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Assessment of nutritional deficits and their implications in autistic children: A focus on macronutrient and micronutrient intake across age and gender

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Abstract
Autism is a neuro-developmental disorder characterized by repetitive behaviors and difficulties with social communication. Globally, autism affects approximately one in every 100 children. Nutritional deficits in children with autism often stem from selective eating habits and food aversions, which can significantly impact their overall health and development. This study aimed to evaluate the nutritional status of children with autism, identify common nutrient deficiencies, and assess the effectiveness of nutritional interventions. A total of 80 autistic children participated, and data collection included demographic details, anthropometric measurements (weight, height, BMI, and MUAC), clinical assessments, meal frequency analysis, nutritional questionnaires, and a three-day diet recall. Significant macronutrient deficiencies, particularly in fats and carbohydrates, were observed through the dietary analysis. Subjective Global Assessment (SGA) revealed that boys were more prone to moderate malnutrition compared to girls. The study highlights the critical role of nutritional interventions in improving health outcomes in autistic children, emphasizing the need for tailored dietary guidelines and feeding strategies to address nutrient deficiencies and promote overall well-being.

Keywords: Autistic children, nutritional intervention, subjective global assessment

Introduction
Autistic disorder is a complex neuro-developmental condition characterized by challenges in social interaction, language, communication, and imaginative play (Sobhana Ranjan *et al*., 2015) [17]. Core features of autism include deficits in social reciprocity and language development, along with stereotyped, repetitive behaviors and restricted interests (Monia Kittana *et al*., 2023) [10]. Globally, autism spectrum disorder (ASD) prevalence varies widely, ranging from 1 in 250 individuals in India to 1 in 36 in the United States. As of 2020, an estimated 1 in 59 children in the U.S. had been identified with autism, with boys being four times more likely to receive a diagnosis than girls (Qian Li, 2022) [9]. Prevalence estimates vary across regions, including 1 in 100 individuals in the United Kingdom and India, 1 in 66 in Canada, 1 in 100 in Australia, and 1 in 250 in Brazil. South Korea reports one of the highest rates, with 1 in 38 children affected, while China reports a lower prevalence of 1 in 186 individuals (Brent Taylor *et al*., 2010) [23].
Both genetic and environmental factors contribute to ASD, with environmental risks including advanced parental age, cesarean section delivery, inadequate breastfeeding, prenatal complications, and lead exposure. Nutritional deficiencies are a common concern for children with ASD due to restrictive eating habits, gastrointestinal (GI) issues, allergies, and metabolic irregularities. Essential micronutrient deficiencies-such as folate, vitamin B12, vitamin D, vitamin A, iron, and zinc-can negatively impact neurodevelopment, with studies showing reduced intake and serum levels in autistic children compared to neurotypical peers.
GI symptoms are prevalent in ASD, affecting up to 70% of children and including constipation, diarrhea, abdominal pain, encopresis, bloating, and gastroesophageal reflux disease (GERD) (Arthur Krigsman *et al*., 2021) [11]. Factors such as restrictive diets, medical comorbidities, hyperactivity, feeding difficulties, and parental dietary beliefs may further increase the risk of undernutrition, negatively affecting health-related quality of life (Pang Cha Xiong *et al*., 2022) [5].

Conversely, autistic children are also at risk for overweight and obesity due to factors like medication side effects, sleep disturbances, reduced physical activity, and food selectivity with preferences for energy-dense foods.

Food selectivity behaviors in autistic children may be influenced by physiological factors like sensory-motor processing impairments, behavioral rigidity, impulsivity, and biological food intolerances. Social factors, including parental anxiety, communication challenges, and reinforcement of maladaptive feeding behaviors, also play a role in feeding difficulties (Sarah H. Al-Mazidi, 2023) [3].

Despite its critical role in overall health, the nutritional status of autistic children remains underexplored. This study aims to address this gap by comprehensively assessing the nutritional status of children with autism, examining dietary habits, nutrient intake, and potential correlations with behavioral patterns. These insights can help enhance holistic care and support for autistic children. An integrative approach that considers behavioral, social, and nutritional components is recommended to improve health outcomes and quality of life for individuals on the autism spectrum.

