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Anthropometric Characterization of Down Syndrome Phenotypes in Children Aged 2- 18 years; A Case-Control Studies in Kaduna State, Nigeria

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ABSTRACT

Down syndrome (DS) or Trisomy 21 is the most prevalent human chromosomal disorder with impact on multiple bodily systems. DS has been associated with a range of phenotypic effects, including altered physical characteristics. This study determined the anthropometric characteristics of children with Down syndrome in the tertiary health institutions in Kaduna State, Nigeria. A total of sixty (60) participants (children), between the ages of 2-18 years, were recruited for the study consisting of thirty (30) children with DS cases and thirty (30) normal (control; non-DS) children. All the participants were categorized into three age groups: 2-5 years, 6-10 years, and >10 years. Several anthropometric measurements were obtained from the participants which included head, body, hand and foot parameters, and some indices. Measured anthropometric characteristics were compared to the control group, and with respect to age categories. Results revealed significant (p<0.05) differences in height, body mass index, morphological facial height, head and hand breadth, hand and foot length, foot and cephalic indexes in DS compared to control participants. A strong positive correlation was observed between BMI, foot breath and foot length (p<0.05) in DS individuals. Relative to age categories, several anthropometric characteristics revealed significant differences when DS individuals were compared to the control. In conclusion, there exist remarkable differences in the anthropometric characteristics of children with Down syndrome and normal children in Kaduna State-Nigeria.

Keywords: Anthropometric indices, Down Syndrome, Hand and foot dimensions, Morphological facial height, Stature

INTRODUCTION

Down syndrome (DS) is the most prevalent genomic disorder of intellectual disability, with worldwide incidence of about 1 per 1000–1100 live births [1,2]. Over the past few decades, the live birth occurrence rate of DS has increased significantly, primarily due to the increase in maternal age at birth, that is women above 35 years giving birth, and improvement in modern medicine, which offer rehabilitation and infancy care [3,4]. Genetically, DS can occur as a result of translocation (3%), mosaicism (2%) and most commonly, full trisomy 21 (95%), resulting from non-disjunction of chromosome number 21 [5,6]. Consequently, trisomy 21 zygotes contain in their genes, three copies of chromosome 21, resulting in cells with 47 chromosomes (karyotype 47, XX, + 21 for females and 47, XY, + 21 for males) [7]. The presence of supernumerary chromosome 21 in DS patients has been reported to cause various phenotypic anomalies and developmental instabilities (i.e., chromosomal imbalance) [8]. Frequently occurring phenotypes in DS include indices that impact multiple bodily systems, particularly the neurological, musculoskeletal, and cardiovascular systems. The musculoskeletal features include short stature, with short fingers, atlantoaxial instability as well as hypotonia. Characteristic facial features including the presence of epicanthic folds, flat nasal bridge and occiput (brachycephaly), small mouth with large and protruding tongue, low set ears, and oblique palpebral fissures are as well common clinical phenotypes in DS [9].

Variation in anthropometric dimensions within a population that may be ascribed to genetic differences has been reported to occur primarily in proportions [10]. An imperative tool for the characterization and elucidation of human biological variability is,

Anthropometry. Anthropometry is a universally applicable, non-invasive and inexpensive method [11] and widely accepted as technique of choice for the assessment of dysmorphic features like those found in DS [12, 13]. It has been estimated that >90% of suspected DS patient can be categorized with >95.0% confidence by anthropometric approach. Consequently, fast clinical diagnosis can then be made on the majority of DS suspects before karyotyping is completed [14]. There is a need to collect several anthropometric characteristics in children with DS, especially in under-represented regions, including northern Nigeria, to provide data on characteristic clinical features that could be studied precisely by comparing with the age matched normal (non-DS) individuals. Hence, this study determined the anthropometric characteristics of children with DS (case) in the tertiary health institutions in Kaduna State, Nigeria and compare with normal (non-DS; control) children.

MATERIALS AND METHODS

Study location and sampling

The study was conducted in health institutions within Kaduna State, Nigeria. Kaduna State is located in the North-western region of Nigeria and shares common borders with Zamfara, Katsina, Niger, Kano, Bauchi, Nasarawa, Plateau States, and the Federal Capital Territory (Abuja). Kaduna State is located between latitudes 9˚ 03¹ and 11˚ 32¹ North of the Equator and longitudes 6˚ 05¹ and 8º 38¹ East of the Greenwich Meridian. The total land mass of the State is estimated at 46,053 km^2 which is about 5% of the total land area of Nigeria [15].

Four (4) Tertiary Health Institutions were selected for this study including, Ahmadu Bello University Teaching Hospital, Shika (ABUTH), Barau Dikko Specialist Hospital, Kaduna (BDSH), Federal Neuropsychological Hospital, Kaduna, and 44 Nigerian Army Reference Hospitals, Kaduna. The selected are referral hospital where cases beyond the primary and secondary health facilities are being referred for proper management.

