Original article

Anthropometric assessment of a Middle Eastern group of autistic children

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Background: **Growth abnormalities are uniquely associated with autism spectrum disorders (ASD); however, the extent to which growth abnormalities are present has hardly been investigated. The current study aims to compare the differences in anthropometric parameters in a group of autistic Egyptian children and the healthy normal population.**

Methods: **We recruited 100 children with ASD from the Outpatient Clinic for "Autistic Children" at the Medical Research Hospital of Excellence, National Research Centre in Cairo, Egypt. They were diagnosed by DSM-IV criteria of the American Psychiatric Association, Autism Diagnostic Interview-Revised, and Childhood Autism Rating Scale. Of these children at age of 3-10 years, 71 were males and 29 females. Eight anthropometric parameters were assessed in view of data of the healthy Egyptians of pertinent sex and age.**

Results: **Weight and body mass index increased because of a significant increase in subcutaneous fat thickness. This tendency with a probable decrease in muscle mass was more evident in male or in older children, likely resulting from sedentary life style and food selectivity.**

Conclusions: **The *Z* head circumference score and its variance significantly increased especially in males or older children, suggesting the relative overgrowth of the brain in a substantial percentage of Egyptian children with autism. We concluded that increased fat composition in Egyptian autistic children with decreased muscle mass necessitates tailoring a specially designed food supplementation program to ameliorate the severity of autism symptoms.**

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Introduction

Autism is the fastest rising developmental disorder in the world today. The centers for disease control released that the incidence of autism is rising at about 12% each year.[1] The lack of successful therapy, etiological heterogeneity, and the increasing incidence make autism one of the most challenging neuro-developmental disorders. It presents a burden upon both the family and the society as a whole. The rising rates of autism and the fact that the concordance of identical twins can not completely support the theory that autism results from a combination of genetic and environmental factors.[2]

Research into this disorder is increasingly focused on both genetic causes and neuroanatomical bases for the heterogeneous behavioral and clinical phenotypes.[3] Thus attempts to discover major autism susceptibility genes have been largely unsuccessful, with only 15% to 20% of cases of autism link to specific genes.[4] Gene expression pattern differs geographically between populations and within population and indicates regional specificity in gene/environment interactions.[5] There is increasing evidence that it is a highly diverse disease affecting multiple systems of the body.[6]

A primary reason for the lack of progress in understanding the etiology and genetic underpinnings of autism spectrum disorder (ASD) is undoubtedly the significant heterogeneity within both behavioral and clinical phenotypes. Anthropometric measurements, as basic physical growth criteria, are valuable tools for assessment of the clinical phenotype and reflect the impact of the genetic background as well as environmental setup, particularly nutritional and health factors. In the last decades, one could observe increasing interest in monitoring the physical growth parameters in patients with psychiatric disorders in general and autism in particular.[7-12] The study of head circumference and other anthropometric variables, and morphological characteristics has begun to

merge into autism research. To stratify ASDs into more homogenous subgroups, recent studies[10,13,14] have found an unexpectedly large proportion of autistic children with large heads, and reported that macrocephaly is a consistent and replicated biological finding in autism. However, some scholars[15] reported no macrocephaly in their autistic children. Even, microcephaly was reported in autistic children with a rate varying from 2.2% to 15%.[16]

Similar differences could be seen in reports on the general body growth in weight and height of children with autism.[17-19] Therefore, the present study aims to explore any differences in some important anthropometric measurements between a group of Egyptian children with autism and the pertinent healthy normal population.

Methods

One hundred children with autism who have received care at the Outpatient Clinic for "Autistic Children" at the Medical Research Center of Excellence of the National Research Centre in Cairo, Egypt, were recruited. They were from different socioeconomic strata and their age ranged from 3 to 10 years. The sex and age of these children are shown in Table 1.

Diagnosis

All patients met the following conditions: 1) Detailed case history, including three generation pedigree analysis, pregnancy history, peri-natal history, developmental history, similarly affected family members, and age of presenting manifestations; 2) Application of the criteria for autism defined in the DSM-IV-TR;[20] 3) Autism Diagnostic Interview Revised;[21] 4) Diagnostic interviews using Childhood Autism Rating Scale.[22]

Exclusion criteria

Exclusion criteria for participation in the study included: severe sensory problems (e.g., visual impairment or hearing loss), significant motor impairments (e.g., failure to sit by 12 months, or walk by 24 months), or identified metabolic, genetic, or progressive neurological disorders, based on screening by clinical staff.

Written informed consent from the parent or caregiver was obtained for all participants. The study was approved by the Ethics Review Committee of the National Research Centre.

Table 1. Distribution of the autistic sample by age and gender

Age	Gender		Total (*n*)
	Male (*n*)	Female (*n*)	
≤50 mon	37	12	49
>50 mon	34	17	51
Total	71	29	100

Anthropometric measurements

According to the recommendations of the International Biological Program,[23] some anthropometric measurements were made. Bilateral measures were taken on the left side of the body. The following measures were attempted by well trained anthropologists: 1) The body height (HT) was measured to the nearest 0.1 cm by a Holtain portable anthropometer; 2) The body weight (WT) was determined to the nearest 0.01 kg on a Seca scale balance with the subject wearing minimal clothing and no shoes; 3) Circumferences were obtained with a flexible non-stretchable measuring tape: Head circumference (HC) was measured (cm) around the child's head. It is the maximum circumference passing around the glabella and occiput; mid upper arm circumference (MUAC, cm) was measured at a point mid-way between the tip of the shoulder and the tip of the elbow; 4) The skin fold thickness (SF) approximated to the nearest 0.1 mm was determined using a Harpenden skin fold caliper over triceps muscle parallel to the long axis of the arm, oblique at subscapular regions, and transverse at supra-iliac regions; 5) Body mass index (BMI) was calculated as body weight (in kilograms) divided by body height (in meters) squared.

Statistical analysis

As there is age and sex variation among the sample members, and we need to compare the growth of the study sample as a whole with normal population, we calculated *Z* scores for the different anthropometrical measurements for each patient. The standard tables of "Anthropometry of Egyptians from Birth till Senility" (which fairly represent Egyptian children from the Big Cairo area and of different socio-economic strata) published by the National Research Centre, Egypt[24] were used as the most precise and suitable reference data for the normal Egyptian population. The data of the normal population were recorded yearly and tabulated as age categories (e.g. the 5-year group include subjects of 4.50-5.49 years old). The interpolation technique was used to calculate the most suitable reference value.[25] For example, if a patient was 5 years and 3 months old, and we have normal tabulated values for age 5 and 6 years. Hence, the following formula was used to calculate the interpolated reference value. $P=P_1+\nabla P/\nabla Age(Age–Age_1)$, where P is the estimated parameter (mean, or standard deviation); P_1, P_2 are parameters at Age_1, and Age_2; $\nabla P=P_2–P_1$; $\nabla Age=Age_2–Age_1$; Age is the patient age. To implement the interpolation technique we have developed a software using Visual Studio. Net running under the Windows operating system. Then the Z score is calculated as follows: $Z=X\text{-}Mean/SD$, where X represents the anthropometric measure; Mean is the estimated reference mean for age and sex; SD is the estimated standard deviation for age and sex. To assess

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whether the anthropometric sample means is different from normal, we used the mean *Z* of the sample as a sample statistic. One sample *t* test ($t=\bar{X}-\mu / SD\ \sqrt{n}$) is used assuming population mean (μ) that is equal to 0, and sample standard deviation (SD) as an estimator for population variance, and $\bar{X}$ is the sample mean.

Results

The mean *Z* score analyses of the 8 parameters and their standard deviations are statistically significant with the exception of mid upper arm circumference (Table 2). Table 3 demonstrates the mean *Z* scores which were distributed by gender and arranged in three groups of relevant characteristics. The first group included weight, body mass index, and mid upper arm circumference which reflects body mass. The second group represented skeletal and neural growth, whereas the third group of measurements represented the distribution of skin fold sickness. Table 4 shows the distribution of the mean *Z* scores, standard deviation, and range of the measurements according to age, i.e. a younger group aged up to 50 months, and an older group aged more than 50 months. We calculated the inter-correlations between the 8 parameters. Positive correlation was significant between all variables except *Z*HT, *Z*BMI; *Z*HT, *Z*TSF; and *Z*HC, *Z* Suprailiac SF (ZSISF) (Table 5).

In addition, *Z*HC was regressed on *Z*HT and the results were: *Z*HC=0.378 (*Z*HT)+0.298.

Both of the slop and intercept were significant (P=0.001 for the slop and P=0.04 for the intercept). This shows that children with autistic manifestations have a larger head of nearly 0.3 than normal children.

On the other hand, the regression of *Z*HT on *Z*HC is shown in the equation: *Z*HT=0.308 (*Z*HC)+0.082. Here the slop is the only significant parameter (P=0.001).

A software module was developed to generate the data for the normal distribution based on the mean and standard deviation. The module was developed using Visual Studio 2008 (Visual Basic) running on the Windows 8 operating system.

Fig. 1 demonstrates the distribution of the

Table 2. The mean *Z* score, SD, range and *t* value of the measurements in an ascending order according to the mean (n=100)

Variables	Mean	SD	Min	Max	*t* value
Z Mid upper arm circumference	0.1	1.42	-3.41	6.74	0.70
Z Height	0.2	1.38	-5.75	4.68	1.45
Z Head circumference	0.37	1.53	-7.02	3.36	2.42*
Z Triceps skin fold thickness	0.4	1.04	-2.16	4.52	3.85†
Z Subscapular skin fold thickness	0.56	1.28	-3.28	5.4	4.38†
Z Weight	0.83	1.34	-1.79	6.42	6.19†
Z Body mass index	0.94	1.42	-2.88	5.79	6.62†
Z Suprailiac skin fold thickess	1.13	2.69	-7.42	11.88	4.20†

*: significant at level <0.05; †: significant at level <0.001; SD: standard deviation.

Table 3. The mean *Z* score, SD, and range of the measurements by gender

Variables	Male (n=71)				Female (n=29)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Z Weight	0.96	1.4	-1.79	6.42	0.53	1.15	-1.64	2.53
Z Body mass index	1.03	1.49	-2.88	5.79	0.73	1.23	-1.93	3.43
Z Mid upper arm circumference	0.1	1.49	-3.41	6.74	0.1	1.24	-1.57	3.03
Z Height	0.33	1.28	-2.77	4.68	-0.13	1.58	-5.75	3.04
Z Head circumference	0.51	1.69	-7.02	3.36	0.04	0.97	-1.91	2.23
Z Suprailiac skin fold thickess	1.21	2.36	-3.96	9.53	0.92	3.40	-7.42	11.88
Z Subscapular skin fold thickness	0.58	1.35	-3.28	5.40	0.49	1.12	-0.88	3.63
Z Triceps skin fold thickness	0.45	1.13	-2.16	4.52	0.29	0.79	-1.22	1.81

SD: standard deviation.