Methodology

This study employed a descriptive, quantitative research design to assess the nutritional status of children with autism aged 5 to 18 years, selected from KRM School for Special Children in Chennai, Tamil Nadu. The descriptive design facilitated systematic data collection to characterize nutritional patterns and identify trends, while quantitative methods enabled structured analysis of data to uncover correlations and potential deficiencies. The study included both boys and girls attending rehabilitation centers or special schools, with children outside the age range or without autism excluded. Primary data were gathered through a questionnaire, interviews, and anthropometric measurements. Anthropometric parameters such as height, weight, BMI, and mid-upper arm circumference (MUAC) were recorded to evaluate physical growth and nutritional status. Height was measured using a tape with participants standing barefoot, and weight was measured using a portable scale with a maximum capacity of 120 kg. The Subjective Global Assessment (SGA) tool was used to assess dietary intake, growth, weight changes, gastrointestinal symptoms, functional capacity, and comorbidities, categorizing participants as well-nourished, mildly malnourished, or severely malnourished. Dietary assessment was conducted a three-day dietary recall. Nutrient intake-including calories, protein, carbohydrates, fats, calcium, vitamins B6, B9, B12, and omega-3-was estimated and compared with recommended daily allowances. Nutrition education was provided to parents and caregivers through pamphlets and video presentations, covering healthy eating habits, nutritional needs, and optimal food choices. This comprehensive methodology aimed to identify nutritional challenges, promote better dietary practices, and enhance the overall well-being of children with autism.

Results & Discussion

Table 1: Nutritional status of selected samples

Variables	Subjective Global Assessment (SGA)				p value
	Mildly Malnourished	Moderately Malnourished	Severely Malnourished	Well Nourished	
BMI					
Normal	4(10.8)	0(0)	1(2.7)	32(86.5)	<0.001* S***
ObesityGrade1	5(55.6)	4(44.4)	0(0)	0(0)	
ObesityGrade2	2(40)	3(60)	0(0)	0(0)	
Overweight	9(64.3)	1(7.1)	0(0)	4(28.6)	
Underweight	11(73.3)	2(13.3)	1(6.7)	1(6.7)	
Age					
4-9yrs	15(45.5)	2(6.1)	2(6.1)	14(42.4)	0.683
10-12yrs	6(28.6)	4(19)	0(0)	11(52.4)	
13-15 yrs	8(42.1)	3(15.8)	0(0)	8(42.1)	
16-18yrs	2(28.6)	1(14.3)	0(0)	4(57.1)	
Gender					
Girls	4(19)	5(23.8)	2(9.5)	10(47.6)	0.010* S**
Boy	27(45.8)	5(8.5)	0(0)	27(45.8)	
Mid upper arm circumference					
Mild	2(100)	0(0)	0(0)	0(0)	<0.001* S***
Normal	29(37.7)	10(13)	1(1.3)	37(48.1)	
Severe	0(0)	0(0)	1(100)	0(0)	

The nutritional status of children based on Subjective Global Assessment (SGA) was analyzed by BMI interpretation, age, gender, and mid-upper arm circumference (MUAC), along with corresponding p-values to indicate statistical significance. Regarding BMI, the majority of children with normal BMI (86.5%) were well-nourished, while 10.8% were mildly malnourished and 2.7% were severely malnourished, showing a significant association with nutritional status ($p < 0.001$). Underweight and overweight children were more likely to be mildly malnourished. In obesity grade 1, 55.6% were mildly malnourished and 44.4% were moderately malnourished, with no well-nourished children. In obesity grade 2, 60% were moderately malnourished, and 40% were mildly malnourished. Overweight children were predominantly mildly malnourished (64.3%), with 28.6% well-nourished and 7.1% moderately malnourished. Among underweight children, 73.3% were mildly malnourished, while 13.3% were moderately malnourished, 6.7% were severely malnourished, and 6.7% were well-nourished.

In terms of age, children aged 4-9 years had 45.5% mildly malnourished, 42.4% well-nourished, and 6.1% each moderately and severely malnourished. However, there was no significant association between age and nutritional status ($p = 0.683$). For children aged 10-12 years, 52.4% were well-nourished, 28.6% were mildly malnourished, and 19% were moderately malnourished. Among those aged 13-15 years, 42.1% were both mildly malnourished and well-nourished, while 15.8% were moderately malnourished. In the 16-18

years group, 57.1% were well-nourished, 28.6% were mildly malnourished, and 14.3% were moderately malnourished.
Gender-based analysis showed that 47.6% of girls were well-nourished, while 19% were mildly malnourished, 23.8% were moderately malnourished, and 9.5% were severely malnourished, with a significant association between gender and nutritional status ($p < 0.010$). Boys were more likely to be mildly malnourished compared to girls, with 45.8% of boys being well-nourished, 45.8% mildly malnourished, and 8.5% moderately malnourished, with no cases of severe malnutrition.
MUAC interpretation revealed that all children with mild MUAC values were mildly malnourished ($p < 0.001$), indicating a significant association. Among children with normal MUAC, 48.1% were well-nourished, 37.7% were mildly malnourished, 13% were moderately malnourished, and 1.3% were severely malnourished. All children with severe MUAC readings were 100% severely malnourished. These results highlight significant associations between BMI, MUAC, and gender with nutritional status, while age did not show statistical significance.

Table 2: Macronutrient Intake

Nutrient	Age	Mean		RDA		Deficit		Deficit %		P Value
		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	
Energy	5-6 year	1014.6	1276	1360	1360	345.37	84	77.8%	50%	0.055
	7-9 years	1077.2	1109.7	1700	1700	622.71	590	50%	75%	
	10-12 years	1304.6	1360.2	2220	2060	915	699	94.1%	100%	
	13-15 years	1448.8	1689	2816	2400	1367.14	711	93.3%	50%	
	16-18 years	1604	1752	3320	2500	1716	747	75%	100%	
Protein	5-6 year	26.1	31.13	16	16	+10.15	+4	66.7%	-	0.074
	7-9 years	30	18	23	23	+7	5	21.4%	25%	
	10-12 years	26.1	35	32	33	5.82	4.05	29.4%	100%	
	13-15 years	28.11	28.95	45	43	16.89	8	60%	25%	
	16-18 years	41.8	39	55	46	13.13	7	75%	66.7%	
CHO	5-6 year	119.67	170	204	204	84.33	34	33.3%	-	0.031* S**
	7-9 years	167.63	187.5	255	255	87.37	67.50	42.9%	62.5%	
	10-12 years	171.39	197.85	333	309	161.61	111.15	64.7%	50%	
	13-15 years	184.03	218	229	360	44.97	142	86.7%	50%	
	16-18 years	212.9	207	498	375	285	167.8	75%	100%	
FAT	5-6 year	23.00	20.00	37.00	37.00	14.00	17.00	22.2%	50%	<0.001* S***
	7-9 years	28.00	29.50	47.00	47.00	19.00	17.50	42.9%	25%	
	10-12 years	26.82	32.00	61.00	57.00	34.18	25.00	64.7%	50%	
	13-15 years	36.71	37.67	79.00	66.00	42.29	28.33	93.3%	75%	
	16-18 years	48.25	42.00	92.00	69.00	43.75	27	100%	100%	

Tables 2 provide a detailed analysis of nutrient intake across different age groups for boys and girls, comparing mean intake to the Recommended Dietary Allowance (RDA) and highlighting the percentage deficits. The tables also include p-values to evaluate the statistical significance of the observed differences.

Energy
Significant energy deficits were observed across all age groups, ranging from 50% to 100% of the RDA. Boys exhibited larger deficits than girls, particularly in the 10-12 and 13-15 years age groups. Although the energy deficits were substantial, the p-value of 0.055 indicates the differences were not statistically significant at the 95% confidence level.

Protein
Protein intake was above the RDA for both boys and girls in the younger age group (5-6 years). However, older children, especially boys, showed protein deficits ranging from 21.4% to 75%. The p-value of 0.074 suggests that the differences in protein intake between boys and girls were not statistically significant.

Carbohydrates (CHO): Carbohydrate intake was notably deficient across all age groups, with deficits ranging from 33.3% to 100%. Boys generally exhibited larger deficits compared to girls, and the p-value of <0.031 indicates that the differences in carbohydrate intake between boys and girls were statistically significant.

Fat
Fat intake was below the RDA for both genders across all age groups, with deficits ranging from 22.2% to 100%. The p-value of <0.001 reflects a statistically significant difference, underscoring a critical gap in fat intake, particularly among older children.
According to Monia Kittana *et al.* (2023) [10], children with autism tend to experience macronutrient deficiencies. This study similarly highlights significant deficits in key macronutrients, particularly carbohydrates and fat, emphasizing the need for dietary interventions to improve nutritional intake.

