Anthropometric data before, during and after in-patient treatment of Anorexia Nervosa: Thigh circumference as reliable direct correlate to BMI and to prognosis.

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Abstract

Purpose The aim of the study was to determine the extent of changes in circumferential measurements taken at various localizations before, during and after in-patient treatment in patients with anorexia nervosa (AN) and their relation to BMI. Furthermore, we analyzed a possible impact of these values on long-term prognosis.

Methods We retrospectively analyzed data of 269 patients (258 females, 11 males) with anorexia nervosa treated between 1999 and 2013 at a single institution by a 6-weeks quick refeeding therapy cycle. A complete set of data was available from 230 patients. BMI and 13 circumferential measuring points at the trunk and the extremities were monitored every day and at follow-up.

Results 229 out of the total collective (85.13 %) had a favourable outcome with restored, stable weight after a mean observation time of 138 +- 52 months. All measuring parameters showed a highly significant increase from admission to end of treatment cycle ($p < 0.0001$ for each parameter. The highest gain expressed as percent of the value at admission was achieved in BMI, followed by girth of thigh. Measurements at the end of term of thorax, waist, upper arm and thigh correlated with a favourable prognosis. A thigh circumference >50 cm was significantly connected to BMI>18 and a beneficial outcome.

Conclusions The highest gain in circumference during refeeding was found at the thigh. A thigh circumference greater than 50 if achieved after the first refeeding cycle was significantly linked to BMI >=18 and was a predictor of a favourable long-term course. Level of evidence Level II, comparative study

Background

Anorexia nervosa (AN) is a severe eating disorder, preferentially found in young female patients. It is characterized by low to extremely low body weight, associated with deficiencies in bone, fat, and lean tissue. Nevertheless, weight loss is mainly due to loss of adipose tissue [1].

Nutritional recovery is the mainstay of treatment for patients with AN, since the restoration of weight is a major prognostic factor. During refeeding, however, significant changes in body composition, especially in regional fat mass distribution may occur. The results regarding a possible trend toward central fat accumulation and trunk adiposity – phenomena feared by the patients and supposed to negatively influence treatment success - are contradictory. Influence of age and the time-course of refeeding have been suggested [1, 2].

Elaborate methods such as dual-energy x-ray absorptiometry (DXA) as well as whole-body impedance vector components, resistance (R) and reactance (X(c) have been used in order to determine the body composition of AN patients [3–6]. Yet some investigators found that comparatively simple anthropometric measurements such as triceps skinfold thickness or girth at different regions of the body

show a very good correlation to the elaborate measurements in AN, whereas BMI proved as less reliable [5, 7].

The aim of the study was to determine the extent of changes in circumferential measurements taken at various localizations before, during and after treatment in patients with AN as well as their relation to BMI. Furthermore, we analyzed a possible impact of these values on long-term prognosis.

Methods

Patients

We retrospectively analyzed data of 269 patients (258 females, 11 males; mean age: 21.4 +- 7.1; range: 12.5–53.8 years) with AN treated between 1999 and 2013 at a single institution by a 6-weeks quick refeeding therapy cycle and concurrent behavior therapy. Data were acquired before, during and at the end of treatment as well as during follow-up. The latter was complete, no patient was lost.

Favourable outcome was defined as maintaining a BMI within normal range, while being able to lead a normal life.

Measurements

Body measurements were routinely taken on a daily basis at the same point of time with the patients wearing underwear. These data were retrospectively available from 230 patients. Measurements included BMI and 13 points for measuring the circumference at different sites of the body. Weight was measured to the nearest 0.1 kg with a calibrated electronic physician's office scale. Height was measured to 1 mm using a wall-mounted stadiometer.

