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Original Article

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Measurement of food sensitivity with special reference to food properties in children with autism spectrum disorder

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ABSTRACT

BACKGROUND & OBJECTIVE: Autism spectrum disorders (ASD) are lifelong neurodevelopmental conditions often associated with atypical dietary behaviors. This study aimed to analyze food sensitivity and its relationship to food acceptance in children with ASD.

METHODOLOGY: Twenty-five children with ASD were selected for the study. Various fruits differing in color, shape, and texture were introduced twice weekly. The Childhood Autism Rating Scale (CARS) assessed behavioral responses and food acceptance.

RESULTS: Hard-textured foods were accepted by 72% of the children. Soft and slippery foods were more likely to be rejected—30% and 10% of children split and rejected them, respectively. Mineral analysis revealed varying zinc (11.5–36.5 µg/dl) and iron levels, with the highest iron levels in 5-year-olds and the highest zinc in 8-year-olds. Behavioral assessments highlighted significant joint attention, play, and sensory processing patterns. Statistical analysis showed no significant difference ($p > 0.05$) in food acceptance based on color, texture, or frequency of intake.

CONCLUSION: Children with ASD exhibit consistent reactions to specific food textures and colors. The findings emphasize the importance of texture-based interventions in early childhood to improve dietary variety and food acceptance in ASD populations.

KEYWORDS: Autism Spectrum Disorder, Iron, Zinc, Children, Pakistan.

INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental state in which modifications may occur in behavior, social interactions, and circumscribed interests, resulting in impairments in major areas of life and ultimately reducing life expectancy and quality associated with the onset of life [1]. Globally, the average prevalence of autism rate is on the rise, with a current estimate of 1 in 160 children. The prevalence of ASD in Pakistanis is unknown due to the lack of national-wide investigation [2].

ASD children exhibit poor nutritional status with remarkable functional difficulties, a condition already demanding the need for health care. A healthy intake of food can improve nutritional status and help in the prevention of the severity of behavioral symptoms such as mood disorders, anxiety, and Attention Deficit Hyperactivity Disorder (ADHD). The nutritional status of ASD children directly relates to their dietary intake. Children with ASD are often said to be picky eaters as they tend to be selective in their food selection [3].

It was observed that reluctant behavior was observed whenever they were introduced to different food items based on texture, shape, and taste. Forcing children to eat can make them hyperactive, resulting in reduced food intake. ASD children tend to exhibit eating patterns by continuously accepting and rejecting certain food products, resulting in deficiencies of certain essential nutrients [4].

Nutrition plays a vital role in the management of autism spectrum disorder. ASD symptoms include repetitive behavior, social challenges, hyperactivity, tantrums, self-harm, and aggressiveness, which all can be managed by employing optimal nutrition [5]. Children with ASD have challenges with their gastrointestinal sensitivity. Processed and synthetic food products are avoided due to digestion problems as they have a fragile gut. Fresh fruits and vegetables are encouraged to be consumed as good sources of vitamins and minerals. Also, provide enough fiber for good health and digestion [6].

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The diet history of ASD children may help determine their food choices and selection. Children with ASD showed more food refusals based on food taste, texture, smell, taste, and shape than normal children. At the same time, they accept food based on its color and temperature. Thus, the selection of food based on specific food proprieties induces micronutrient deficiencies among ASD children [7,8].

Children with ASD were mostly found to be deficient in iron and zinc due to their restricted food choices and more rejection behavior towards most food items. It was also associated with the complications of autism. Iron and zinc levels were assessed among ASD children, and zinc and iron deficiency was found [9].

Maintenance of adequate iron intake is demanding due to its essential role in brain development and function. It was found that Iron depletion was present in 32.9% of ASD children (serum ferritin ≤ 20 µg/L), and iron deficiency was present in an additional 4.3% (serum ferritin ≤ 12 µg/L) [10]. Zinc is needed for the functioning of brain cells and for boosting the immune system. Study results suggested that ASD children were examined with zinc inadequacy and deficiency that is closely related to mediate gene expression [11]. Alteration of gene expression may affect different developmental processes that result in delayed growth, mental retardation, and poor immune system [12].

Thus, the present study was planned to assess the sensitivity of food among autistic children and its relation to their behavior regarding food acceptance. Selected food groups were introduced, and nutritional biomarkers were checked to relate them further to the hyperactivity of autistic children.

METHODOLOGY

Participants for the present study were recruited from a private rehabilitation center in Faisalabad, and this selection was based on a simple random sampling method, a general probability sampling method with an equal chance of selection of each member in the population. Further, it warrants a lower risk of research biases like sampling and selection bias. The study duration was six months (180 days) from January to June 2019. A set of 25 children, including both genders, were taken in the age group from 5 to 13 years. Further, there were 12 male and 13 female participants with a mean age of 9.3 years. Consent from parents, as well as permission from the ethical review committee of the institution, the UAF 4009/ORIC, was taken.

The inclusion criteria were children diagnosed with ASD, aged 5 to 13 years, with parental consent for participation. Exclusion criteria included children with other neurodevelopmental disorders or medical conditions that could affect food intake or digestion. Children were exposed to food items across different sessions. Food acceptance and food rejection were recorded at different times. Six (06) fruits were selected and divided into two groups. Test fruits from the fruit group were introduced to test subjects in different shapes (geometric and diced), textures (slippery, hard, and soft), and consistency (raw, juice, and puree) to improve acceptance [13]. Post-study evaluation includes testing the food sample's acceptance or rejection based on shape, color, and texture via proforma, including time records.

The questionnaire used for the data collection was a Childhood Autism Rating Scale (CARS) proforma, which consists of different parameters, including initial history and eating patterns record. At baseline, a food frequency questionnaire was used to record past food history by interviewing a trained psychologist and nutritionist working with ASD children. Proforma was used to check the acceptance and rejection of test food samples using different time records such as 5sec, 30sec, and 60 seconds. The fruits were divided into two groups. Each group contained three fruits, which were introduced for 2 weeks: Group A: Apple, Banana, Grapes, and Group B: Pineapple, Strawberry, and Papaya. Different foods, including raw, juice, and puree, were provided to the children, and acceptability was checked for each one.

The initial history was taken through a proforma that included personal information such as name, age, gender, family history, medical history, food preferences, and food allergies of the ASD children. It also included anthropometric measurements (BMI) so that the nutritional status of the subject could be analyzed [14].

At the start of the study, anthropometric measurements like weight and height were recorded to calculate BMI. The weight was taken without shoes and heavy clothes on a digital weight machine. The height was measured by standing the children in an erect position without shoes, and their feet were attached to the wall for accurate measurements. The children's BMI was calculated using the Quetelet equation. The percentile charts were used for comparison [15].

Hair and nail samples from ASD children were collected for iron and zinc analysis. Hair samples were collected using stainless steel scissors and taken about one inch from the scalp. Fingernail samples were collected by using a stainless-steel nail clipper. Hair and nail samples were stored in polyethylene bags to avoid contamination. They were stored at room temperature and were prepared for wet digestion [16]. An atomic absorption spectrometer was used to quantify iron and zinc. Wet digestion for hair and nail samples was done before analysis. Hair and nail solutions for zinc and iron determination were further analyzed on a spectrophotometer.

Data obtained from the intervention was subjected to statistical analysis (ANOVA-CRD), and the results were concluded based on p-values as well as F-statistics. Results are divided into six treatments for each food property. These include rejected, spitted out immediately, in 30 seconds, in 60 seconds, chewed but spitted and swallowed. Standard formulas are used to calculate average, standard deviation, and standard error.

$$\text{Average} = \bar{X} = \frac{X_1+X_2+.....X_N}{N}$$

$$SD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(Xi-\bar{X})^2}$$

SE=SD / √ N

Here, it represents the frequency of each variable in each category. 'N' is the total number of variables. For example, in the case of Food Intake (Fruits), we have N = 6 (Six types of fruits are considered), and for each of the six categories (rejected, spitted out immediately, spitted in 30 seconds, spitted in 60 seconds, chewed but spitted and swallowed) average is calculated by summing the frequency of six fruits for a particular category and then dividing by N. Mathematically, for food intake (fruits),

$$\text{Average}_{\text{Rejected}} = \frac{0+0+2+2+0+20}{6} = 4$$

Standard deviation and standard error are also calculated in the similar way.

ANOVA calculations are done as follows.

Between Groups Degrees of Freedom: DF = k -1, where k is the number of groups/treatments.