Table 4. The mean *Z* score and SD of the measurements by age

Variables	Age ≤50 mon (n=49)				Age >50 mon (n=51)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Z Weight	0.87	1.00	-1.02	3.29	0.8	1.61	-1.79	6.42
Z Body mass index	0.84	1.47	-1.93	5.79	1.04	1.39	-2.88	4.94
Z Mid upper arm circumference	-0.09	1.23	-3.41	3.54	0.28	1.57	-2.62	6.74
Z Height	0.44	1.14	-2.77	3.04	-0.04	1.55	-5.75	4.68
Z Head circumference	0.3	1.58	-7.02	3.23	0.44	1.49	-3.79	3.36
Z Suprailiac skin fold thickess	1.11	3.35	-7.42	11.88	1.14	1.89	-1.16	8.10
Z Subscapular skin fold thickness	0.65	1.24	-3.28	3.26	0.47	1.32	-1.39	5.40
Z Triceps skin fold thickness	0.26	0.95	-2.16	3.05	0.54	1.11	-1.22	4.52

SD: standard deviation.

measurements representing body mass, i.e. body weight and BMI, with a significant shift to the right (the more shift the more increased value), but mid upper arm circumference almost similar to the normal. In Fig. 2, the distribution of body height and head circumference is significantly shifted to the right but more evidently for HC. It is realized that the distribution of skin fold thicknesses is normally skewed to the right; however Fig. 3 demonstrates quite evidently the higher values for the three folds in the autistic patients with a wide range for the supra iliac (or abdominal) fold. Fig. 4 shows the sex difference in the distribution of HC, which is significantly higher in males, whereas the curve in females almost coincides with the normal distribution.

Table 5. Pearson's product-mount correlations between the eight anthropometric variables

Variables	*Z*WT	*Z*HT	*Z*BMI	*Z*MUAC	*Z*HC	*Z*SSSF	*Z*TSF	*Z*SISF
*Z*WT	1	0.606†	0.708†	0.602†	0.413†	0.630†	0.628†	0.410†
	.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
*Z*HT	0.606†	1	- 0.087	0.322†	0.341†	0.347†	0.159	0265†
	0.000	.	0.391	0.001	0.001	0.000	0.114	0.008
*Z*BMI	0.708†	-0.087	1	0.487†	0.243*	0.465†	0.655†	0.232*
	0.000	0.391	.	0.000	0.015	0.000	0.000	0.020
*Z*MUAC	0.602†	0.322†	0.487†	1	0.324†	0.492†	0.539†	0.431†
	0.000	0.001	0.000	.	0.001	0.000	0.000	0.000
*Z*HC	0.413†	0.341†	0.243*	0.324†	1	0.293†	0.260†	0.109
	0.000	0.001	0.015	0.001	.	0.003	0.009	0.280
*Z*SSSF	0.630†	0.347†	0.465†	0.492†	0.293†	1	0.559†	0.414†
	0.000	0.000	0.000	0.000	0.003	.	0.000	0.000
*Z*TSF	0.628†	0.159	0.655†	0.539†	0.260†	0.559†	1	0.380†
	0.000	0.114	0.000	0.000	0.009	0.000	.	0.000
*Z*SISF	0.410†	0.265†	0.232*	0.431†	0.109	0.414†	0.380†	1
	0.000	0.008	0.020	0.000	0.280	0.000	0.000	.

*: correlation is significant at the 0.05 level (2-tailed); †: correlation is significant at the 0.01 level (2-tailed); "." : *P* value is not applicable. *Z*WT: *Z* weight; *Z*HT: *Z* height; *Z*BMI: *Z* body mass index; *Z*MUAC: *Z* mid upper arm circumference; *Z*HC: *Z* head circumference; *Z*SSSF: *Z* subscapular skin fold thickness; *Z*TSF: *Z* triceps skin fold thickness; *Z*SISF: *Z* suprailiac skin fold thickess.

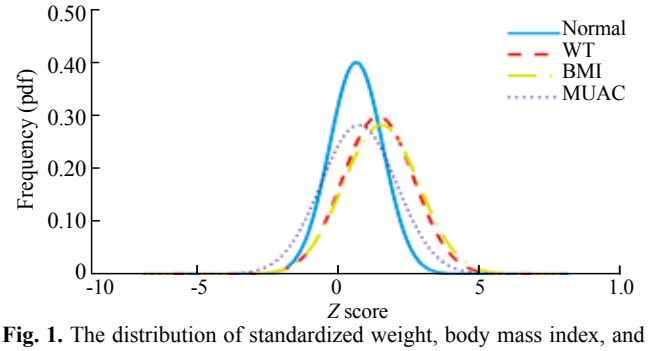

Fig. 1. The distribution of standardized weight, body mass index, and mid upper arm circumference in comparison to the standard normal distribution. WT: weight; BMI: body mass index; MUAC: mid upper arm circumference; pdf: probability density function.

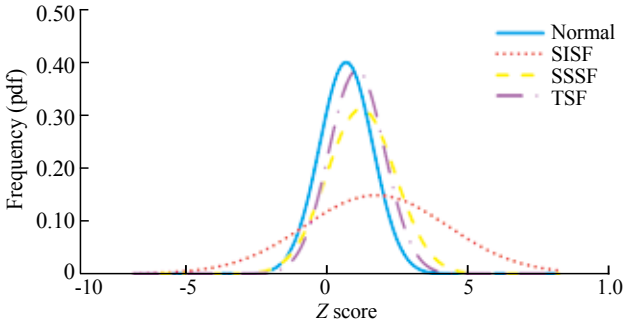

Fig. 3. The distribution of standardized skin folds in comparison to the standard normal distribution. SISF: suprailiac skin fold thickess; SSSF: subscapular skin fold thickness; TSF: triceps skin fold thickness; pdf: probability density function.

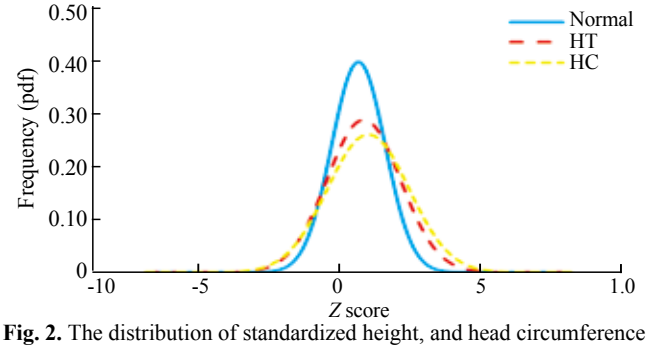

Fig. 2. The distribution of standardized height, and head circumference in comparison to the standard normal distribution. HT: height; HC: head circumference; pdf: probability density function.

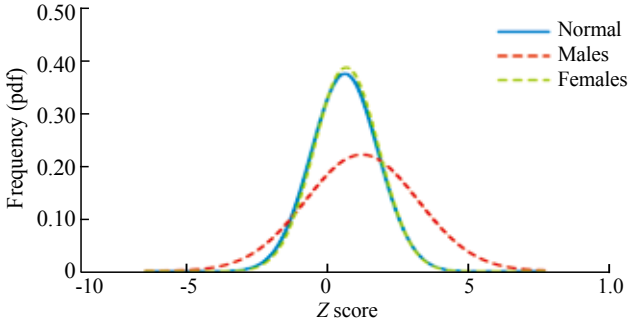

Fig. 4. The distribution of standardized head circumference for the male and female groups. pdf: probability density function.

Discussion

The need is obvious for early clinical signs specific to autism. Anthropometric assessment might be an additional research helpful to early diagnosis. Autism as a complex developmental neuropsychiatric disorder characterized by impairment of social and communicational interactions seems to affect the life style mobility and feeding behavior as well. Studies[17,26,27] have focused on aberrations in conduct during meals, selectivity of food as well as problems in timing of meals.

Our results show a tendency towards the increase of *Z* body weight and *Z* body mass index, indicating an increase in total body mass as well as weight per height. Searching for the body components that share in this tendency, one could observe that the *Z* upper mid arm circumference is almost similar to the reference norm. Likely this means that taking the circumference of bone, muscle and subcutaneous fat layer together, it is similar in autistic children to normal healthy children.