A cluster non-random sampling techniques was adopted to recruit the study participants in accordance to certain stated selection criteria, namely: consent received from parents of children with DS; diagnostically confirmed DS children, and apparently healthy individual aged 2-18 years, as control participants.

Study participants and design

A total of sixty (60) participants (children), between the ages of 2-18 years, were recruited for the study consisting of thirty (30) children with DS cases and thirty (30) normal (control; non-DS) children. All the participants were categorized into three age groups: 2-5 years, 6-10 years, and >10 years. Several anthropometric measurements were obtained from the participants. Measured anthropometric characteristics were compared to the control group, and with respect to age categories.

Ethical clearance and access to clinical data

Study was conducted in accordance to globally acceptable best practice recommended for human related investigations. Ethical clearance was granted by the Ministry of Health and Human Services, Kaduna State, Nigeria (Ref. ID: HERC-17-0013). Additional ethical consent and permissions were obtained from the management of the selected health facilities to enable access to hospital records (clinical data). A checklist was used to collect the hospital numbers of all cases of children with DS taking into cognizance confidentiality measures.

Anthropometric apparatus and measurements

Some of the materials used for the study are: Stadiometer, Weighing balance (Balance Scale, Ningbo, China), Flexible non-stretchable measuring tape, Sliding caliper, Digital Vernier caliper, Consent form, Questionnaire for biographic information, etc.

All anthropometric parameters were taken according to the methods reported by the World Health Organization (WHO) [11] and Singh [16] as described by Asha et al. [13] as follows: Height and Weight; Standing height (stature) and body weight were measured using a stadiometer. Participants were requested to stand at the center of platform, in the anatomical position (arms to the side and feet together) to measure height, and to remove shoes, heavy garments or hair ornaments to measure body weight. Waist circumference; Waist circumference was measured at a level midway between the lower rib margin and the iliac crest with a measuring tape all around the body in a horizontal position. The participants were asked to raise clothing exposing the belly button and the tape positioned around the waist. Chest circumference; Chest circumference was measured as the horizontal circumference of the upper part of the body trunk at the level of the mesothermal in the resting stage using a tape. The participants were asked to stand straight, breath normally, and readings were recorded.

Hand and foot dimensions were measured using calipers. Hand Length; measured as straight distance between the midpoint of a line joining the two *stylion* and *dactylion* of the middle finger. Hand Breadth; measured as straight distance between *metacarpal radiale* and *metacarpal ulnae*. Foot Length; measured as a straight distance directly from *pternion* to *acropodion*. Foot Breadth; measured as straight

distance between *metatarsal tibiale* and *metatarsal fibulare*.

Cephalometric parameters were taken using a spreading caliper as follows: Maximum head length; measured as a straight distance from between the *glabella* and the *opisthocranion*. Maximum head breadth; measured as straight distance between the two *eurya*. Morphological facial height; measured as straight distance between *nasion* and *gnathion*. Morphological facial breadth or breadth of bizygomatic arch; measured as distance between two *zygia* i.e.; the most lateral points on the zygomatic arch.

Anthropometric indices

The following anthropometric indices were computed using the indicated formulae [13, 16]:

i. Body mass index: $\frac{\text{Weight (kg)}}{\text{Height (m2)}}$

ii. Hand index: $\frac{\text{Breadth of the hand}}{\text{Length of the hand}}$ x 100

iii. Cephalic index: $\frac{\text{Maximum head breadth}}{\text{Maximum head length}}$ x 100

iv. Foot index: $\frac{\text{Breadth of the foot}}{\text{Length of the foot}}$ x 100

v. Morphological facial index: $\frac{\text{Morphological facial height}}{\text{Breadth of bizygomatic arch}}$ x 100

Data analysis

Data obtained were analyzed using the Statistical Package for Social Sciences (IBM SPSS version 25.0). Results were expressed as Mean ± SD. Independent Student *t*-test was used to determine differences in DS and control participants. Pearson's Correlation was used to determine the relationship between parameters studied. A *p*- value < 0.05 was considered statistically significant.

RESULTS

Descriptive statistics

The descriptive statistics of anthropometric parameters of children with DS and control participants were determined and observations made; the mean values for DS participants are: stature (height; 1.08 ± 0.29 m); weight (30.04 ± 29.38 kg), morphological facial height (7.68 ± 2.23 cm), and chest circumference (65.03 ± 19.81 cm) (Table 1a). The mean values for control participants are: stature (height; 1.47 ± 0.20 m); weight (26.38 ± 14.63 kg); morphological facial height (10.81 ± 1.81 cm), and chest circumference (61.69 ± 10.62 cm) (Table 1b).

Anthropometric indices

The mean values for anthropometric indices of children with DS and the control participants revealed the following: BMI (19.92 ± 10.10 kg/m^2) and morphological facial index (78.76 ± 10.33) (Table 2a). The mean values for control participants are: BMI (11.58 ± 4.87 kg/m^2) and morphological facial index (81.38 ± 14.95) (Table 2b).

Relationships between anthropometric parameters and indices

The relationship between anthropometric parameter for the DS participants revealed a strong positive correlation between BMI, morphological facial height and foot length ($p<0.05$), while there was a weak negative correlation between morphological facial height and hand index. There was a strong negative correlation between BMI and cephalic index (Table 3a). The control participants revealed a strong positive correlation between BMI, foot breath and foot length ($p <0.05$), while there was a weak negative correlation between morphological facial height and height. There was a strong negative correlation between cephalic index and hand index (Table 3b).

Comparison of anthropometric characteristics of Down syndrome and control

Several anthropometric characteristics revealed remarkable ($p <0.05$) differences in mean values when DS and the control participants were compared. Generally, the stature (height) and morphological facial height in control was significantly ($p <0.05$) higher compared to that of DS. The BMI and head breadth of control were lower ($p <0.05$) compared to that of the DS participants; the hand and foot length lengths in the control were higher ($p <0.05$) compared of DS (Table 4).

Comparison of anthropometric indices of Down syndrome and control

The mean anthropometric indices revealed differences when DS and the control participants were compared. The cephalic index in control participants was lower ($p <0.05$) compared to DS, and foot index in control was lower ($p <0.05$) compared to DS (Figure 1).

Comparison of anthropometric characteristics of Down syndrome and control participants by Age classifications

The anthropometric characteristics for DS and control participants were compared in relation to age categories (2 – 5 years, 6 – 10 years, and >10 years). In age 2-5 years, the mean height and

morphological facial height values of the control was higher ($p < 0.05$) compared to that of the DS individual. However, BMI in control was lower ($p < 0.05$) compared to DS (Tables 5a).

Similarly, in age 6-10 years, the mean height and morphological facial height values of control were higher ($p < 0.05$) compared to DS; and BMI in the control was lower ($p < 0.05$) compared to DS. Mean head breadth in the control was lower ($p < 0.05$) compared to DS (Tables 5b). Above 10 years of age, the mean weight, BMI, morphological facial breadth, and head breadth of DS individuals were significantly higher than that of the control (Tables 5c).

Comparison of anthropometric indices of Down syndrome and control participants by age classification

The means of anthropometric indices for DS and control participants were compared in relation to age categories (2 - 5, 6 - 10, and >10 years), and the following recorded: in age 2 - 5 years, morphological facial index and cephalic index were higher ($p > 0.05$) in DS than control participant. However, hand index was lower ($p < 0.05$) in DS compared to the control (Figure 2a). In age 6 - 10 years, cephalic, hand and foot indices were higher ($p > 0.05$) in DS than control participant (Figure 2b)**.** In age >10 years, CI was higher ($p < 0.05$) in DS than control participant. However, foot index was lower ($p < 0.05$) in the DS (Figure 2c).

DISCUSSION

This study describes the anthropometric characteristics of children with DS in tertiary health institutions in Kaduna State, Nigeria and, compared values with control participants (children with no DS).

Observed in this study were anthropometric characteristics including height and weight which are integral factors of BMI, and morphological facial height and index, which differed in overall mean values with respect to DS status. These findings are in accordance with certain common physical traits that have been associated with DS individuals, presenting features different from typical individuals with no DS [13, 17].

The significantly strong positive correlation between BMI, morphological facial height, and foot length observed in individuals with DS agrees with reported strongly correlated distinctive anthropometric patterns in DS, primarily characterized by disproportionately short limbs, broader hands and feet, round face, and tendency towards higher BMI, and by extension, obesity due to slower metabolism or reduced activity. [18, 19, 20, 21, 22]

Stature difference observed as a significantly lower mean height value for DS participants compared to that of the control participants indicates short stature in DS participants. This is in line with the reports of Asha *et al.* [13] who reported an under 3rd to 10th percentile height in children with DS compared to normal participants with under 25th to 75th percentile of the pediatric growth. Similarly, the finding is in agreement with the study of Shaqiri and Bahtiri [23], who reported lower height in DS children compared to the control participants. Thus, finding aligns with the commonly reported distinct patterns linked to DS; primarily growth retardation [24, 25].

The mean BMI value observed to be significantly higher in DS children relative to the control participants is consistent with the work of Zemel *et al*. [26], who reported a higher BMI value in DS children in the United States compared with the CDC standard value. Additionally, findings in this study agree with the reports of Aburawi *et al*. [27] and El-Feel *et al*. [28], who both reported higher BMI in children with DS compared to the control in the Arab population. This manifestation may be due to abnormality in leptin hormone, as well as energy metabolism that has been reported in previous studies on DS children [29, 30], suggesting a tendency for developing obesity in children with DS.

The remarkably lower values in morphological facial height of DS participants compared to the control in this study are a discriminating factor for the identification of DS individuals. This finding is in line with the report of Allareddy *et al*. [31], who reported a significant reduction in the anterior facial height in DS patients. Reduced morphological facial height in DS has been associated with the underdevelopment of specific structures that present with an altered facial proportion. Characteristic features like midfacial hypoplasia (underdevelopment), a flatter profile, shorter overall face and nose, and relatively larger/ lower facial height compared to upper/ middle sections [32, 33, 34], resulting from a small cranial base, reduced maxillary length [35], and often a normal or slightly smaller mandible, contribute to the distinctive facial features and airway issues in DS [36]. Similarly, differences in head dimensions with a higher mean head breadth (width) value for DS individuals compared to the control individuals with no DS align with reported dimensions; while both head length and width are often reduced, the width dimension can be relatively better developed compared to the length in DS individuals. People with DS have often been described with craniofacial dysmorphologies, including smaller head circumference [37, 38] and a broad, flat head shape (brachycephaly), and micrognathia, compared to typical individual [39, 40].

Relative to hand and foot dimensions, lower (shorter) mean values observed in DS participants compared to control is in agreement with the reported phenotypic

characteristics of children with DS [41]. People with DS often have shorter, broader hands with shortened fingers, a single crease across the palm (simian crease). These characteristics stem from shortened bones, affecting the overall hand and limb length [42, 43]. Shortened upper and lower extremities are typical of DS patients [44], which impacts on balance and physical activities.

Cephalic index, a function of the breadth (biparietal diameter) and length (occipitofrontal diameter) of the head, is an important anthropometric feature for the identification of DS related characteristics [45]. In this study, cephalic index of DS participants was remarkably higher compared to the control participants indicating difference in the head parameters. This finding is in line with the reports of Asha *et al*.[13] which included brachycephaly in the list of twenty-five signs of DS. Brachycephaly, a shorter, rounder head shape leads to a higher cephalic index in children with DS compared to typically developing individuals [46, 47, 48].

The significantly higher foot index observed in the DS participants compared to the control is in line with the work of Lizis and Alter [49]. People with DS often have distinct foot shapes, characterized by wider, flatter feet and pronation, leading to footwear issues and potential mobility challenges [50, 51].

Body growth is a critical indicator of childhood health and well-being and gives information about possible pathologies [37]. Stature is an important clinical feature for DS and an integral factor of BMI [52]. Across the studied age categories (2 - 5years, 6 - 10 years, and >10 years), observed shorter statue (height) of the DS individuals compared to the control participants aligns with the report from previous workers; Björkstén *et al.* [53], McCoy [54], and George *et al.* [55] reported increased growth stagnation in children with DS, encountered after birth from the age of 3 - 6 years. Lopes *et al*. [56] and Shaqiri and Bahtiri [57] reported a different growth pattern in children with DS, characterized by an early impairment and reduced linear growth rate which results in shorter stature than the general population. Specifically, short stature was reported by Farkas and colleagues [58] as a stigma in DS. Clinically, these unique growth patterns are crucial for monitoring development, identifying potential obesity risk early, and managing overall health of individuals with DS [24, 59, 60]. Generally, growth lags in DS individuals compared with individuals with normal development.

A higher mean BMI for the DS participants compared to the control across the age categories is in line with the findings of Bertapelli *et al.* [25], who studied the growth rate of DS children with respect to BMI for age intervals of 2-18 years and reported an uninterrupted growth in BMI with age in DS. Reduced height potentially leads to higher BMI, indicating potential fat accumulation, especially with age, due to reduced metabolic rate and activity [20, 61]. DS has been linked to distinct patterns, primarily growth retardation and often higher BMI and central adiposity [24, 25, 62, 63, 64].

Significant difference observed in morphological facial height and other head parameters between children with DS and the control individuals across age categories is in agreement with reports of previous workers; there is a delay in the overall head growth, with circumference at age two potentially similar to a normal nine-month-old [41]. Studies note differences in head length to be shorter and head breadth narrower, but with a higher cephalic index (a ratio of width to length), indicating a broader head [47]. Vicente *et al.* [65], and Shaqiri and Bahtiri [57] reported children with DS have a smaller head circumference than healthy children.

Certain common physical traits have been associated or attributed to DS individuals, presenting a wide range of features, which may not be present in all patients. Observed differences in anthropometric indices between children with DS and the control individuals across age categories are in agreement with reports of previous workers [25, 66, 67]. In essence, DS presents a unique growth trajectory, compared to development of typical individuals, showing significant differences in stature (height), weight, head parameters, and body composition profile; prone to overweight and obesity in later childhood or adulthood. Hence, necessitating tailored anthropometric standards and assessment tools beyond typical growth charts.

CONCLUSION

There exist remarkable differences in the anthropometric characteristics of children with Down syndrome and normal children in Kaduna State-Nigeria. Thus, these specific and recognizable anthropometric deviations from the normal could be beneficial in discrimination and identification of Down syndrome individuals in Nigeria.

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Table 1a: Anthropometric parameters of Down's syndrome participants

Variables	Mean ±SD	Minimum	Maximum
Age (years)	7.00 ± 0.09	2.00	16.00
Weight (kg)	30.04 ±29.38	6.20	97.00
Height (m)	1.08 ± 0.29	0.74	1.57
MFH (cm)	7.68 ±2.23	4.61	12.00
MFB (cm)	9.78 ±2.84	6.63	17.00
Head Length (cm)	23.07 ±4.15	3.20	26.00
Head Breadth (cm)	24.47 ±2.19	21.00	30.00
Hand Breadth (cm)	5.74 ±1.97	3.52	9.00
Hand Length (cm)	11.14 ±3.98	1.70	18.00
Foot breadth (cm)	6.65 ±2.62	3.20	11.00
Foot length (cm)	16.30 ±5.47	9.23	24.00
Chest Circumference (cm)	65.03 ±19.81	44.00	117.00

n =30; MFH=Morphological facial height; MBH= Morphological facial breadth

Table 1b: Anthropometric parameters of control participants

Variables	Mean ±SD	Minimum	Maximum
Age (years)	7.23±3.37	3.00	13.00
Weight (kg)	26.38±14.63	5.00	53.00
Height (m)	1.47±0.20	0.62	1.70
MFH (cm)	10.81±1.81	5.00	13.00
MFB (cm)	8.73±1.88	4.50	14.00
Head Length (cm)	23.50±3.99	10.00	29.00
Head Breath (cm)	20.33±5.71	5.50	26.00
Hand Breadth (cm)	9.69±7.19	5.00	28.00

Hand Length (cm)	16.21±5.42	10.00	28.00
Foot breath (cm)	7.54±1.47	5.00	10.00
Foot length (cm)	20.75±3.80	14.00	28.00
Chest Circumference (cm)	61.69±10.62	44.00	81.00

n =30; **MFH**=Morphological facial height; **MBH**= Morphological facial breadth

Table 2a: Anthropometric indices of children with Down syndrome (n =30)

Variables	**Mean ±SD**	**Minimum**	**Maximum**
Body Mass Index (kg/m^2)	19.92 ±10.10	10.22	44.89
Morphological facial index	78.76± 10.33	53.85	100.00
Cephalic Index	95.14±16.87	10.67	109.52
Hand Index	63.12±7.04	43.30	470.59
Foot Index	40.22±4.65	31.33	52.38

Table 2b: Anthropometric indices of control (n =30)

Variables	**Mean ±SD**	**Minimum**	**Maximum**
Body Mass Index (kg/m^2)	11.58±4.87	5.03	20.20
Morphological Facial Index	81.38±14.95	61.54	127.27
Cephalic Index	84.71±16.60	44.44	100.00
Hand Index	55.13±18.33	38.89	100.00
Foot Index	36.50±3.90	28.57	44.44

Table 3a: Relationships between anthropometric parameters in Down syndrome participants

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1- Age	1																
2- WT	.634**	1															
3- HT	.755**	.870**	1														
4- BMI	.521**	.979**	.794**	1													
5- MFH	.484**	.808**	.805**	.824**	1												
6- MFB	.438*	.853**	.817**	.864**	.898**	1											
7- MFI	.121	-.027	.067	-.008	.358	-.080	1										
8- Head L	.127	-.226	.009	-.282	-.151	-.269	.187	1									
9- Head B	.385*	.623**	.686**	.605**	.716**	.694**	.195	-.143	1								
10- CI	-.052	-.462*	-0.295	-.503**	-.453*	-.532**	.045	.891**	-.571**	1							
11- Hand B	.717**	.882**	.970**	.806**	.801**	.828**	.025	-.019	.718**	-.327	1						
12- Hand L	.543**	.851**	.807**	.854**	.780**	.848**	-.072	-.079	.540**	-.303	.757**	1					
13- Hand I	.155	-.068	.150	-.169	-.012	-.091	.197	.130	.223	.010	.237	-.437*	1				
14- Foot B	.643**	.793**	.944**	.733**	.779**	.739**	.175	.060	.721**	-.265	.934**	.706**	.254	1			
15- Foot L	.704**	.745**	.961**	.677**	.784**	.740**	.197	.113	.679**	-.209	.922**	.714**	.241	.957**	1		
16- Foot I	.151	.509**	.443*	.492**	.368*	.367*	.012	.072	.431*	-.225	.510**	.353	.146	.623**	.382*	1	
17- CC	.626**	.975**	.896**	.956**	.839**	.867**	.030	-.282	.677**	-.533**	.894**	.862**	-.070	.833**	.804**	.479**	1

n=30, Pearson's correlation; *=p<0.05; **=p<0.01; B= Breadth; BMI= Body mass index; CC= Chest circumference; CI= Cephalic index; HT= Height; L= Length; I= Index; MFH= Morphological facial height; MFB= Morphological facial breadth; MI= Morphological index; WT= Weight

Table 3b: Relationships between anthropometric parameters in control participants

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1- Age	1																
2- WT	.617**	1															
3- HT	.133	.677**	1														
4- BMI	.720**	.926**	.36	1													
5- MFH	.378	.202	.178	.186	1												
6- MFB	.580**	.044	.278	.232	.582**	1											
7- MFI	.361	-.084	.449*	.147	-.249	.634**	1										
8- Head L	.214	.147	-.082	.256	.274	.25	.04	1									
9- Head B	.005	-.114	-.245	.014	.19	.17	.023	.892**	1								
10- CI	-.188	-.305	-.305	-0.2	.08	.034	-.035	.660**	.925**	1							
11- Hand B	.263	.304	.259	.229	-.052	.071	.14	-.731**	-.927**	-.957**	1						
12- Hand L	.461*	.428*	.219	.410*	.008	.22	.267	-.578**	-.775**	-.847**	.931**	1					
13- Hand I	.108	.224	.267	.13	-.04	-.013	.026	-.748**	-.936**	-.948**	.954**	.791**	1				
14- Foot B	.626**	.601**	.042	.761**	.431*	.532**	.249	.471*	.283	.054	-.012	.23	-.124	1			
15- Foot L	.770**	.743**	.259	.833**	.298	.519**	.369	.361	.091	-.173	.232	.481*	.061	.833**	1		
16- Foot I	-.235	-.189	.338	-.074	.23	.007	-.221	.153	.277	.329	-.357	-.37	-.257	.324	-.248	1	
17- CC	.759**	.706**	.1	.842**	.199	.395*	.322	.213	-.023	-.249	.33	.567**	.155	.736**	.851**	-.162	1

n=30, Pearson's correlation; *=p<0.05; **=p<0.01. B= Breadth; BMI= Body mass index; CC= Chest circumference; CI= Cephalic index; HT= Height; L= Length; I= Index; MFH= Morphological facial height; MFB= Morphological facial breadth; MI= Morphological index; WT= Weight

Table 4: Comparison of anthropometric parameters of Down syndrome and control participants

Variables	Down Syndrome	Control	*t*	*p*-value
Age (yrs)	7.00±0.75	7.23±3.37	2.005	0.820
Weight (kg)	30.04±5.36	26.38±2.87	0.601	0.551
Height (m)	1.08±0.05	1.47±0.04	-5.860	0.001
BMI (kg/m^2)	19.92±1.84	11.58±0.96	4.016	0.001
CC (cm)	65.03±3.62	61.69±2.08	0.801	0.427
MFH (cm)	7.68±0.41	10.81±0.36	-5.702	0.001
MBH (cm)	9.78±0.52	8.73±0.37	1.656	0.104
Head Length (cm)	23.07±0.76	23.50±0.78	-0.390	0.698
Head Breadth (cm)	24.47±0.40	20.33±1.12	3.482	0.001
Hand Breadth (cm)	5.74±0.36	9.69±1.41	-2.717	0.011
Hand Length (cm)	11.14±0.73	16.21±1.06	-4.024	0.001
Foot breath (cm)	6.65±0.48	7.54±0.29	-1.585	0.120
Foot length (cm)	16.30±1.00	20.75±0.74	-3.568	0.001

n =30; mean±SD. MFH=Morphological facial height; MBH= Morphological facial breadth; CC=Chest circumference; BMI= Body mass index.

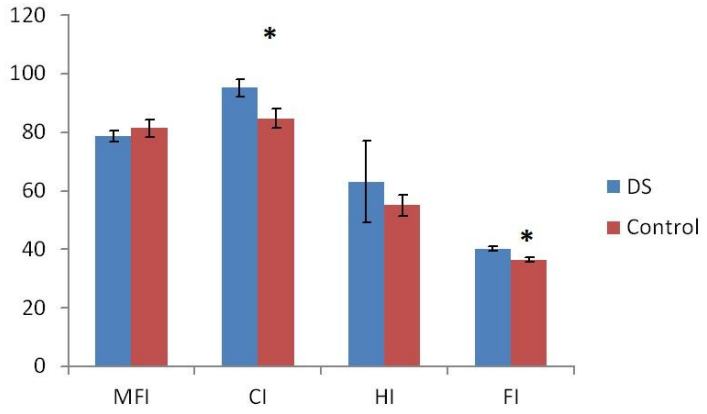

Figure 1: Comparison of anthropometric indices in Down syndrome and control participants
n=30; Mean ± SD, *t*-test; *=p<0.05. MFI=Morphological Facial Index, CI=Cephalic Index, HI=Hand Index, FI=Foot Index

Table 5a: Anthropometric characteristics of Down syndrome and control participants aged (2-5) years