Using a standard cloth tape measure, trunk circumference was measured in millimeters at the subaxillary level, at the maximum expanse of the breasts or nipple-level, respectively, at the submammary fold, at the level of the navel, at the iliac crest and 10 cm below the iliac crest. At the extremities, circumference of the upper arm was taken below the axillary fold, at the lower arm 5 cm distal to the elbow crease, at the thigh 10 cm distal to the crotch, at the knee at the level of the patella and at the lower leg 10 cm distal to the tip of the patella. The measurements were taken by four trained assistants.

The study was approved by the Ethics Board of the Province of Carinthia (institute of Klagenfurt and Villach) Austria.

Statistics

Mean, standard deviation and range as well as absolute and relative frequencies were calculated as basic statistics. Differences of measurements at different time points were assessed using t-test for paired samples. Potential impact of measurements on outcome (favourable or not) was evaluated by logistic regression analysis. Binary variables were compared by chi2-test. Statistical evaluations were carried out

with the Stata package version 15 (Stata Corp, College Station, Texas, USA). A $p < 0.05$ was considered to indicate statistical significance.

Results

Mean initial BMI was 15.1 +- 2.0 (range: 10.5–20.7). 187 patients had complete weight restoration (defined as a BMI > = 18) after the first treatment cycle. 150 did not need further in-patient therapy after having completed the first treatment cycle, 103 required additional in-patient treatment until eventual complete and permanent weight restoration. 17 patients discontinued the therapy prematurely and did not finish the first cycle. 229 out of the total collective (85.13%) had a favourable outcome with restored, stable weight after a mean observation time of 138 +- 52 months.

All 14 measuring parameters showed a highly significant increase from admission to end of treatment cycle (Table 1; t-test for paired samples: $p < 0.0001$ for each measuring point). The highest gain given as percent of the value at admission was achieved in BMI, followed by circumference of thigh, upper waist, lower waist, upper arm and knee. The lowest gains were found at the upper and lower thorax, upper and lower hip, and forearm (Table 1).

This effect persisted until last follow-up in patients who had a favourable treatment result. Comparison of values at the end of follow up with those at admission revealed $p < 0.0001$ for each measurement (Table 2). There was still a further increase from end of term to end of follow up for all values except lower thorax (Table 3). The strongest further gain was seen in the upper arm, followed by lower leg, thigh and knee.

Obviously, there was a significant correlation between the body measurements on the one hand and the BMI on the other. This relationship was highly significant (Spearman rank correlation test: $p < 0.0001$) for each parameter, with the strongest correlations found for thigh, upper arm, knee and lower leg (Table 4). Remarkably, a thigh circumference > 50 cm was significantly connected to BMI > 18 ($chi2 = 43.12$, $p < 0.001$), height, age or sex of the patient notwithstanding. Whereas BMI > 18 after the first treatment cycle had no correlation to prognosis, thigh circumference > 50 cm at this very point of time was significantly linked to a favourable outcome (chi2-test: $p = 0.003$; Table 5).

To assess a potential influence of age, patients were divided into two groups: adolescents with age = < 19 years (127 patients), and adults with age > 19 years (142 patients). There were 5 males in the adolescent group and 6 males in the adult group, with females predominating in both groups (96.1 and 95.8%, respectively).

Concerning basic parameters, both groups did not only differ in age, but in height, weight at admission and BMI at admission, with slightly higher values in the adult subgroup. There was no difference as to the time of follow-up (Table 6). Concerning the body measurements at admission, the values for adults were higher in all body regions compared to adolescents. All these differences – except lower leg – were statistically significant (Table 7). At the end of term, only 6 out of 13 body measurements showed a

significant difference between adolescents and adults, while in the remaining 7 measurements the difference that had existed at admission was attenuated at the end of term (Table 8). Considering the relative increase in each body measurement, as a rule this increase was more pronounced in the adolescent group than in the adult group. These differences were again statistically significant – with the exception of the lower leg (Table 9).

Discussion

Our study is based on a large collective of 269 patients with AN, the vast majority of whom experienced a favourable long-term outcome, eventually achieving a stable BMI within normal range and adequate psychosocial functioning. Detailed body measurements were available from 230 patients.

The increase of BMI to at least low-normal values is the therapeutic aim of refeeding in AN. In general, this implicates a regain of the lost body fat, which is a highly relevant prognostic criterion: Failure to achieve a normal body composition is a risk factor for relapse [2, 8]. Attempts have been made to exactly monitor the increase of body fat. For this purpose, skinfold anthropometry and DXA as well as whole-body impedance vector components, resistance (R) and reactance (X(c) have been used [3–6].

Apart from these more or less sophisticated methods simple measurement of the circumference at different regions of the body have been applied as a comparatively crude additional monitoring of regional weight gain or weight loss, respectively [2, 5]. Kerruish in 2002 found significant correlations between triceps skinfold thickness and percentage of body fat as measured by DXA and BMI and percentage of body fat likewise determined by DXA in adolescent AN patients.

There are numerous publications about the distribution of subcutaneous fat tissue in AN prior to and after short-term or long-term complete or partial weight restoration. The studies were carried out in small collectives of patients and controls the number of which ranged between 15 and 64 individuals.

The findings concerning the pretherapeutic distribution of fat were in part contradictory concerning the distribution at the trunk or the extremities if compared to healthy controls. Some authors described predominant fat loss at the extremities [9, 10], others found predominant loss at the trunk [1] especially in adolescent girls, whereas a few studies described a general loss of fat tissue without predilection of special regions [11–13]. There was, however, unanimity about the fact, that the gain of fat tissue at the trunk was predominant during short term weight restoration, and that this effect levelled out during the further course of weight gain and weight consolidation [3, 9, 14].

Our pretreatment body measurements showed that adults had higher measurement values than adolescents at the time of admission. The difference, in general, was more pronounced at the trunk than at the extremities. This corroborates the findings of El Ghoch and De Alvaro [1, 3, 9, 13]. We were also able to confirm the findings of El Ghoch [3, 9, 13], that the highest absolute gain in circumference after initial refeeding was at the trunk. However, if the gain was expressed as percent of the value at admission, the

highest value was for circumference of thigh, followed by upper waist, lower waist, upper arm and knee. These findings may explain the somewhat contradictory results in the literature.

Thigh circumference seems to constitute a special parameter. In 2011 Konstantynovich compared body measurements of 64 adolescent and adult females with 71 healthy controls. He found that thigh circumference was the most specific and sensitive anthropometric marker of body fat. It correlated with DXA-FM and BMI, demonstrating even a slight clinical advantage over BMI in his cohort. He suggested that this simple measurement might also serve as a useful predictor of body fatness in adolescent girls with AN [5].

In the present, large collective we were able to confirm the findings of Konstantynovic [<link rid="bib5">5</link>]. We found that out of all 13 measurement points the thigh circumference showed the best correlation to BMI. What is more, a circumference greater than 50 cm was strongly related to a BMI of at least 18. This effect was independent of age, height or sex of the patient. Interestingly, a thigh circumference greater than 50 if achieved after the first refeeding cycle was also a highly significant predictor of a favourable long-term course. BMI > = 18 after the first treatment cycle, in contrast, had no prognostic impact.

Conclusion

The simple measurement of body circumferences in addition to weight is a reliable tool when monitoring the treatment of AN. Special attention should be put on thigh circumference, which correlates with BMI, but has a prognostic meaning beyond BMI. Though in our large collective thigh circumference greater than 50 cm achieved after the first treatment cycle was the most significant anthropometric parameter connected with a favourable long-term prognosis, further studies on this issue are warranted.

Abbreviations

AN
anorexia nervosa
BMI
body mass index
DXA
dual-energy x-ray absorptiometry
R
resistance and
(X(c)
reactance

Declarations

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Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding athor on reasonable request.

Authors´contributions

Study conception and design: WD,WW,RG,SJ. Data collection, statistical expertise, analysis and interpretation of data: SJ,WD, LT Manuscript preparation, supervision, administrative support and critical revision of the manuscript: SJ,WD,RG,WS,WW,EJ,LT. All authors read and approved the final manuscript.