However, the skin-fold thicknesses on the triceps as well as the sub-scapular and supra-iliac skin-folds are significantly thicker in autistic children than in normal children. This agrees with the statement of Berry et al[26] that typically children with autism spectrum disorders have strong preference for carbohydrates and rejection to fruits, vegetables, and diary products. Probably, our findings indicate that the increase of fat component is the factor responsible for the increase of body mass index in the sample, due to increased carbohydrate and fat intake as well as sedentary life style. Comparing males with females (regardless of the difference in numbers) shows that the same tendency is repeated in both genders though it is more evident in males. Comparing the *Z* scores of measurements in the younger group to those in the older group shows a similar tendency though it is more evident in the older group, particularly the *Z* scores for upper mid-arm circumference, body mass index, and triceps skin-fold thickness.

These findings have immediate and important implications for raising autistic children and suggesting a feeding program to control the relevant physical consequences of the disease. Meanwhile, scholars[28] assume some type of deviant overgrowth in the cerebral, cerebellum and limbic structures that underlie AS disorder and predispose to language dysfunction among others. This overgrowth results in increased brain size which could be measured directly by MRI in postmortem studies or indirectly by head circumference. Generally, head circumference correlates perfectly with brain size till the age of 12 years with a coefficient of correlation that is equal to 0.88.[10] Later, the coefficient of correlation decreases due to continuation of cranial growth, thickening of bone, and increased size of air sinuses, whereas the neural pattern of growth practically stops at that age.

However, macrocephaly may not be specific to autism, and in the present it may index the presence of additional symptoms[29] or superimposition of other pathologies, or constitute a distinct subgroups of the spectrum.[30] Normal or small head circumference was also observed in children with autism.[15] Miles et al[16] reported microcephaly in autistic children with a rate varying from 2.2% to 15%. In our study, 14% of the patients were macrocephalic with a *Z* score >1.96, 2% microcephalic, and 84% normocephalic. Our study showed an increased *Z* score of head circumference, also with a wide range of distribution (between 7 to 3.36 SDs of the normal healthy children).

In contrast to normal female children, *Z*HC score increased in males. This finding agrees with those reported elsewhere.[10,31] Besides, the *Z*HC score also increased in the older group than in the younger group. As a matter of fact, the proper assessment of increased head circumference in autistic children necessitates a study of head circumference in the family[12] and at birth[32] and exclusion of superimposed pathology.[14]

It is worthy to mention that the absolute brain size in general is significantly larger in males than in females, but not equal in all parts.[33] It may be part of excessive body growth. If *Z*HC score in autistic patients is high but equal to the *Z* score of body height, this excludes overgrowth of the brain alone. In our patients, *Z*HC was higher than height *Z* score although both tended to be higher than in normal children. This tendency is underscored in males. But in our female patients, height *Z* score is insignificantly negative and *Z*HC is almost nil, indicating no differences from normal children.

In our younger group, height *Z* score was higher than *Z*HC score, but there were no differences in height in the older group except for increased head circumference, indicating that the relative overgrowth of head circumference is evidenced by age.

Moreover, head circumference is correlated with discrepancies between verbal and nonverbal IQ scores independent of the absolute level of verbal ability.[34,35] In autistic children with higher head circumference, there are higher nonverbal abilities but problems in verbal abilities and differences in neuro-cognitive profile.[30] This implies that overgrowth in the brain areas responsible for language generation in autistic children is associated with the decrease of verbal abilities and increase of head size.[36] The overgrowth in certain areas of the brain might lead to alteration of connectivity between neurons.[37] Peculiar brain disconnection is hypothesized to be the neural substrata of autism core symptoms as confirmed by some diffuse tensor imaging studies on altered structural connectivity in individuals with ASD.[37]

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