Mayer et al. (2007) found that, after evaluating a group of women with AN using DXA, lower percentages of total body fat mass were associated with poorer long-term prognosis. In this same sense, in our study we did not find significant differences in these same measures between the control groups, which we can attribute to the age of the sample. However, although the data does not provide us with significant results, if we look at the tables previously exposed, in the measurements of fat mass and visceral fat we find that the values obtained in the group of sedentary women are higher than in those of women active. Therefore, the benefits of the practice of physical exercise include positive effects not only on fat loss but also on the reduction of visceral fat along with the preservation of lean mass (Shephard, 2011), thus improving the cardiometabolic health of practitioners (Bellicha et al., 2021).

Another means by which useful information about body shape, proportionality and composition can be obtained is through the evaluation of the somatotype of people (Carter et al., 2007) since it has been shown that the nutrition and exercise influence it (Carter and Phillips, 1969). The mesomorphic component is related to the muscular component, while in the endomorphic component it is related to the prevalence of body fat (Sánchez-Muñoz, Zabala and Williams, 2012). These data are consistent if we take into account the characteristics of body composition typical of people with AN and the data provided in our study, since in the mesomorphic somatotype, we found significantly lower values in women with AN compared to the control group of active women, in addition to not finding significant differences with the group of sedentary women. Therefore, thanks to the benefits of greater muscle mass, we once again emphasize the importance of comparing people with chronic pathologies, or in this case, eating disorders, with people who do physical exercise.

Conclusions

This study emphasizes the importance of comparing individuals with chronic diseases, such as eating disorders, with those who maintain a regular physical exercise routine in both clinical and research settings. It was found that women with AN in treatment showed lower skinfold and mass (fat, muscle and visceral) measurements compared to both control groups. Furthermore, in terms of skinfolds, it was evident that participants in the active control group had better body composition than those in the sedentary control group, thus underlining the benefits of physical exercise in reducing visceral fat and preserving lean mass. Additionally, somatotype analysis revealed lower mesomorphic values in individuals with AN compared to active controls, reinforcing the importance of greater muscle mass, a feature more prominent in those who maintain regular physical activity.

Limitations of the study

Menstrual cycle disturbances are common in women with AN, and the absence of menstruation may influence muscle mass. However, at this stage of the research, we considered it more appropriate to analyze the relationships between physical activity and body composition in a general manner, without including menstrual status as variable. Additionally, no specific measurements were taken regarding contraceptive use in the control group, which could have influenced some results. Moreover, the present study did not include detailed information on the time elapsed since the diagnosis of anorexia nervosa (AN), the duration of treatment, or the participants' prior exercise history. The limitations should be considered when interpreting the findings and addressed in future research.

Declarations

This work has not previously been published in any form including preprint servers, and is not currently under consideration elsewhere, nor will it be submitted elsewhere until a final decision has been made. The authors have no real or perceived conflicts of interest arising from intellectual, personal, or financial circumstances of this research. All authors acknowledge ethical responsibility for the content of the manuscript and will accept the consequences of any ethical violation. This research is not part of a larger study

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ANNEX I: Formulas for the evaluation of body composition skin mass prediction

To calculate the skin mass,

$$\mathrm{MS} = \mathrm{SA} \times \mathrm{T_{SK}} \times 1.05$$

where:

- MS = mass of skin in kg
- SA = surface area in square meters
- T_{SK} = skin thickness of skin (obtained from cadavers): it is 2.07 for men and 1.96 for women
- 1.05 = skin density (obtained from cadaveric dissection)

To calculate the body surface area,

$$\mathrm{SA} = \mathrm{C}_{SA} \times \mathrm{W}^{0.425} \times \mathrm{H}^{0.725}/10{,}000$$

where:

- W = body mass expressed as weight, in kg
- H = height in centimeters
- SA = surface area in square meters
- C_{SA} = 68.308 in males aged > 12 years; 73.704 in females aged > 12 years; 70.691 in males and females, < 12 years (represents the mean of male and female constants).

General formula for the prediction of adipose tissue, muscle, bone and residual tissue masses (PHANTOM Tactic).

The fractionation tactic requires deriving the Phantom proportionality index for each mass, object according to the following formula:

$$\mathrm{Z} = 1/\mathrm{s} \times [\mathrm{V} \times (\mathrm{C_P}/\mathrm{C_S})^{\mathrm{d}} - \mathrm{P}]$$

where:

- Z = Phantom value of proportionality
- V = value of the variable(s)
- d = dimensional constant: 1 for lengths, diameters and perimeters, 2 for areas and 3 for volumes (such as weight)
- C_P = height or size Phantom
- C_S = height or size of the evaluated person
- P = Phantom value for the variable V
- S = Phantom standard deviation for the variable V

The sum of the anthropometric values for each subgroup of predictor variables is used to determine a Phantom value of proportionality (Z) for each tissue mass: adipose, muscle, bone and residual. The deviation from the Phantom value of proportionality for each tissue mass is considered to represent the dysplastic characteristics of the tissue mass. To calculate the fractional mass for each tissue, the following formula is used:

$$\mathrm{M} = (\mathrm{Z} \times \mathrm{s} + \mathrm{P}) / (\mathrm{C_p}/\mathrm{C_s})^3$$

where:

- M = any mass, for example: adipose mass, bone mass, muscle mass or residual mass (in kg).
- Z = value of the Phantom proportionality of each mass (expresses the Z proportionality of the subgroup of measurements assigned to a given mass of tissue)
- P = specific phantom value for the mass of tissue in question.
- S = Phantom standard deviation for the tissue mass to be calculated
- C_P = Phantom height or size (seated height or size is used for residual mass calculation)
- C_S = height or size of the evaluated person
- 3 = dimensional exponent (assuming geometrical similarity where mass = litres (or m^3))

Prediction of skeletal or bone mass:

First of all, it should be clarified that skeletal or bone mass is calculated separately: a) head bone mass; b) body bone mass.

The skeletal mass of the head is predicted according to the general method described above, thus:

$$\mathrm{Z\ OSEA\ HEAD} = (\mathrm{head\ circumference} - 56.0) / 1.44$$

Where:

- 56.0 = Phantom head circumference
- 1.44 = Phantom standard deviation for head circumference
- M HEAD BONE = Bone mass of head (in kg)
- Z HEAD BONE= Phantom proportionality score for head bone mass

- 1.20 = Method constant for mean Phantom head bone mass (in kg)
- 0.18 = Method constant for standard deviation of the Phantom head bone mass (in kg)

The skeletal mass of the body is calculated according to the following equations:

$$\text{S OSEA BODY} = \text{summation}\,[\,\text{BIAC} + \text{BIIL} + (2 \times \text{HUM}) + (2 \times \text{FEM})\,]$$

Where:

- BIAC = biacromial diameter
- BIIL = biiliocristal diameter
- HUM = humerus diameter
- FEM = femur diameter

$$\text{Z BODY BONE} = [\text{S BODY BONE} \times (170.18 / \text{HT}) - 98.88] / 5.33$$

Where:

- Z BODY BONE = Phantom proportionality score for bone mass of the body
- S BODY BONE = Sum of the sum described above
- 98.88 = Phantom summation value of bone diameters
- 5.33 = Phantom summation value of the standard deviations of bone diameters
- 170.18 = Phantom height constant
- HT = Height or size of the evaluated

$$\text{M BODY BONE (kg)} = \frac{(\text{Z BODY BONE} \times 1.34) + 6.70}{(170.18/\text{HT})^3}$$

Where:

