Clinical Nutrition xxx (2015) 1–9

Contents lists available at ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Original article

Changes in lean and skeletal muscle body mass in adult females with anorexia nervosa before and after weight restoration

Marwan El Ghoch [a, *], Maryam Pourhassan [b], Chiara Milanese [c], Manfred J. Müller [b], Simona Calugi [a], Paola Vittoria Bazzani [d], Riccardo Dalle Grave [a]

[a] Department of Eating and Weight Disorders, Villa Garda Hospital, Via Montebaldo, 89, I-37016 Garda, Verona, Italy
[b] Institute of Human Nutrition and Food Science, Christian-Albrechts University, Kiel, Germany
[c] Department of Neurological and Movement Sciences, University of Verona, Italy
[d] Department of Radiology, Villa Garda Hospital, Via Montebaldo, 89, 37016 Garda, Verona, Italy

ARTICLE INFO

Article history:
Received 6 June 2015
Accepted 20 October 2015

Keywords:
DXA
Lean body mass
Total body skeletal muscle mass
Anorexia nervosa
Eating disorders
Inpatient treatment

SUMMARY

Background & aims: Data on the deficits in lean body mass (LBM) and total body skeletal muscle mass (SM) in anorexia nervosa (AN) is scarce and inconsistent. Furthermore, the usefulness of the reported body mass index (BMI) severity cut-off for AN has not been tested with respect to these important parameters. The study had two aims, namely to study LBM patterns and SM in adult females with AN before and after weight restoration, and to examine the clinical usefulness of the 16.5 kg/m^2 BMI cut-off for assessing the protein status in terms of LBM and SM in AN patients.

Methods: Body composition was measured by dual-energy X-ray absorptiometry (DXA) before and after weight gain in 90 adult female inpatients with AN, and 90 controls matched by post-treatment BMI and age. Patients were stratified into two groups using BMI 16.5 kg/m^2 as a cut-off.

Results: Before weight restoration, patients in the BMI $\leq$ 16.5 kg/m^2 subgroup (n = 65) had lower LBM, SM and lean extremity mass percentage, but higher %LBM and lean trunk-to-extremity ratio on average than controls. However, those with BMI >16.5 kg/m^2 (n = 25) displayed lower lean extremity mass percentage and higher %LBM, but no significant differences in LBM and SM with respect to controls. Moreover the time × subgroup interaction was significant in terms of LBM and SM, meaning that, changes occur in different manner over time in the two AN subgroups. However no differences were found between the two AN subgroups in either demographic or other eating disorder characteristics. After weight gain, normalization of LBM, %LBM, lean extremity mass percentage and SM was achieved across the entire AN sample, and the BMI $\leq$ 16.5 kg/m^2 subgroup. The fat mass was the major determinant of gain in LBM; the higher the FM at baseline, the greater the increase in LBM.

Conclusions: Our results suggest a BMI cut-off $\leq$16.5 kg/m^2 as a clinical threshold for determining AN severity. As short-term weight restoration is associated with a normalization in LBM and SM, it appears that biological regulation of weight gain remains intact in AN, i.e., unaffected by the severity of malnutrition.

Clinical trials registry: Changes in lean and skeletal muscle body mass in adult females with anorexia nervosa before and after weight restoration (ISRCTN168721194).

1. Introduction

In spite of considerable research devoted to body composition in anorexia nervosa (AN), little data has been published on lean body mass (LBM) in this population [1]. This is an important shortcoming, as in other populations LBM deficit and abnormalities, and total body skeletal muscle mass (SM) are associated with several serious medical repercussions, such as low vitamin D [2], low bone mineral density [3], reduction in physical fitness (i.e., strength, metabolic function and athletic performance) [4], longer hospitalization [5], and high rates of mortality [6].

What little data is available on LBM and SM in AN is also inconsistent. Indeed, while several studies have reported a reduction in total LBM during AN [7–14], findings have been rather

* Corresponding author. Tel.: +39 045 8103915; fax: +39 045 8102884.
E-mail address: marwan1979@hotmail.com (M. El Ghoch).

http://dx.doi.org/10.1016/j.clnu.2015.10.006
0261-5614/

variable [15–17]; the few studies to investigate regional LBM distribution during AN to date report no changes in regional LBM patterns [9,13,18], and require confirmation [16]. In addition, little is known about changes in SM in AN [19–21], although a recent study based on DXA, which estimated SM using validated models [22], reported a reduction of SM in severely underweight females with AN [23]. These results need replication, also in less severely affected patients, and longitudinal data using such models is still lacking.

Few studies have assessed the influence of eating disorder characteristics on LMB. One study reported that the duration of illness (malnutrition) alters the regional fat distribution, but has no effect on regional lean mass patterns (lean extremity mass and lean trunk mass percentages) [18]. Another study found that episodes of binge eating or purging may lead to an increase in FM percentage, but with no effect on LBM [24].

Finally, although in vivo nitrogen activation analysis suggested that a BMI $\leq$ 16.5 kg/m^2 is an indicative cut-off for protein status [17] in patients with AN, this cut-off has not yet been tested in terms of LBM and SM, the major components of body protein status in adults [25].