Within Groups Degrees of Freedom: DF = n – k, where n is the total number of variables, e.g., we have six variables for fruit frequency and six groups so n = 36 and DF = 36-6 = 30, while for fruit texture we have four variables and six groups so n = 24, and DF = 24-6 = 18.

Total Degrees of Freedom: DF = n -1

Sum of Square Between Groups: $SS_B = \sum_{i=1}^{K} m_i (X_i - \bar{X})^2$ Where

m_i is the number of subjects in the i-th group.

Sum of Squares Within Groups: $SS_{W=} \sum_{i=1}^{K} (m_i - 1) SD_i^2$, Where

SD_i is the standard deviation of i-th group.

Total Sum of Squares: $SS_T = SS_B + SS_W$

Mean Square between Groups: $MS_B = SS_B / k-1$

Mean Square within Groups: $MS_W = SS_W / n-k$

F-statistic: $F = \frac{MS_B}{MS_W}$

RESULTS

A set of 25 children were taken from the age group 6 to 10 years. Socio-demographic characteristics of the participants showed that patients of both male and female genders were included in the study, with a percentage of 50% of each. The mean age of the children recorded was 9.3 years ± 2.75. The mean number of members present in a family was recorded as 4.6 ± 1.17. Anthropometric data included the BMI status of the children, which ranged from normal (60%), underweight (20%), and overweight (10%).

In the present study, different food properties were recorded to assess food sensitivity among children with autism spectrum disorder. These properties included food intake (only fruits), food texture, food colour, and food shapes. Moreover, the intake frequency of test food samples was also checked in different forms.

Results showed that bananas, apples, and strawberries were widely accepted. Apple and strawberry showed the most prominent acceptance among all of the studied fruits. Grapes were acceptable to only 12% of the participants, while the rest (88%) showed dislike of grapes. Pineapple was disliked by all of the respondents. Papaya was the most shunned fruit, with 80% of the study respondents reporting rejection (Table-I). Further, statistical analysis reveals that there is insufficient evidence to conclude that there's a statistically significant difference or relationship between the groups or variables due to extremely high p-value and very low F-stat (Table-II).

We considered food texture as another important factor for the dietary intake of children with autism spectrum disorder. Observed data for the food texture showed that hard food was better tolerated than soft-textured food. Food with dry texture with low moisture showed better acceptability as compared to slippery foods based on texture (smooth, lubricated) (Table-I). The statistical analysis shows that acceptability based on food texture does not show enough evidence that there are statistically significant differences between the group means (Table-II).

Data on the food color acceptability showed that, most of the children preferred food in white color, followed by red. Orange was the most rejected among all of the food color. Again the statistical analysis demonstrate that the acceptability of food based on color does not show enough evidence that there are statistically significant differences between the group means due to high p-value (Table-II).

Raw foods were found to be the most accepted by children, as the swallowing percentage was recorded to be 100% among the study participants. Fresh fruit juices were also found to be acceptable among the majority of the children. Pure forms of fruits were unacceptable among all of the children. (Table-I). Statistically, acceptability based on different forms does not show any significant difference, as all categories have reasonably large p-values (Table-II).

Fruits were introduced in different forms, including diced and geometric. The majority of the children accepted both diced and geometrical shapes of fruit; 68% of participants swallowed diced-shaped fruits, and 32% tried chewing but spitted soon after without swallowing. Foods in geometrical shapes indicate that food is liked regardless of being diced or geometrical (Table-I). Furthermore, there is a statistically significant difference for all groups, as the p-value is zero (Table-II).

Collected samples of hair and nails were tested for levels of iron and zinc, which yielded the results shown in Table 4. Mineral analysis was performed using atomic absorption spectrometry after wet digestion of hair and nail samples to measure zinc and iron levels. Normal iron serum values range between 50-120µg/dL, and normal zinc serum values between 60-110µg/dL. The specific age ranges and observed values for iron and zinc are included in the results. The highest levels of iron were recorded in children of age 5 years, while the lowest level (22 µg/dl) seemed to prevail among the children of age 11 years.

In the same way, zinc scores varied with the age of the participants. Scores for zinc ranged between 11.5-36.5 µg/dl. The highest score of zinc was found in children of age 8 years (36.5 µg/dl), while the lowest score was present among children of age 6 years (11.5 µg/dl).