Compliance with ethical standards

Ethics approval and Consent to Participate

This is a retrospective study of routine diagnostic and therapeutic data. Treatment and data acquisition had taken place exclusively in the “Kurheim Paracelsus” clinic in Villach, Carinthia. Therefore, the ethics committee of Carinthia (institute of Klagenfurt and Villach) was responsible for approving this retrospective analysis. All procedures performed in this study involving human participants were in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the Ethics Board of the Province of Carinthia, Austria. Informed consent was obtained from all participants and from the parents of participants if minors were affected.

Consent for publication

Not applicable

Competing interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Tables

Table 1

Body measurements in patients with anorexia nervosa. Comparison of values at admission with values at end of term.

measurement region	admission	end of term	% increase	p value*)
BMI	15.0+-2.0	18.2+-1.1	22.2+-10.9 %	p < 0.0001
upper thorax	69.4+-5.0	73.4+-3.8	5.0+-4.8 %	p < 0.0001
lower thorax	69.8+-4.8	73.8+-3.8	5.9+-5.0 %	p < 0.0001
upper waist	60.9+-6.2	70.3+-4.3	16.2+-9.9 %	p < 0.0001
lower waist	61.5+-5.7	70.4+-4.0	15.2+-9.1 %	p < 0.0001
upper hip	76.5+-5.0	81.2+-4.2	6.5+-4.7 %	p < 0.0001
lower hip	76.4+-4.9	81.2+-4.2	6.5+-4.7 %	p < 0.0001
upper bottom	77.1+-6.0	83.6+-4.8	8.7+-5.1 %	p < 0.0001
lower bottom	77.2+-5.9	83.8+-4.7	8.8+-5.2 %	p < 0.0001
upper arm	19.0+-2.1	21.4+-1.6	13.3+-7.6 %	p < 0.0001
forearm	19.5+-1.6	20.7+-1.4	6.8+-5.5 %	p < 0.0001
thigh	41.8+-5.4	48.8+-3.6	17.9+-10.0 %	p < 0.0001
knee	29.7+-2.8	33.3+-2.1	12.4+-7.7 %	p < 0.0001
lower leg	28.5+-2.6	30.8+-2.0	8.2+-7.1 %	p < 0.0001

*) T-test for paired values.

Table 2

Body measurements in patients with anorexia nervosa. Comparison of values at admission with values at the end of follow-up.

measurement region	admission	end follow-up	% increase	p value*)
BMI	15.0+-1.9	18.8+-1.8	26.9+-17.6 %	p < 0.0001
upper thorax	69.4+-5.0	73.8+-4.2	6.5+-6.1 %	p < 0.0001
lower thorax	69.8+-4.8	73.7+-4.2	5.8+-5.7 %	p < 0.0001
upper waist	60.9+-6.2	71.2+-5.8	17.7+-12.6 %	p < 0.0001
lower waist	61.5+-5.7	71.2+-5.8	16.3+-11.7 %	p < 0.0001
upper hip	76.5+-5.0	83.3+-5.1	9.2+-7.2 %	p < 0.0001
lower hip	76.4+-4.9	83.4+-5.0	9.3+-6.9 %	p < 0.0001
upper bottom	77.1+-6.0	86.2+-5.6	12.2+-8.9 %	p < 0.0001
lower bottom	77.2+-5.9	86.3+-5.6	12.3+-8.7 %	p < 0.0001
upper arm	19.0+-2.1	22.4+-2.0	19.1+-13.4 %	p < 0.0001
forearm	19.5+-1.6	21.4+-1.4	10.3+-8.8 %	p < 0.0001
thigh	41.8+-5.4	50.6+-4.3	22.7+-16.3 %	p < 0.0001
knee	29.7+-2.8	34.4+-2.7	16.8+-12.3 %	p < 0.0001
lower leg	28.5+-2.6	32.0+-2.3	12.8+-10.8 %	p < 0.0001

*) T-test for paired values.

Table 3

Body measurements in patients with anorexia nervosa. Comparison of values at end of term with values at the end of follow-up.

measurement region	end of term	end follow-up	% increase	p value*)
BMI	18.2+-1.1	18.8+-1.8	4.5+-9.1 %	p < 0.0001
upper thorax	73.4+-3.8	73.8+-4.2	0.6+-3.8 %	p = 0.0338
lower thorax	73.8+-3.8	73.7+-4.2	0.1+-4.0 %	p = 0.7815
upper waist	70.3+-4.3	71.2+-5.8	1.6+-7.0 %	p = 0.0021
lower waist	70.4+-4.0	71.2+-5.8	1.3+-7.1 %	p = 0.0149
upper hip	81.2+-4.2	83.3+-5.1	2.7+-5.6 %	p < 0.0001
lower hip	81.2+-4.2	83.4+-5.0	2.8+-5.5 %	p < 0.0001
upper bottom	83.6+-4.8	86.2+-5.6	3.3+-5.8 %	p < 0.0001
lower bottom	83.8+-4.7	86.3+-5.6	3.2+-5.9 %	p < 0.0001
upper arm	21.4+-1.6	22.4+-2.0	5.1+-8.2 %	p < 0.0001
forearm	20.7+-1.4	21.4+-1.4	3.6+-5.8 %	p < 0.0001
thigh	48.8+-3.6	50.6+-4.3	4.1+-8.0 %	p < 0.0001
knee	33.3+-2.1	34.4+-2.7	4.0+-7.6 %	p < 0.0001
lower leg	30.8+-2.0	32.0+-2.3	4.4+-7.2 %	p < 0.0001

*) T-test for paired values.

Table 4

Correlation of body measurements at admission and Body Mass Index (BMI)

measurement region	rho	p value*)
upper thorax	0.64	p < 0.0001
lower thorax	0.61	p < 0.0001
upper waist	0.78	p < 0.0001
lower waist	0.74	p < 0.0001
upper hip	0.66	p < 0.0001
lower hip	0.65	p < 0.0001
upper bottom	0.77	p < 0.0001
lower bottom	0.76	p < 0.0001
upper arm	0.88	p < 0.0001
forearm	0.76	p < 0.0001
thigh	0.91	p < 0.0001
knee	0.86	p < 0.0001
lower leg	0.80	p < 0.0001

*) Spearman rank correlation test

Table 5

Thigh circumference > 50 cm at the end of term and positive outcome in long-term follow-up (Chi2-test: p = 0.003).

	thigh circumference =< 50 cm	thigh circumference > 50 cm	total
negative outcome	23 (85.2 %)	4 (14.8 %)	27
positive outcome	112 (55.2 %)	91 (44.8 %)	203
total	135	95	230

Table 6

Comparison of basic data of adolescents (age =< 19 years) and adults (age > 19 years)

parameter	age group	mean +- SD	min – max	p*)
age	adolescents	16.3+-1.6	12.5-18.9	not applicable
	adults	26.0+-7.1	19.1-53.8	
Height	adolescents	163+-7	150-183	p = 0.0150
	adults	166+-7	153-184	
weight at admission	adolescents	39.4+-6.1	27.1-61.1	p = 0.0001
	adults	42.6+-6.6	28.7-60.6	
BMI at admission	adolescents	14.6+-1.8	10.5-20.2	p = 0.0006
	adults	15.4+-2.0	10.6-20.7	
follow-up (months)	adolescents	135+-54	52-256	p = 0.3819
	adults	141+-52	52-256	

*) Student’s t-test

Table 7

Comparison of body measurements of adolescents (age =< 19 years) and adults (age > 19 years) at admission

parameter	adolescents (mean+-SD)	adults (mean+-SD)	p*)
BMI	14.6+-1.8	15.4+-2.0	p = 0.0006
upper thorax	67.3+-4.5	71.0+-4.8	p < 0.0001
lower thorax	67.8+-4.4	71.5+-4.5	p < 0.0001
upper waist	58.9+-4.5	62.5+-5.5	p < 0.0001
lower waist	59.7+-5.9	63.1+-5.0	p < 0.0001
upper hip	75.9+-5.3	77.7+-4.4	p < 0.0001
lower hip	75.8+-4.9	77.8+-4.4	p < 0.0001
upper bottom	75.8+-6.3	78.2+-5.6	p = 0.0024
lower bottom	75.9+-6.2	78.2+-5.5	p = 0.0029
upper arm	18.5+-2.0	19.3+-2.1	p = 0.0031
lower arm	19.1+-1.5	19.8+-1.6	p = 0.0017
thigh	40.9+-5.1	42.4+-5.7	p = 0.0334
knee	29.3+-2.8	30.1+-2.9	p = 0.0102
lower leg	28.2+-2.6	28.8+-2.7	p = 0.0815

*) Student’s t-test

Table 8

Comparison of body measurements of adolescents (age =< 19 years) and adults (age > 19 years) at end of term

parameter	adolescents (mean+-SD)	adults (mean+-SD)	p*)
BMI	18.1+-1.2	18.2+-1.1	p = 0.4693
upper thorax	72.2+-3.5	75.5+-3.8	p < 0.0001
lower thorax	72.5+-3.5	74.8+-3.8	p < 0.0001
upper waist	69.7+-4.4	70.7+-4.2	p = 0.0738
lower waist	69.8+-4.2	71.0+-3.8	p = 0.0248
upper hip	80.3+-4.4	81.2+-1.2	p = 0.0023
lower hip	80.4+-4.6	82.0+-3.7	p = 0.0038
upper bottom	83.0+-4.9	48.2+-4.7	p = 0.0736
lower bottom	83.1+-4.8	84.4+-4.6	p = 0.0481
upper arm	21.3+-1.6	21.5+-1.6	p = 0.2054
lower arm	20.6+-1.6	20.9+-1.2	p = 0.1312
thigh	48.7+-3.5	48.9+-3.7	p = 0.6287
knee	33.4+-1.9	33.2+-2.3	p = 0.5332
lower leg	30.7+-2.0	30.8+-1.9	p = 0.5680

*) Student’s t-test

Table 9

Comparison of body measurements of adolescents (age =< 19 years) and adults (age > 19 years): relative increase from time of admission to time at end of term

parameter	adolescents (mean+-SD)	adults (mean+-SD)	p*)
BMI	24.7+10.1 %	19.8+-11.1 %	p = 0.0006
upper thorax	7.4+-4.5 %	4.9+-4.7 %	p = 0.0001
lower thorax	7.1+-4.5 %	4.8+-5.1 %	p = 0.0006
upper waist	19.2+-10.4 %	13.7+-8.6 %	p < 0.0001
lower waist	17.7+-9.2 %	13.1+-8.4 %	p = 0.0001
upper hip	7.5+-5.1 %	5.6+-4.1 %	p = 0.0015
lower hip	7.7+-4.9 %	5.5+-4.3 %	p = 0.0005
upper bottom	9.9+-5.2 %	7.7+-4.9 %	p = 0.0016
lower bottom	9.8+-5.3 %	8.0+-5.0 %	p = 0.0078
upper arm	15.4+-7.6 %	11.5+-7.2 %	p = 0.0001
lower arm	8.1+-7.1 %	5.7+-6.0 %	p = 0.0054
thigh	20.1+-9.5 %	16.1+-10.0 %	p = 0.0023
knee	14.9+-7.6 %	10.2+-7.2 %	p < 0.0001
lower leg	9.2+-6.3 %	7.4+-7.7 %	p = 0.0610

*) Student’s t-test