Hence, we set out to determine changes in LBM, regional LBM distribution and SM in adult females with AN before and after weight gain, comparing the data with controls matched by age and post-treatment BMI. We also undertook to examine the clinical usefulness of the 16.5 kg/m^2 BMI cut-off for assessing the protein status, in terms of LBM and SM, in patients with AN.

2. Methods

2.1. Participants

We recruited 90 adult female patients with a diagnosis of AN, who were voluntarily and consecutively admitted to the eating disorder inpatient unit at Villa Garda Hospital during the years 2010–2015. Inclusion criteria were the following: (i) age 18–45 years; (ii) body mass index (BMI) $\leq$18.5 kg/m^2 at baseline; (iii) diagnosis of AN according to the Diagnostic and Statistical Manual of Mental Disorders criteria (DSM-IV) [26] and reanalysed post hoc using the recent DSM-5 criteria [27]; (iv) failure of less intensive outpatient treatment, or an eating disorder of clinical severity not manageable in an outpatient setting; and (v) a post-treatment BMI of at least 18.5 kg/m^2. Patients with AN were carefully matched with 90 control subjects of the same age with a BMI equivalent to the patients' BMI at the end of the treatment. Controls were recruited randomly from university listservs and advertisements, and were all healthy and weight-stable, with regular menstruation and no history of eating disorders or other significant psychiatric or medical conditions, or current psychotropic medication intake.

The study design was reviewed and approved by the Institutional Review Board of Villa Garda Hospital, Verona, and all participants gave informed written consent for the anonymous use of their personal data.

2.2. The inpatient treatment

The inpatient treatment has been described in detail elsewhere [12], but, in brief, is based on an adapted version of CBT-E – an enhanced form of cognitive behavioural therapy for eating disorders [28]. Patients were treated for a total of 20 weeks, 13 weeks as inpatients, and 7 weeks in day hospital. Patients received dietician-assisted eating until they reached a BMI $\geq$18.5. This BMI threshold was achieved by increasing the daily energy content of the diet from 1500 to 2500 kcal, providing a steady weight gain rate of 1–1.5 kg per week. When BMI reached $\geq$19.0 kg/m^2, the daily calorie content was continually adjusted to maintain a body weight within a 2-kg range of this target. The diet was designed to conform to the Italian National Guidelines for Healthy Eating [29], and contained all the main food groups. All adult patients were considered medically stable when they achieved a BMI $\geq$ 15 kg/m^2, at which point they attended twice-weekly 60-min physiotherapist-led calisthenics exercise sessions.

All data were collected in the first and last weeks of the treatment.

2.3. Body weight and height

Medical weighing scales and a stadiometer were used by a medical doctor to measure, respectively, body weight and height. Participants were weighed in only their underwear and without shoes before breakfast.

2.4. Body composition

No special preparation was required for body composition assessment, except for making sure participants wore only underwear and no metal jewellery, etc. DXA (Prodigy Primo Lunar, A223040501, General Electric Company, Madison. WI 53707-7550, USA-EnCORE TM 2009 (v13.31) software) assessment was performed under the same conditions in all participants, in the morning after overnight fasting, measuring total and regional fat, lean and bone masses. For the latter categories, the following districts were considered: arm (arms and shoulders), trunk (neck, trunk and pelvis), leg (legs and lateral hip area), android and gynoid regions. Lean trunk mass percentage, lean extremity mass percentage and lean trunk to extremity mass ratio were calculated from whole body DXA as:

1. Total fat mass (FM) = total fat mass in kilograms.
2. Total fat mass percentage (%FM) = total fat mass/total body weight $\times$ 100.
3. Lean body mass (LBM) = total lean mass in kilograms.
4. Lean body mass percentage (%LBM) = lean body mass/total body weight $\times$ 100.
5. Lean trunk mass percentage = lean trunk mass/lean body mass $\times$ 100.
6. Lean extremity mass percentage = (lean arms mass + lean legs mass)/lean body mass $\times$ 100.
7. Lean trunk to extremity ratio = lean trunk mass/lean extremity mass.

2.5. DXA modelling of total body skeletal muscle mass (SM)

Kim et al. have developed three models for predicting SM through the use of DXA-derived measurements. All three have been validated in large and diverse US samples of healthy adults [22], but we elected to use the following model-1, as it provides a good prediction of SM in adult females with AN with respect to MRI [30]:

1. Total body skeletal muscle mass (SM in kg) = (1.19 $\times$ ALM*) – 0.01
2. Total body skeletal muscle mass index (SMI in kg/m^2) = SM/height^2

*Appendicular lean mass (ALM in kg): the sum of lean mass in arms and legs, measured by DXA.

Please cite this article in press as: El Ghoch M, et al., Changes in lean and skeletal muscle body mass in adult females with anorexia nervosa before and after weight restoration, Clinical Nutrition (2015), http://dx.doi.org/10.1016/j.clnu.2015.10.006