- M BODY BONE = body bone mass (in kg)
- Z BODY BONE = Phantom proportionality score for body bone mass
- 6.70 = Method constant for average Phantom body bone mass (in kg)
- 1.34 = Method constant for standard deviation of body bone mass Phantom (in kg)

$$\text{TOTAL BONE MASS (in kg)} = \text{M BODY BONE} + \text{M HEAD BONE}$$

Prediction of adipose mass

The following equations are used:

$$\text{S ADIP} = \text{summation}\,(\text{TPSF} + \text{SSSF} + \text{SISF} + \text{ABSF} + \text{THSF} + \text{MCSF})$$

$$\text{Z ADIP} = [\text{S ADIP} - (170.18 / \text{HT}) - 116.41] / 34.79$$

Where:

- 116.41 = sum of Phantom means of the skinfolds
- 34.79 = sum of Phantom standard deviations for the skinfolds
- TPSF = triceps skinfold
- SSSF =subscapular skinfold
- SISF = supraspinal skinfold
- ABSF = abdominal skinfold
- THSF = frontal skinfold of the thigh
- MCSF = skinfold of the mid-calf

$$\text{M ADIP (kg.)} = [\,(\text{Z ADIP} \times 5.85) + 25.6] / (170.18 / \text{HT})^3$$

Where:

- M ADIP = Adipose mass (in kg)
- Z ADIP = Phantom Proportionality Score for Adipose Mass
- 25.6 = method constant for average Phantom fat mass (in kg)
- 5.85 = Method constant for standard deviation of the Phantom adipose mass (in kg)

Muscle mass prediction

$$\text{S MUS} = \text{Sum}\,(\text{C ARC} + \text{C FA} + \text{C THC} + \text{C MCC} + \text{C CHC})$$

$$\text{Z MUS} = [\text{S MUS} \times (170.18 / \text{HT}) - 207.21] / 13.74$$

Where:

- 207.21 = sum of the Phantom averages of the corrected perimeters
- 13.74 = sum of the Phantom standard deviations for the corrected perimeters
- C ARC = arm circumference (relaxed), corrected for triceps skinfold
- C FA = forearm circumference (uncorrected)
- C THC = thigh circumference, corrected for the skin fold of the front thigh.
- C MCC = calf circumference, corrected for medial calf skinfold
- C CHC = thorax circumference, corrected for subscapular skinfold

$$\text{M MUS (kg.)} = [\,(\text{Z MUS} \times 5.4) + 24.5] \,/\, (170.18 \,/\, \text{HT})^3$$

Where:

- M MUS = Muscle mass (in kg)
- Z MUS = Phantom Proportionality Score for muscle mass
- 24.5 = Method constant for average Phantom muscle mass (in kg)
- 5.4 = Method constant for Phantom standard deviation for muscle (in kg

Residual mass prediction

$$\text{S RES} = \text{Sum}\,(\text{D APTH} + \text{D TRTH} + \text{P WC})$$

Where:

- D APTH = Anteroposterior diameter of the thorax
- D TRTH= Transverse diameter of thorax
- P WC = waist circumference, corrected by the abdominal skinfold

$$\text{Z RES} = [\text{S RES} \times (89.92 \,/\, \text{SIT HT}) - 109.35] \,/\, 7.08$$

Where:

- S RES = Sum of variables for calculating residual mass
- Z RES = Phantom proportionality score for residual mass
- 89.92 = Phantom seated height or size
- 109.35 = Sum of the Phantom means of the variables used
- 7.08 = Sum of the Phantom standard deviations of the same variables
- SIT HT = Seated height or size

$$\text{M RES (in kg)} = [(\text{Z RES} \times 1.24) + 6.10\,] \,/\, (89.92 \,/\, \text{SIT HT})^3$$

Where:

- M RES = Residual mass (in kg)
- Z RES = Phantom Proportionality Score for residual mass
- 6.10 = Method constant for the average residual mass Phantom
- 1.24 = Method constant for the standard deviation for the residual mass Phantom

Prediction of total body mass

Predicted body mass is estimated from the sum of the five calculated fractional tissue masses:

$$\text{M TOT (in kg)} = (\text{M skin} + \text{M fat} + \text{M muscle} + \text{M bone} + \text{M residual})$$

Where:

M TOT = predicted body mass (in kg)