Table-I: Frequency and percentage for different food properties.

Variable	Category	Rejected n(%)	Spitted out immediately n(%)	Spitted In 30 Seconds n(%)	Spitted in 60 seconds n(%)	Chewed but spitted n(%)	Swallowed n(%)
Food Intake (Fruits)	Banana	0(0)	2(8)	5(20)	3(12)	10(40)	5(20)
	Apple	0(0)	0(0)	5(20)	2(8)	10(40)	8(32)
	Grapes	2(8)	10(40)	5(20)	5(20)	0(0)	3(12)
	Pineapple	2(8)	3(12)	10(40)	7(28)	3(12)	0(0)
	Strawberry	0(0)	2(8)	3(12)	5(20)	7(28)	8(32)
	Papaya	20(80)	5(20)	0(0)	0(0)	0(0)	0(0)
	Mean ± SD	4 ± 7.9	3.67 ± 3.5	4.7 ± 3.3	3.7 ± 2.5	5 ± 4.6	4 ± 3.6
Acceptability of food based on food texture	Soft	7(28)	0(0)	5(20)	8(32)	5(20)	0(0)
	Hard	0(0)	0(0)	0(0)	0(0)	7(28)	18(72)
	Slippery	2(8)	0(0)	8(32)	10(40)	5(20)	0(0)
	Dry	0(0)	0(0)	5(20)	7(28)	5(20)	8(32)
	Mean ± SD	2.2 ± 3.3	0 ± 0	4.5 ± 3.3	6.2 ± 4.3	5.5 ± 1	6.5 ± 8.5
Acceptability of food based on food color	Yellow	5(20)	5(20)	7(28)	8(32)	0(0)	0(0)
	Green	7(28)	7(28)	7(28)	4(16)	0(0)	0(0)
	Red	3(12)	3(12)	7(28)	7(28)	3(12)	2(8)
	Orange	12(48)	8(32)	5(20)	0(0)	0(0)	0(0)
	White	0(0)	0(0)	0(0)	3(12)	8(32)	14(56)
	Mean ± SD	5.4 ± 4.5	4.6 ± 3.2	5.2 ± 3	4.4 ± 3.2	2.2 ± 3.5	3.2 ± 6.1
Acceptability of fruits based on different forms.	Raw	0(0)	0(0)	0(0)	0(0)	0(0)	25(100)
	Juice	0(0)	0(0)	0(0)	0(0)	8(32)	17(68)
	Puree	5(20)	12(48)	8(32)	0(0)	0(0)	0(0)
	Mean ± SD	1.7 ± 2.9	4 ± 6.9	2.7 ± 4.6	0 ± 0	2.7 ± 4.6	14 ± 12.8
Acceptability of fruits based on Shapes	Diced	0(0)	0(0)	0(0)	0(0)	8(32)	17(68)
	Geometrical	0(0)	0(0)	0(0)	2(8)	5(20)	18(72)
	Mean ± SD	0 ± 0	0 ± 0	0 ± 0	1 ± 1.4	6.5 ± 2.1	17.5 ± 0.7

DISCUSSION

The study was conducted to widen the scope of food behavior in special children. A previous study concluded that, in the age group of 6–13 years (boys), 15% were underweight, 11.3% were healthy, and 7.5% were overweight. Among girls of the age group (6–13 years), the percentage for underweight, healthy, and overweight was found to be 5.6%, 7.5%, and 3.7%, respectively. Another study reported the mean BMI scores of ASD children as 17.88 in girls and 17.36 in boys, indicating undernutrition [17,18].

Apple and strawberry showed the highest acceptance among all of the studied fruits. Moreover, it was observed that 78% of children omitted one or more food groups [19]. Food rejection, unique mealtime behaviour, and acceptance of a restricted range and texture of food items are more common in children with autism than in neurotypical children [20]. The findings of this study, in particular, are backed by earlier studies [21], which concluded that children with ASD have a constrained eating behaviour affected by food type and texture.

A similar trend was observed in the acceptance of food on the basis of color by ASD children: 3 out of 17 children preferred eating only 'red' apples, 'red' jam, and white vegetables [22]. Another study looked at the food preferences of children with ASD. The study suggested that food acceptability was mostly decided by appearance, with more than half of the children (n = 152) being very particular about the color of their food, which clarified the impact of food's color on the nutritional status of the ASD child [23].

Most of the children with ASD (70%) were fond of eating crunchy, hard, textured foods, smooth foods (60%), and dry foods (67%). Moist foods were the most unlikely (36% acceptable) among children with ASD, which supports the findings of our study [24]. Parents of 5 to 12-year-old children with ASD reported significantly more feeding issues compared to parents of typically developing children. These issues include refusing foods, requiring specific utensils or food presentation, accepting only low-textured foods such as pureed foods, and eating a limited variety of foods.

Food shapes were also considered to understand the behavior outcomes for dietary patterns of children involved in this study. Diced and geometrical shapes of foods were tested with equal acceptance for both of them in our study. Children with ASD were more likely to decline meals based on texture and form as compared to typical children, but both groups of children seldom refused food for these reasons, which supports our finding [25]. Six children, which made up 11.3% of the ASD population under study, rejected food based on their shape [25]. The food selectivity of children with ASD found that a small proportion (11.1%) of children were involved in food refusal based on the shape at baseline [24].

Table-II: Statistical Analysis results (One-Way ANOVA).

Variable	Groups	n	Mean ±SD	Standard Error	P-value (ANOVA)
Food Intake (Fruits)	Rejected	6	4±7.899	3.225	0.994
	Spitted Immediately	6	3.667±3.502	1.43	
	Spitted 30s	6	4.667±3.266	1.33	
	Spitted 60s	6	3.667±2.503	1.02	
	Chewed but Spitted	6	5±4.648	1.897	
	Swallowed	6	43.633	1.483	
Acceptability of food based on food texture	Rejected	4	2.25±	1.652	0.2826
	Spitted Immediately	4	0±0	0	
	Spitted 30s	4	4.5±3.3166	1.6583	
	Spitted 60s	4	6.25±4.3493	2.1747	
	Chewed but Spitted	4	5.5±1	0.5	
	Swallowed	4	6.5±8.54	4.272	
Acceptability of food based on food color	Rejected	5	5.4±4.5056	2.0149	0.8017
	Spitted Immediately	5	4.6±3.2094	1.4353	
	Spitted 30s	5	5.2±3.0332	1.3565	
	Spitted 60s	5	4.4±3.2094	1.4353	
	Chewed but Spitted	5	2.2±3.4928	1.562	
	Swallowed	5	3.2±6.0992	2.7276	
Acceptability of fruits based on different forms.	Rejected	3	1.667±2.886	1.667	0.2056
	Spitted Immediately	3	4±6.928	4	
	Spitted 30s	3	2.667±4.618	2.667	
	Spitted 60s	3	0.0±0.0	0	
	Chewed but Spitted	3	2.667±4.618	2.667	
	Swallowed	3	14±12.767	7.3711	
Acceptability of fruits based on Shapes	Rejected	2	0.0±0.0	0	≤0.001
	Spitted Immediately	2	0.0±0.0	0	
	Spitted 30s	2	0.0±0.0	0	
	Spitted 60s	2	1±1.4142	1	
	Chewed but Spitted	2	6.5±2.1213	1.5	
	Swallowed	2	17.5±0.7071	0.5	

Table-III: Levels of iron and zinc.

Age (yrs.)	5	6	7	8	9	10	11	12	13
Iron (µg/dl)	56	25.5	47.5	38.5	23	41	22	25	25
Zinc (µg/dl)	33	11.5	29	36.5	28	30	19	20.5	27

Disscussion to be continue....

The level of micronutrients, especially the one under consideration in this study, was affected by the child's diet, as the eating habits were quite dissimilar with respect to the age of the study population. Moreover, iron and zinc deficiency was also tested. One limitation of the study was that the sample size studied in this population was a smaller one due to difficulty in recruitment of ASD children. The study explores a rather neglected group that needs more attention from the researchers to improve the quality of food for this group with special needs. Further research in this area should expand on the current body of literature that has focused on eating patterns helping parents deal with children better.

CONCLUSION

We concluded that complications of ASD affect the eating patterns and nutritional status of the children, but they can be managed by training parents and counseling the child by professionals. Children with ASD are often said to be picky eaters as they tend to be selective in their eating routines. Autistic children have a compromised nutritional status due to their poor food intake and more rejection of food items. Making their acceptance towards even one food group can even act as a huge milestone.

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