Variables	Down Syndrome	Control	*t*	p-value
Weight (kg)	13.88±3.69	10.60±0.51	0.54	0.597
Height (m)	0.87±0.05	1.36±0.01	-5.50	0.001
BMI (kg/m^2)	15.30±1.41	5.75±0.29	4.10	0.001
MFH (cm)	6.70±0.57	9.40±0.24	-2.85	0.012
MFB (cm)	8.49±0.64	6.80±0.37	1.58	0.134
Head Length (cm)	22.85±0.53	20.40±2.71	0.89	0.423
Head Breath (cm)	23.62±0.51	18.30±3.28	1.60	0.182
Hand Breath (cm)	4.41±0.37	8.90±3.78	-1.18	0.301
Hand Length (cm)	9.16±0.73	14.00±3.02	-1.56	0.186
Foot Breath (cm)	4.99±0.57	5.80±0.20	-0.86	0.405
Foot Length (cm)	12.46±1.23	15.40±0.68	-1.43	0.173
Chest Circumference (cm)	54.15±3.17	49.40±1.36	0.90	0.380

n=30; BMI= Body mass index; MFH=Morphological facial height; MBH= Morphological facial breadth.

Table 5b: Anthropometric characteristics of Down syndrome and control participants aged (6-10) years

Variables	Down Syndrome	Control	*t*	p-value
Weight (kg)	34.82±8.79	23.00±2.41	1.07	0.298
Height (m)	1.18±0.07	1.5±0.02	-4.61	0.001
BMI (kg/m^2)	21.42±3.27	10.10±0.83	2.76	0.013
MFH (cm)	7.89±0.65	11.00±0.46	-3.52	0.002
MFB (cm)	10.40±0.91	9.00±0.33	1.44	0.172
Head Length (cm)	22.68±1.81	24.75±0.41	-0.91	0.374
Head Breath (cm)	25.08±0.72	22.50±0.33	2.77	0.013
Hand Breath (cm)	6.34±0.51	6.75±0.23	-0.63	0.535
Hand Length (cm)	11.58±1.29	14.06±0.62	-1.48	0.155
Foot Breath (cm)	7.64±0.72	7.44±0.18	0.27	0.788
Foot Length (cm)	18.27±1.26	20.44±0.70	-1.31	0.207

Chest Circumference (cm)	68.42±5.77	59.00±1.60	1.30	0.210

n=30; BMI= Body mass index; MFI=Morphological facial height; MBH= Morphological facial breadth,

Table 5c: Anthropometric characteristics of Down syndrome and control participants aged (above 10) years

Variables	**Down Syndrome**	**Control**	***t***	**p-value**
Weight (kg)	60.60±14.79	34.54±4.25	1.69	0.042
Height (m)	1.40±0.09	1.49±0.08	-0.64	0.265
BMI (kg/m^2)	28.35±5.34	14.73±1.23	2.48	0.012
MFH (cm)	9.75±0.41	11.23±0.60	-1.46	0.163
MFB (cm)	11.69±0.89	9.31±0.60	2.13	0.049
Head Length (cm)	24.60±0.60	23.92±1.07	0.38	0.711
Head Breath (cm)	25.20±0.80	19.77±1.84	2.70	0.016
Hand Breath (cm)	7.74±0.71	11.81±2.37	-1.65	0.122
Hand Length (cm)	15.22±1.01	18.38±1.62	-1.16	0.263
Foot Breath (cm)	8.60±0.81	8.27±0.43	0.36	0.731
Foot Length (cm)	21.60±1.44	23.00±0.85	-0.85	0.406
Chest Circumference	85.20±9.24	68.08±2.88	1.77	0.140

n=30; BMI= Body mass index; MFI=Morphological facial height; MBH= Morphological facial breadth.

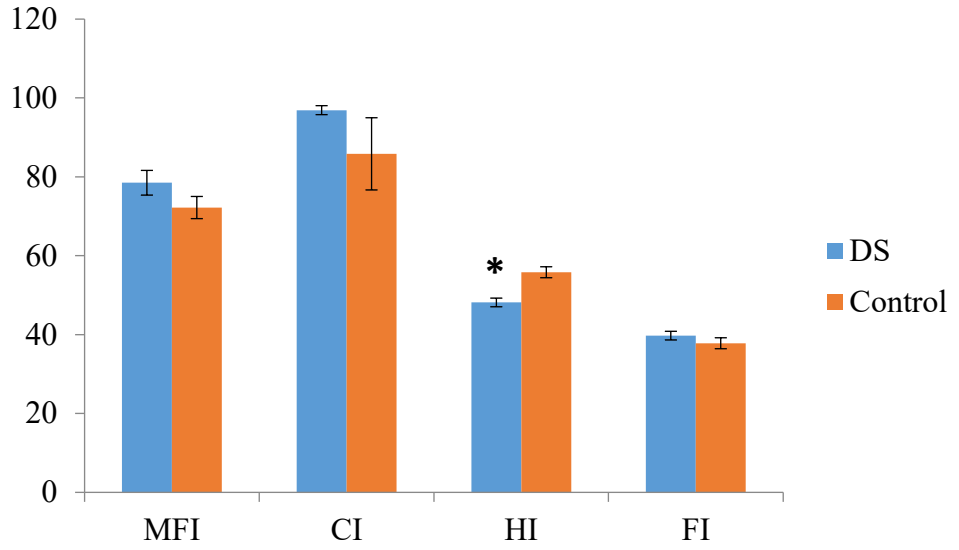

Figure 2a: Comparison of anthropometric indices of Down syndrome and control participants aged 2-5 years n=30; Mean ± SD, *t*-test: *=p<0.05. DS= Down syndrome, MFI=Morphological Facial Index, CI=Cephalic Index, HI=Hand Index, FI=Foot Index

