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Somatotype and Nutrient Intake of the Sabar Males of Purulia, West Bengal, India

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Abstract

Somatotype expresses the present morphological state of an individual and can be used as an effective measure to assess health status. Studies reveal a significant influence of several factors, including nutrient intake, on somatotype. But there is scarcity of data on the relationship of somatotype with nutrient intake in the Indian context. This study, therefore, has been undertaken in a small scale to investigate the relationship of somatotype with the consumption of selected nutrients among the Sabar males living in the Purulia district of West Bengal, India. For this study a sample of 350 Sabar males (18-60 years) was selected randomly from fifteen villages under five administrative blocks of Purulia district. The anthropometric measurements of height and weight were recorded using standard techniques and somatotype was determined following Rohrer's Index (RI) with Curtis key and categorised into three groups: endomorphy, mesomorphy and ectomorphy. The 24-hour dietary recall method was used to collect information on dietary intake. Results revealed ectomorphy as the dominant somatotype in this population. Significant variation in mean intake of nutrients across three somatotype categories was also noticed. Furthermore, there was a strong correlation between energy consumption and somatotype among the studied population. The result of the present study expressed the relationship between somatotype and nutrient intake as a sustainable strategic tool, which can be useful for future public health care research to address vulnerable ethnic groups and gender-responsive health.

Keywords: The Sabar, Somatotype, Diet, Nutrient Intake, Tribe, Purulia District

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1.0 Introduction

Food is an essential as well as a distinctive component in the cultural contour of humankind. What is edible in one culture may be considered non-edible in another (Reddy & Anitha 2015). Humans can cope with environmental capriciousness (arctic to desert, grassland to forest, marine to tundra) better than any other primate species on the planet. Therefore, humans can subsist on a wide variety of foods that are available in different ecological niches and acquire the ability to deal with environmental challenges through cultural or behavioural responses such as use of tools, fire, clothes, shelter, etc. (Ulijassek et al. 2012). Moreover, diet composition and food choice are inextricably linked to major transitions in human prehistory, which featured a number of significant dietary changes in response to changes of habitat and ecology (Freimer et al. 1983). Decades of anthropological research have been devoted to the historical and present-day importance of food (Wrangham 2003).

The diet of hunter-gatherer ancestors varied vastly with geography, season and opportunity, but is often described as excellent for metabolic and cardiovascular health by many researchers: the kind of diet to which we have been adapted by evolution (Crittenden & Schnorr 2017 and Pontser et al. 2018). Over time, the extraction of energy from the human diet improved when people discovered techniques of cooking and food processing (Ulijassek et al. 2012). Cooking food makes raw vegetables, meat and marine foods more digestible (Milton 2000 and Ulijassek et al. 2012). Changes in the diet have not only affected human biological evolution, but have also given rise to new cultural traditions (Ulijassek et al. 2012; