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Comparative study of chronic energy deficiency among adult males of Andaman and Nicobar Islands and their counterparts

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Abstract: The indigenous islanders of Andaman and Nicobar Islands are representing the earliest form of developmental stage, their nutritional assessment and anthropometric comparison with contemporary populations are the main objective of the present paper. In this study we present a cross sectional analysis of anthropometric data of 2010 individuals of 19 different groups. The data were collected by the trained anthropologists of Anthropological Survey of India, following standard techniques and ethical guidelines. It was found that the Indigenous Islanders have small body size as compared to immigrants and counterparts. The prevalence of chronic energy deficiency (CED) was found highest among the mainlanders. Highest prevalence of overweight was found among Great Andamanese (18.2%), followed by Onge (7.4%). Individuals below 21 years of age were not found to be overweight or obese. On the other side, 16.7% of individual of age 41+ of local born were found to be overweight (BMI 25.0-29.9 kg/m^2). It can be concluded that the Indigenous people of the Islands are short in stature and nutritionally better than immigrants. The immigrants are better than their counterparts in the mainland, but still they are not able to reach at par of the indigenous people in the level of nutrition whereas logarithmic transformation of data and scaling exponent (β) of weight to height was found ~2 across these populations.

Key words: undernutrition, obesity, overweight, migration, scaling exponent, indigenous people

Introduction

Epidemiological transition is still being witnessed in developing countries. They are facing dual burden of diseases; at one side they have traditional, infectious and vector borne diseases. On the other side, nutritional transition has posed life style diseases: like obesity and associated problems. The indigenous people i.e. tribes of Andaman and Nicobar Islands have been inhabited the islands since time immemorial. The earliest archaeological evidence of their presence has been dated to approximately 2,200 years BP. It has been estimated that they have

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inhabited the Islands since the Middle Paleolithic period.

At present, Andaman and Nicobar islands are abode of indigenous people known as: Jarawas, Onges, Sentineles, Great Andamanese, Shopmen and Nicobarese. These groups are fascinating due to their culture, unique location, isolation and developmental status. Besides the indigenous populations, these islands are also inhabited by immigrants from Indian Sub-continent, who belong to different social strata and caste hierarchy of pan-Hindu religion. These immigrants were endogamous in mainland, but the practice could not be maintained in the Island setting. In this way, the immigrants of Andaman and Nicobar Islands form a unique group of people and require investigation from different angles. Anthropologically, they are important, because they provide an opportunity to investigate the people of different regions, religion, ecology, economy and ethnic affinities in a distinct and Island settings.

Studies reveal that an immigrant population have an elevated body dimensions, and differ from the original populations (Boas 1912; Bose and Mascie-Tylor 1998). The change may be due to improvement in environment, economy, level of nutrition and hygienic factors. The urbanization and economic development lead to high calorie intake and reduced physical activity and ultimately the outcome is the change in body dimensions (Popkin 1994; Shetty 1997). Sahani (2005) has also reported higher body mass index and body dimensions among the immigrant population.

The Indigenous tribes of Andaman and Nicobar Islands are still heavily dependent on their traditional subsistence: hunting-gathering and horticulture; whereas the immigrant populations have wide range of alternative subsistence. Considering the above-mentioned situations in account, the objective of this study was to explore if the immigrant and indigenous peoples were nutritionally and anthropometrically different from each other. In addition, we wanted to find out whether mode of subsistence and migration determines nutrition and anthropometric characteristics or not.

Chronic energy deficiency (CED) is the most widespread nutritional deficiency in the world. It refers to an intake of energy less than the requirement, for a prolonged period. CED is difficult to identify directly, as measurements of energy intakes are difficult to obtain; therefore, CED is usually identified by proxy variables such as deficits in anthropometry, body composition or growth. There are many scholars who have focused on the problem of CED among Indian populations; some of them are Ferro-Luzzi et.al. (1992), Khongsdier (2001), Adak et al.(2006), Bharti (1989), Naidu et al. (1991 and 1994), Gautam et al. (2006), Gautam (2007), Gautam and Thakur (2009), Mishra and Mohanty (2009), Gautam et al.(2013), Kumar and Gautam (2015) and Gautam et.al. (2016). Nonetheless, such studies are limited to North-Eastern, Southern, and Central Part of India. This is probably the first attempt to study the people of Andaman and Nicobar Islands in a comprehensive way for their comparative nutritional and anthropometric analysis. Here is an attempt to understand the anthropometric characteristics viz. stature, sitting height, weight, cormic index (CI) and body mass index (BMI) of indigenous populations of the islands, immigrants to the islands, counterparts of immigrants residing in the mainland and the locally born or ad-

mixture of immigrants residing in the Islands. Besides, attempt was made to find out the difference in body dimensions and BMI among the indigenous islanders (tribes), immigrant islanders and mainlanders followed by the people of different ethnic origin, level of subsistence and occupations. An attempt was also made to understand the role of ecology in shaping the body dimension, level of nutrition and the process of acclimatization.

Material and Methods

The study samples were recruited purposively from individuals belonging to 19 ethnic groups viz. 4 Indigenous Tribes of Andaman and Nicobar Islands namely *Jarawas, Onges, Great Andamanese* and *Car Nicobarese;* 11 Immigrant islanders- *Karen, Moplah, Bhantu, Chakkliyan, Kharia, Munda, Namasudra, Oraon, Paniyan, Vadabaliza, Valmiki; and* 4 Mainlanders-*Bhantu, Munda, Oraon and Valmiki*. The analysis is based on a total of 2010 adult males which also include 'local born' the admixture of immigrant islanders. Basic anthropometric data on body weight, height and sitting height were collected following the standard procedure. Similarly, the data on immigrants and their counterpart were collected by the trained physical anthropologists of Anthropological Survey of India (Bhowmik 1988; Banerjee and Basu 1991; Bhattacharya et al. 1993 and Sahani 2013) following standard techniques (Martin and Saller 1956; Weiner and Lourie 1981) and ethical guidelines.

Measurements were taken on adult males who looked apparently active and healthy. Efforts were also made to exclude closely related individuals, such as brothers, fathers and sons, and individuals with any kind of physical deformities. Therefore the samples were free from any selection bias. Before collection of the data, the instruments were standardized, and the errors were taken care of. Simultaneously, verbal informed consent was obtained from the study participants and they were illustrated in detail about the study objectives.

Data Management and Analysis

The individual data on anthropometric measurements, age, ethnicity, economic/cultural status, occupation, geo-climatic setup and migration were entered into an excel worksheet, where the data was filtered and errors were removed, followed by calculation of cormic index (CI) (sitting and BMI for each individual. A similar file was designed in SPSS (statistical package for social sciences), for further analysis. Chronic energy deficiency (CED) was estimated on the basis of BMI following Adak et al. (2006), Gautam et al. (2006) and Gautam (2009). BMI<16.0 is classified as CED Grade III (Severe), followed by BMI 16.0-16.99, CED Grade II and BMI 17.0-18.49 is CED Grade I.

Central tendency (arithmetic mean) and dispersion (standard deviation) of body weight, height, sitting height, CI and BMI for each population and group of populations were calculated using MS-Excel and SPSS software. Subsequent analysis like distribution of population as per level of nutrition i.e. CED grade were obtained considering cutoff point 18.5 kg m^{-2} of BMI, following Ferro-Luzzi et al. (1992), James et al. (1998), Khongsdier (2001), Adak et al. (2006), Gautam et al. (2006), Gautam and Thakur (2009), Gautam (2007a, 2007b), Das and Bose (2010), Gautam et al. (2013), Kumar and Gautam (2015). Logarithmic transformation, regression analysis and t-test were also executed using the SPSS software.

Limitations

It was not possible for investigators to record the exact age of indigenous islanders, therefore, age of *Great Andamanese, Onges* and *Jarawas* was not recorded, although, all subjects recruited were apparently adults. Similarly, the data on sitting height of all the samples was not possible to record; because indigenous islanders like *Jarawas* were highly nomadic and partially cooperated; hence out of 42 Jarawas included in the study, the information on sitting height and cormic index was based on 11 individuals only. As the total population size of *Great Andamanese* was less than 50, hence only 11 adult males were available. Similarly, the total population of *Onges* was 99 at the time of recruitment of samples; hence, only 27 adult Onge males were recruited for present investigation.

Area and People

The Andaman and Nicobar Islands are part of Republic of India and situated in the Bay of Bengal. It is located between latitudes 10°30´ and 13°45´ N, comprising more than 300 islands, out of which 26 are inhabited. There are six indigenous groups of people known as *Jarawas, Onges, Nicobarese, Great Andamanese, Sentineles and Shopmen*. First four, out of these six were recruited for present investigation. These Islands are also inhibited by immigrants from the Indian mainland. A brief description about the population studied is being given herewith for elucidation of the facts.

Indigenous Islanders

The indigenous people i.e. tribes of Andaman and Nicobar Islands are the first native of these islands, but how they reached there is still not definitely known. From the point of view of ethnic affinities they belong to two distinct stocks known as Negrito and Mongoloid (although this is an obsolete classification, it is being used for heuristic purpose). The Great Andamanese, Jarawas and Onges fall under the category of so called "Negritos" whereas, the Nicobarese are people of Mongoloid affinity. Some of them like the Sentinels are still not in contact, whereas the Jarawas came in contact in the late eighties. The Census of India (Census of India, 1991) had enumerated 101 Onges. Recently, their population was recorded 112. The Nicobarese comprise the largest indigenous population. According to Census of India (Census of India, 2011) the population of Nicobar district was 36819.

Immigrant Islander

The Andaman and Nicobar Islands are populated by immigrants of Indian Sub-continent. For present investigation sample were drawn from a total of 11 groups of immigrants. They are known as-*Karen, Moplah, Bhantu, Chakkiliyan, Kharia, Munda, Namasudra, Oraon, Paniyan, Vadabaliza,* and *Valmiki*. They had migrated from different parts of the sub-continent for example-*Karen* were migrated from Myanmar; *Namasudra* from Bangladesh and West Bengal; *Munda, Kharia* and *Oraon* from Chhotanagpur, Chhatishgarh and Orissa; and *Valmiki* from Uttar Pradesh. *Vadabaliza, Chakkiliyan, Paniyan* and *Moplah* belong to Southern states of India.

The *Moplah* or *Mappila* refers to one of the Muslim communities of Kerala that inhabit the region. Significant numbers of the community are also present in the Southern districts of Karnataka and Western parts of Tamil Nadu.

The *Bhantu* were one of the many nomadic groups found in North India. During colonial administration, they were notified under the Criminal Tribes Act and many were exiled to the Andaman Islands.

Local Born

The term 'local born', implies that they are offspring of immigrants. In mainland, all the above-described ethnic groups are endogamous, but in their new abode; they do not stick to endogamy and practicing exogamy. So, the locally born are admixture of different ethnic group.

Mainlanders

A total of 547 individuals of four different ethnic groups namely *Bhantu, Munda, Oraon* and *Valmiki* of Chhotanagpur, Chhatishgarh, Orissa and Uttar Pradesh were considered for present investigation and comparison. They all are endogamous and most of them are agriculturists.

Results

Population wise sample size along with descriptive statistics of age, height, sitting height, body weight, body mass index (BMI) and cormic index (CI) are displayed in Table 1. It is apparent that the *Bhantu* of mainland (Uttar Pradesh) are taller with 165.8±5.3 cm average height, whereas the *Onges*, the indigenous tribe of Andaman Islands were shortest with 150.7± 4.2 cm of average height. For further explanation of facts the mainlander and islanders are grouped and an error-bar-diagramme (Fig. 1) was constructed, which indicate that the local born islanders were significantly taller followed by immigrant islanders and mainlander. In addition, the indigenous islanders were significantly short in stature. The ranking is relatively in the following order: indigenous islander<mainlander <immigrant islanders<local born islanders. Further, it is apparent that among indigenous islanders, the Nicobarese are comparatively taller than Great Andamanese, Jarawa and Onge.

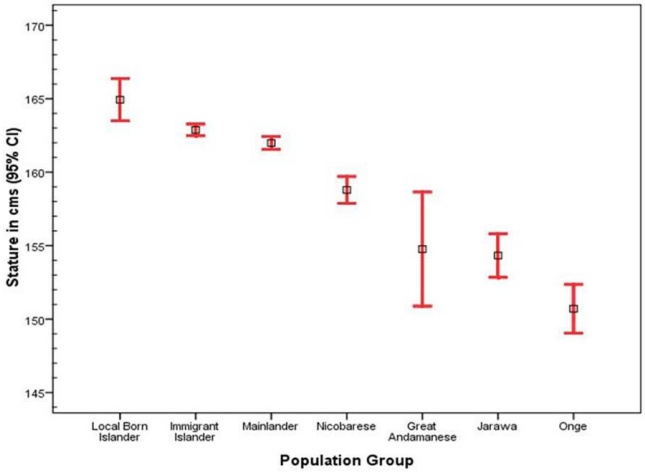

Figure 1. Error bar diagram showing comparative difference of stature (at 95% confidence of interval) among different groups of people.

Table 1. Means and standard deviations of age, stature, sitting heights, body weights, cormic indices and BMIs of adult males from 19 ethnic groups belonging to different geo-climatic setups, ethnic affinity and socio-cultural background

No	Population	N	Age (years)	Stature (cm)	Sitting height (cm)	Weight (kg)	Cormic Index	BMI (kg/m^2)
			Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Mainlander								
1.	Bhantu	50	29.5±9.6	165.8±5.3	86.3±3.1	51.8±8.3	0.521±0.011	18.8±2.4
2.	Munda	98	32.7±9.6	158.6±6.2	79.6±2.9	46.8±4.4	0.502±0.014	18.6±1.5
3.	Oranon	199	32.8±10.5	160.5±5.4	81.7±3.3	46.3±4.9	0.509±0.015	17.9±1.6
4.	Valmiki	200	37.6±10.5	165.7±5.3	80.3±3.6	51.7±6.8	0.485±0.017	18.8±2.2
	Total	547	34.3±10.6	162.5±6.3	81.2±3.8	48.9±6.5	0.500±0.020	18.5±1.9
			F=12.7	*F*=52.8	*F*=52.6	*F*=36.1	*F*=121.8	*F*=8.1
Immigrant Islanders								
5.	Karen	99	33.1±13.8	163.4±5.4	87.0±3.4	57.5±7.0	0.532±0.015	21.5±2.4
6.	Moplah	100	32.9±12.8	164.2±7.0	84.8±3.1	54.0±7.9	0.517±0.013	20.0±2.7
7.	Bhantu	72	28.3±9.1	165.7±5.2	85.9±2.9	53.0±6.2	0.518±0.012	19.3±1.9
8.	Chakkiliyan	99	35.7±12.0	161.9±6.6	82.5±3.4	52.6±7.6	0.510±0.015	20.0±2.4
9.	Kharia	99	41.0±12.1	162.6±5.9	82.6±3.0	52.2±6.2	0.508±0.014	19.7±2.0
10.	Munda	99	39.8±13.0	161.7±5.8	82.6±2.9	52.6±5.1	0.511±0.012	20.1±1.7
11.	Namasudra	255	33.8±11.7	160.8±6.6	84.4±3.4	50.2±6.1	0.525±0.014	19.4±1.8
12.	Oraon	110	39.2±11.3	160.6±6.9	81.7±3.4	50.2±5.5	0.509±0.016	19.4±1.9
13.	Paniyan	50	29.2±9.7	163.9±6.0	84.1±3.1	52.3±5.6	0.513±0.014	19.5±1.8
14.	Vadabaliza	100	33.4±10.9	162.6±5.7	82.6±4.1	53.1±6.3	0.508±0.022	20.1±1.9
15.	Valmiki	92	32.3±13.2	163.8±5.2	84.9±2.5	51.4±7.7	0.518±0.014	19.1±2.5
	Total	99	34.8±12.4	162.4±6.3	83.9±3.6	52.3±6.8	0.517±0.017	19.8±2.2
			F=10.3	*F*=6.5	*F*=24.7	*F*=11.2	*F*=32.4	*F*=10.3
Offspring of immigrants								
	Local born	100	29.5±10.7	164.9±7.3	85.0±3.0	52.9±7.8	0.516±0.017	19.4±2.5
Indigenous population (Tribes)								
16.	Car Nicobarese	108		158.8±4.8	83.5±2.5	54.6±4.6	0.526±0.014	21.7±1.6
17.	Great Andamanese	11		154.8±5.8	78.2±3.8	54.7±8.1	0.456±0.152	22.8±2.7
18.	Jarawas	42		154.3±4.8	78.4±3.3	46.4±5.2	0.516±0.011	19.5±2.2
19.	Onge	27		150.7±4.2	77.7±2.2	49.1±8.3	0.516±0.014	21.6±3.4
	Total	188		156.4±5.6	81.8±3.7	52.0±6.6	0.519±0.044	21.2±2.3
				F=24.8	*F*=49.1	*F*=25.2	*F*=9.7	*F*=12.7
Total Islanders		1463	34.3±12.4	161.8±6.7	83.7±3.6	52.3±6.9	0.517±0.022	20.0±2.3
			F=11.2	*F*=19.9	*F*=28.7	*F*=11.3	*F*=21.2	*F*=14.6
Total population		2010	34.3±11.9	162.0±6.6	83.1±3.8	51.4±6.9	0.512±0.022	19.6±2.3
			F=10.9	*F*=24.0	*F*=43.4	*F*=20.5	*F*=49.0	*F*=24.2

Note: All the *F* ratio values are significant $p<0.001$

To assess the length of trunk, sitting height is taken, which is a composite measurement of height of head, neck and trunk. It was found that the *Karen* of mongoloid affinities, an immigrant to Andaman Islands have larger trunk as they have the highest mean of sitting height (87.0±3.38 cm), whereas the *Onges* had the shortest trunk with 77.7±2.2 cm of mean sitting height. For further illustration, an error-bar-diagram is constructed (Fig. 2), which clearly indicates the comparative status on the basis of sitting height or trunk size of the populations, and here too, the indigenous islanders are found to have short trunk as compared to other groups of people. However, it should be noted that the Karen and Nicobarese together had comparatively larger trunk than the remaining group of people (Fig. 3). The *Karen* were also found to be heavier as they had 57.5±7.0 kg of average body weight, whereas the *Oraon* tribe of mainland were found to have lowest average body weight (46.3±4.9 kg).

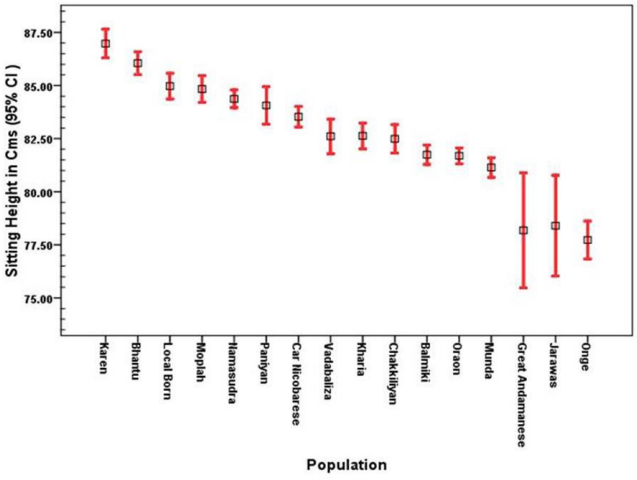

Figure 2. Error bar diagram showing comparative difference of sitting height (at 95% confidence of interval)

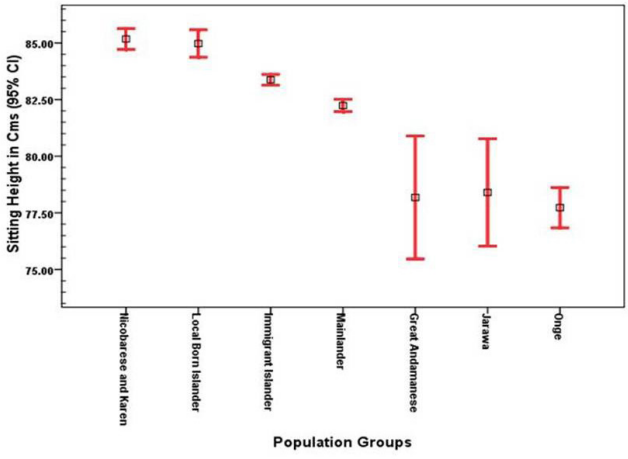

Figure 3. Error bar diagram showing comparative difference of sitting height (at 95% confidence of interval) among groups and individual tribes of Andaman and Nicobar Islands

To find out the inter-population differences with respect to anthropometric measurements and indices one-way analysis of variance (ANOVA) was computed. The *F* ratios was found to be highly significant $p<0.001$ in all the comparisons (Table 1). The analysis also indicates that the immigrant islanders were more homogenous as compared to their counterpart mainlanders especially in respect of their stature, sitting height, weight and cormic index. The *F* ratios were higher for mainlanders as compared to immigrant islanders, whereas indigenous islanders were also heterogeneous; especially in stature, sitting height and weight as compared to immigrant islanders. They also had higher *F* ratios for these anthropometric characteristics. This analysis leads to conclude that the indigenous people had comparatively shorter body dimension. The people who migrated were anthropometrically taller and heavier than their counterpart or it can be concluded that migration is an anthropometric selective phenomenon. The individuals of particular body dimension were fit to migrate. This is also proved, as after being from different ethnic affinities, ecology and cultural background they had homogeneity in their body dimensions.

In the present investigation, it was found that the *Karen* had larger trunk and were heavier, hence they had the highest mean of BMI (21.5 kg/m^2). The lowest mean of BMI was found for *Oraon* (17.9 kg/m^2), although their sitting height was not the lowest. The lowest mean sitting height was found for *Onges*. Sitting height and BMI had significant but weak correlation. In case of average body weight, the Karen were followed by 'Local born' (53.4 kg), but in case of BMI, they were forerunner. Great Andamanese (Indigenous Tribe) were in the second position with 20.7 kg/m^2 of mean BMI. This is because of their short stature and small trunk size.

The percentage distribution of population according to different grades of chronic energy deficiency (CED) is given in Table 2. Considering the cut-off point of BMI 18.5 kg/m^2 for screening the individuals into normal and CED groups (Adak et al. 2006; Gautam et al. 2006; Gautam 2007b; Khongsdier 2001; James et al. 1988; Ferro-Luzzi et al. 1992; Kumar and Gautam 2015) the prevalence of CED was found highest among mainlanders. The Oraon had registered 67% of CED, followed by Bhantu (56%), Valmiki (53%) and Munda (47%). Among immigrant islanders the prevalence of CED varies from 9-49%. Here the Valmiki immigrants were found to have the highest prevalence of CED (49%), followed by 'Local born', Oraon, Bhantu and others. The Karen had registered the lowest (9%) CED among the immigrants.

Among indigenous islanders, the highest prevalence of CED was found among the Jarawas (33%) a most hostile tribe of the island; followed by Onge (7%), the Car Nicobarese had negligible proportion (1%) of CED.

The highest prevalence of overweight was found among Great Andamanese (18.2%), followed by Onge (7.4%). Valimiki, Karen and Onge also had obesity respectively 0.5%, 1% and 3.7%. Further, it should be noted that none of the individuals below 21 years of age were found to be overweight or obese. On the other side, 16.7 % of individual of age 41 and above of local born were found to be overweight (BMI 25.0—29.9 kg/m^2), but none of them were found to be obese (BMI>30 kg/m^2). It is apparent that the indigenous people had better nutritional status as 87.0% of them had BMI between

Table 2. Percent distribution of nutritional status among adult males from 19 ethnic groups of Andaman and Nicobar Islands according to their ethnic affinities and age groups

Population	Nutritional status						
	Chronic deficiency energy (grade)			Normal and Obese			
	III Severe	II Moderate	I Mild	Low weight normal	Normal	Obese I	Obese II
Mainlander							
Bhantu	6.0	16.0	34.0	20.0	20.0	4.0	
Munda	3.1	10.2	33.7	37.8	15.3		
Oranon	7.0	20.6	39.2	24.1	9.0		
Valmiki	3.0	15.0	35.0	22.0	24.0	0.5	0.5
<21 years	1.8	22.8	56.1	12.3	7.0		
21-30 years	5.2	14.9	34.5	28.4	17.0		
31-40 years	5.0	11.5	34.5	32.4	15.1	1.4	
41+ years	5.1	19.7	32.5	20.4	21.0	0.6	0.6
Total	4.8	16.3	36.2	25.4	16.6	0.5	0.2
Immigrant Islanders							
Karen	2.0		9.1	15.2	71.7	3.0	1.0
Moplah	4.2	12.0	15.0	25.0	41.0	5.0	
Bhantu	2.0	6.9	23.6	26.4	38.9		
Chakkiliyan	1.0	7.1	18.2	25.3	43.4	4.0	
Kharia		5.1	23.2	35.4	35.4		
Munda	4.3	3.0	13.1	27.3	56.6		
Namasudra		2.7	24.7	32.9	34.9	0.4	
Oraon	2.0	6.4	28.2	30.0	33.6	1.8	
Paniyan		4.0	22.0	36.0	36.0		
Vadabaliza	2.2	1.0	17.0	33.0	47.0	2.0	
Valmiki	1.9	13.0	33.7	26.1	21.7	3.3	
<21 years	2.6	9.8	31.4	30.1	26.1		
21-30 years	1.5	4.7	19.1	31.8	40.9	2.0	
31-40 years	1.2	2.8	19.8	27.4	46.4	2.4	
41+ years	2.5	5.4	19.9	25.9	44.4	1.6	0.3
Total	1.9	5.2	21.1	28.8	41.3	1.7	0.1
Offspring of immigrants							
Local born	3.0	6.0	31.0	29.0	26.0	5.0	
<21 years	5.9		47.1	29.4	17.6		
21-30 years	1.9	9.3	25.9	37.0	24.1	1.9	
31-40 years	9.1		27.3	27.3	27.3	9.1	
41+ years		5.6	33.3	5.6	38.9	16.7	

Table 2 continued

Indigenous population (Tribes)							
Car Nicobarese			0.9	13.9	83.3	1.9	
Great Andamanese				18.2	63.6	18.2	
Jarawas	4.8	9.5	19.0	23.8	42.9		
Onge		7.4		29.6	51.9	7.4	3.7
Total	1.1	3.2	4.8	18.6	68.6	3.2	0.5
Total population	2.6	8.1	24.2	26.9	36.4	1.7	0.1

Normal and Obese. Classification: 1) Low weight normal (BMI 18.5-19.9 kg/m^2); 2) Normal (BMI 20.0-24.9 kg/m^2); 3) Obese grade I (BMI 25.0-29.9 kg/m^2); 4) Obese grade II (BMI > 30 kg/m^2)
CED – chronic energy deficiency. Classification: 1) grade III severe BMI<16.0; 2) grade II moderate BMI 16.0-16.9; 3) grade I mild BMI 17.0-18.5.

18.5 to 24.9 kg/m^2. Further, it is apparent from Table 1 that there were significant differences between populations with respect to CI, the highest *F* ratio was found among mainlanders (F=121.8), followed by immigrant islanders (F =32.4) and indigenous islanders (F=9.7). The mean value of CI was found highest for *Karen* followed by *Car Nicobarese* (0.526±0.014) both having same affinity. The lowest CI was found for *Great Andamanese* (0.456±0.152), who were indigenous islander. It may be noted that Strickland and Tuffrey (1997) have observed lower values of CI among non-Mongoloid populations.

The results of the linear regression indicate that the BMI is significantly dependent on CI, except among indigenous islanders who belong to different affinities. Furthermore, the CI accounts for not more than 21.0% variability on BMI (Table 3). As, it is apparent from Table 1, the studied population groups differ more in CI (F=49.0) than in BMI (F=24.2). Only indigenous islanders had inverse trend, as they largely differed in BMI (F=12.7) as compared to CI (F=9.7).

Regression analysis of BMI on CI is presented in Table 3. It is apparent that the regression is significant and there is positive correlation between age and BMI. It is also evident that age accounts up to 45.0% variability on BMI for 18-40 years of age. The regression is positive and significant at 1.0% level (p<0.001). For older than 40 years of age the regression coefficient was found insignificant.

To understand the relationship of body mass (weight) and height, logarithmic transformation were executed and scattered plot diagrams were drawn (Fig. 4 and 5). It is evident from Fig. 4 that Indigenous islanders are quite away from regression line. The immigrants' islanders and 'local born' (descendent of immigrants) are closer to the line, similar is for mainlanders; although they are widely scattered. Fig. 5 shows that the Car Nicobarese are taller and heavier than remaining three. Most of them are clustered under circle B. Circle A is dominated by Jarawa and Onge; whereas the Great Andamanese are scattered in and around of both the circles. Although the indigenous population have distinctly low body weight and height; still the scaling exponents was found ~2 for Mainlander (β=2.007±0.111)and Indigenous Islanders (β=1.912±0.224), followed by Immigrant Islanders (β=1.791±0.080) and 'local born'(β=1.608±0.281). There-

Table 3. Linear regression coefficient of BMI on Cormic Index in adult males from Andaman and Nicobar Islands according to their ethnic affinities and age groups

Population group	R^2	β	SE	t	df	F	*p*
Mainlander	0.019	13.4	4.1	3.2	546	10.3	*
Islanders	0.050	23.5	2.7	8.6	1430	75.0	*
Immigrant Islanders	0.071	34.6	3.6	9.4	1174	90.2	*
Local born	0.066	38.3	14.5	2.6	99	6.8	#
Indigenous Islander	0.029	8.4	3.9	2.1	155	4.6	#
Total	0.080	28.9	2.2	13.1	1977	171.3	*
Linear regression coefficient of mean BMI on age							
Age group (years)							
18-40	0.451	0.042	0.01	4.1	22	17.2	*
41+	0.058	0.021	0.01	1.1	23	1.3	NS
18+	0.185	0.019	0.006	3.1	46	10.2	*