Table 3: Micronutrient Intake

Nutrient	Age	Mean		RDA		Deficit		Deficit%		P value
		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	
Calcium	5-6 years	279.4	680.25	550	550	270.6	+100	66.7%	-	0.109
	7-9 years	325.8	358.42	650.00	650.00	324.14	291.58	50%	75%	
	10-12 years	365.7	258.95	850.00	850.00	484.29	591.05	88.2%	100%	
	13-15 years	426.6	693.33	1000	1000	753.39	306.67	80%	75%	
	16-18 years	269.9	693.3	1000	1000	753.3	446	50%	100%	
Vitamin B6	5-6 year	0.52	0.72	1.20	1.20	0.68	0.48	66.7%	100%	0.715
	7-9 years	0.58	0.55	1.50	1.90	0.92	0.95	57.1%	75%	
	10-12 years	0.71	0.81	2.00	2.30	1.29	1.09	76.5%	75%	
	13-15 years	0.99	3.025	2.60	2.20	1.61	0.82	100%	-	
	16-18 years	1.02	0.53	3.00	2.30	1.98	1.77	75%	33.3%	
Vitamin B9	5-6 year	69.52	16.35	135.00	135.00	65.48	118.65	100%	-	0.233
	7-9 years	70.10	57.8	170.00	170.00	99.90	112.16	57.1%	87.5%	
	10-12 years	93.81	74.2	220.00	225.00	126.19	150.75	88.2%	100%	
	13-15 years	81.75	69.35	285.00	245	203.25	175.65	80%	100%	
	16-18 years	97.40	68.33	340	270	242	231.6	100%	100%	
Vitamin B12	5-6 year	0.03	0.90	2.20	2.20	2.17	1.30	100%	100%	0.724
	7-9 years	0.32	0.44	2.20	2.20	1.88	1.76	100%	100%	
	10-12 years	0.53	0.29	2.20	2.20	1.67	1.91	94.1%	100%	
	13-15 years	0.23	0.02	2.20	2.20	1.97	2.18	93.3%	100%	
	16-18 years	0.04	0.20	2.20	2.20	2.16	2.00	100%	100%	

The analysis of nutrient intake revealed significant deficits in calcium, Vitamin B6, Vitamin B9 (folate), and Vitamin B12 across all age groups for both boys and girls. Calcium intake was consistently below the RDA, with deficits ranging from 50% to 100%. The p-value of 0.109 suggests no statistically significant difference between boys and girls. Vitamin B6 intake showed deficits of 33.3% to 100% for both genders, with a p-value of 0.715 indicating no significant gender differences.

Vitamin B9 (folate) intake was markedly deficient across all age groups, with deficits ranging from 57.1% to 100%. The p-value of 0.233 suggests that the differences between boys and girls were not statistically significant. Similarly, Vitamin B12 intake was well below the RDA for both genders, with deficits ranging from 94.1% to 100%. The p-value of 0.724 indicates no significant difference between boys and girls in Vitamin B12 intake.

These findings are consistent with previous research. Studies by Adams *et al*. (2011) [26] and Matson & Goldin (2013) [27] have reported similar nutrient deficiencies in children with autism, particularly in vitamins such as B12 and folate. According to Monia Kittana *et al*. (2023) [10], children with autism are prone to macronutrient and micronutrient deficiencies, which can impact growth, cognitive development, and overall health. The observed deficits in this study, particularly in calcium and essential B vitamins, highlight the critical need for targeted nutritional interventions to address these nutrient gaps and support optimal development.

Conclusion

This study highlights significant nutritional challenges faced by children with autism, with notable disparities in macronutrient and micronutrient intake across different age groups and genders. Boys were at a higher risk of mild malnutrition compared to girls, and significant associations were found between BMI, MUAC, and nutritional status. Energy, carbohydrate, and fat intake were substantially below the RDA, particularly among older children, with statistically significant deficits observed for carbohydrate and fat intake.

Protein intake was adequate in younger age groups but showed considerable deficits in older children, especially boys. Micronutrient intake analysis revealed pervasive deficiencies in calcium, Vitamin B6, Vitamin B9 (folate), and Vitamin B12, all of which were significantly below recommended levels. The lack of significant gender differences in these nutrient intakes emphasizes the universal nature of these deficiencies in children with autism.

Consistent with previous research by Adams *et al*. (2011) [26], Matson & Goldin (2013) [27], and Monia Kittana *et al*. (2023) [10], this study underscores the vulnerability of children with autism to macronutrient and micronutrient deficiencies, which can negatively impact growth, cognitive development, social behaviors, and overall well-being. The findings emphasize the urgent need for targeted dietary interventions, regular nutritional assessments, and education for caregivers to address these deficiencies. A holistic approach involving tailored nutrition plans and regular follow-up with dietitians can help mitigate the nutritional risks and promote better health outcomes for autistic children. Future research should focus on longitudinal interventions to monitor and improve the nutritional status of children with autism over time.

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Conflict of interest

No conflict of interest was declared by the authors.

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