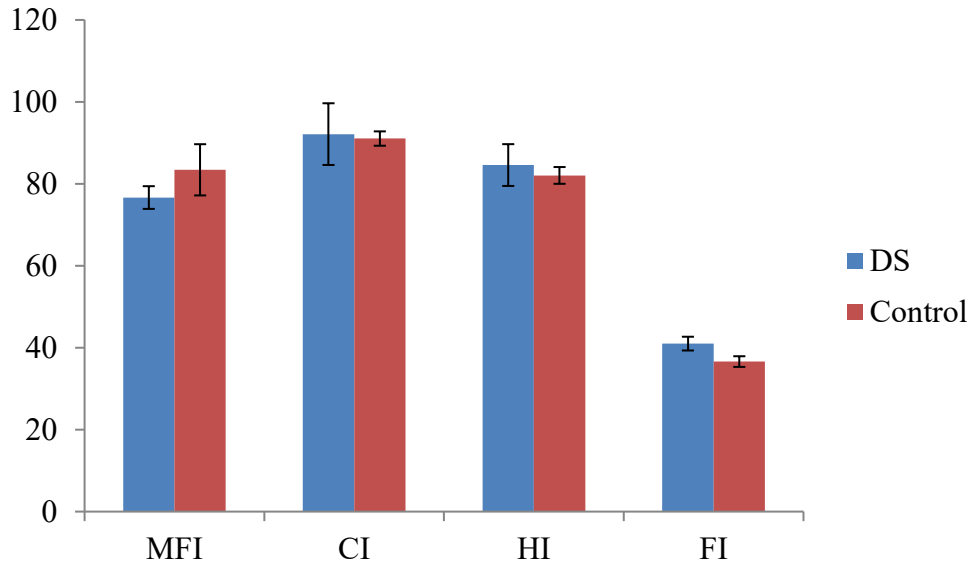

Figure 2b: Comparison of anthropometric indices of Down syndrome and control participants aged 6-10 years n=30; Mean ± SD, *t*-test: p>0.05. DS= Down syndrome, MFI=Morphological Facial Index, CI=Cephalic Index, HI=Hand Index, FI=Foot Index

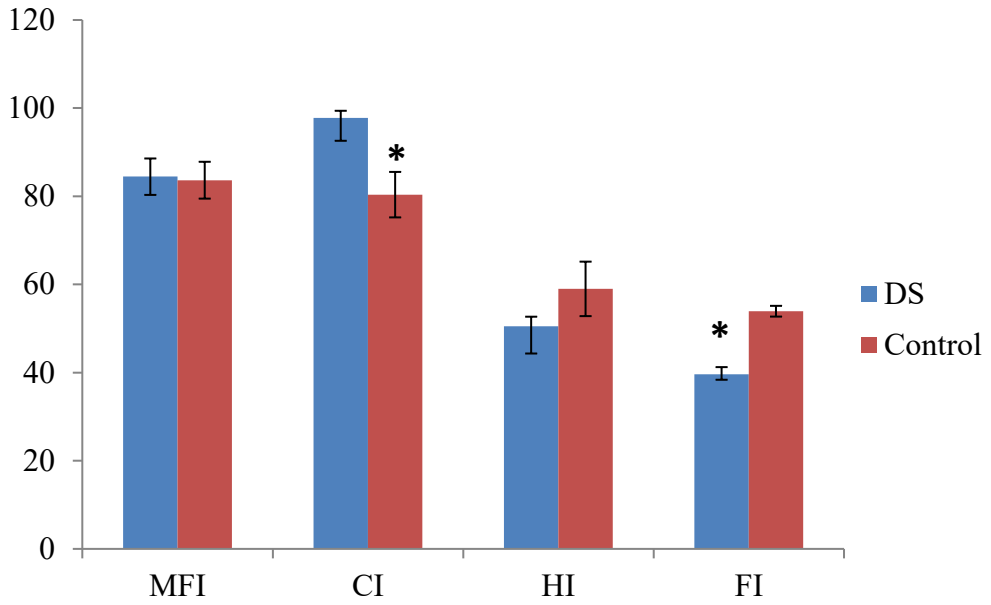

Figure 2c: Comparison of anthropometric indices of Down syndrome and control participants aged >10 years n=30; Mean ± SD, *t*-test: *=p<0.05. DS= Down syndrome, MFI=Morphological Facial Index, CI=Cephalic Index, HI=Hand Index, FI=Foot Index