*$p<0.001$, #$p<0.05$ and NS= non-significant

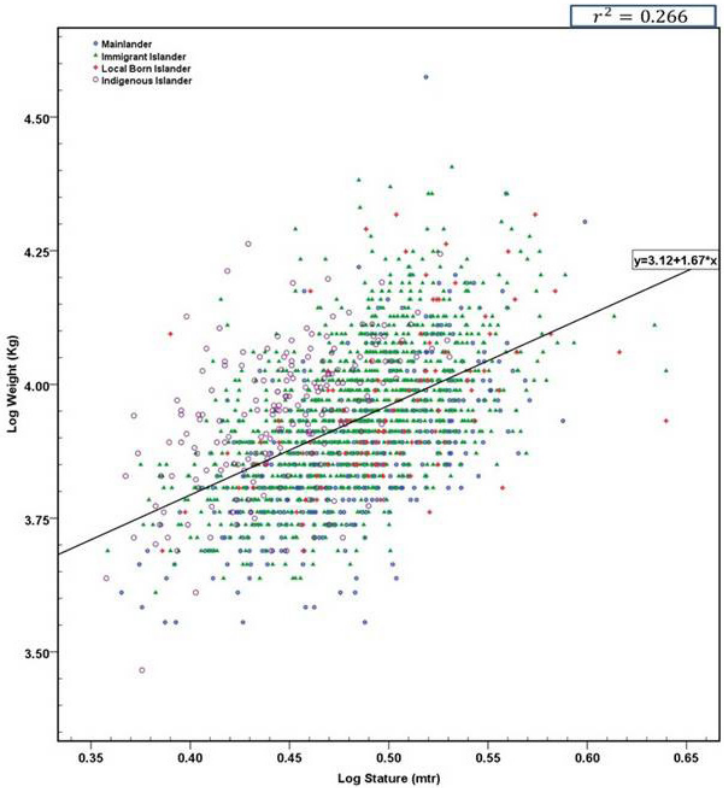

Figure 4. Scattered plot diagram showing indigenous islanders are quite away from regression line. The immigrants' islanders and 'local born' (descendent of immigrants) are closer to the line, similar is for mainlanders; although they are widely scattered.

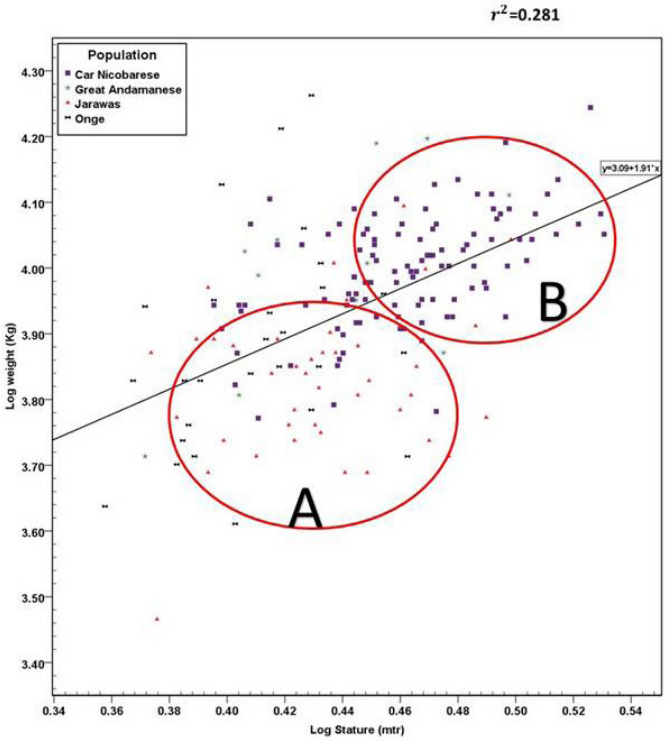

Figure 5. Scattered plot diagram showing distribution of indigenous islanders. Car Nicobarese are taller and heavier than remaining three. Most of them are clustered under circle B. Circle A is dominated by Jarawa and Onge; whereas the Great Andamanese are scattered in and around of both the circles.

fore it can be inferred that model for BMI applies to these population (Heymsfield et al. 2014).

Discussion

It is apparent from the findings that 'local born' were comparatively taller than their progenitor immigrants. There can be three explanations about the comparatively tall stature of the 'local born': First, secular trend around the globe. Younger generations tend to be taller than their parent generations as a result of overall development, increasing medical care, immunization and supplementary diet programmes to overcome the widespread undernutrition. The other two explanations are genetic and environmental. In mainland, the caste groups were endogamous, so the gene flow was restricted within the group (caste). But, in the Islands, they started practicing group (caste) exogamy, providing an opportunity for intermixing of the gene pools, which resulted into an increased stature. Further, in mainland, the caste groups categorised as scheduled castes and backward castes are socially, economically and politically deprived in many ways, which is correlated with stature (Gautam 2007). But in a new place, they got independence, liberal environment and over all better living conditions; hence the

local born were taller than their parental groups. Further, stature is a polygenic and multifactorial feature. In the new environment, all factors were positively influencing the growth of children have resulted into increased stature of the 'local born'.

In case of average body weight, the Karen are followed by 'local born'(53.4 kg), but in case of BMI they are forerunner. Andamanese (Indigenous Tribe) are in the second position with 20.7 kg/m^2 of mean BMI. This is because of their short stature and small trunk size. Here, it should be noted that BMI may be more nutritionally than genetically related (Rolland-Cachera 1993). Therefore, it is widely accepted as one of the best indicators of nutritional status among the adults (James et al. 1988; Ferro-Luzzi et al. 1988; Shetty and James, 1994). Although, Benn (1971) suggested to apply population-specific powers in a weight-height index, Heymsfield et al. (2014) suggested that bodyweight scales to height within and across sex and race/ethnic groups do not vary significantly and powers centered around 2. Their analysis allowed for generalization to non-institutionalized non-Hispanic (NH) whites, NH blacks, Mexican Americans, and Korean Asians. Finally they concluded that BMI, BW/height^2, is a reasonable stature independent metric for across-sex and race/ethnic comparisons of body shape and composition. In the present investigation, we also found that the scaling exponents were approximately 2 (Mainlander $\beta=2.007\pm0.111$; Indigenous Islanders $\beta=1.912\pm0.224$; Immigrant Islanders $\beta=1.791\pm0.080$; and 'Local Born' $\beta=1.608\pm0.281$), which is the first reporting for Indian populations and further proves that BMI is a universal indicator of adiposity.

It is apparent that the indigenous people have better nutritional status as 87.0% of them have BMI between 18.5 to 24.9 kg/m^2. Khongsdier (2001) also reported better nutritional status among the tribes of Northeast, but Adak et al. (2006) have established that nutritional status is associated with socio-economic status and reported that in Central India, the tribes have poor nutritional status with higher proportion of CED, which seems to be contradictory. However, it should be noted that the indigenous population of Andaman and Nicobar Islands are still not in the ambit of social stratification, whereas in some regions like Central India, the tribes are part of the process of social stratification. Therefore, it could be postulated that the indigenous population have better equality in social status, which can explain their better nutritional status.

According to Norgan (1994) BMI is correlated with sitting height, in the present study too, we found that the correlation of BMI and sitting height is positive and significant ($r=0.167$, $p<0.001$).

As evident from present findings, the problem of obesity does not exist among foragers (viz. Jarawa) and its prevalence among agriculturists is less. However, with change of subsistence pattern and the adoption of sedentary life styles, the prevalence of obesity is increasing. Even Great Andamanese and Onge like indigenous islanders are not immune to obesity; as soon as they departed from their foraging way of subsistence they are prone to be obese. It is a matter of great concern that with increasing prevalence of obesity, the problems of life style disorders like diabetes, hypertension, and cardio-vascular disorders as well as multiple chronic conditions (MCC) would be common; and the health care system is

not ready to tackle such problems. Countries like India have dual burden of nutritional problems, at one end there are masses in different grades of CED, and at the other end obesity and related MCC is stepping gradually.

Conclusion

On the basis of the present investigation, it can be concluded that chronic energy deficiency (CED) was common in many parts of India, especially among deprived sections known as scheduled caste/tribes and other backward castes. Better nutritional status of foragers proves that in early phase of development, CED and obesity were not prevalent, but with change of subsistence pattern (agriculture/modern economy) there is a shift in dietary habits, which ultimately resulted into malnutrition in the form of CED and obesity. It is apparent that the indigenous islanders have short body size and dimension as compared to other populations. At the same time, they have better nutritional status as compared to immigrants and mainlanders.

Despite the fact that the immigrants belong to different ethnic groups; variation in physical features and subsistence practice, still they have homogeneity in their body dimension, which leads to conclude that the migration is an anthropometric selective phenomenon. Genetically, hybrid organisms have advantage in adaptation and survival in the changed environment. This hypothesis is corroborated by the findings from local born individuals, who are ethnically admixed and are significantly taller than their counterparts (progenitors). Besides, genetic makeup, the caste structure in mainland hamper the expression of genes and the deprived caste groups remain short in stature. As soon as they migrated to a new place, where there was no caste hierarchy; their next generation got an opportunity of better environment, which resulted into increment in stature. Here, stature and body weight is being found to be associated with the level of subsistence too, as there is a successive increment in mean stature from indigenous tribal groups (or hunter gatherer) to immigrated scheduled tribes (or agriculture) and from immigrated scheduled tribes to others (industrialized/modern economy). The people of different ethnic origin also differ significantly in their body dimensions, as there is significant difference in stature, sitting height and body weight of studied population. Although, the immigrants have better nutritional status than their mainland counterparts, at the same time, they (immigrants) are lagging behind from the point of view of their levels of nutrition, compared to the indigenous islanders. In spite of earliest stage of economic development, the indigenous islanders have better nutritional status, which require further investigation of their dietary habits and food content. As evident from logarithmic transformation of body mass and height, and its linear regression scaling exponent β is $\sim$2. Hence, among present studied populations too, the BMI is a generalizable height-independent measure of nutritional assessment.

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Authors' contributions

RKG and RS planned the study. RS collected data from Indigenous Tribe. The analysis and interpretation were done collectively by RKG, RS, AHG and NV.

Conflict of interest

The authors declare that there is no conflict of interests regarding publication of this paper.

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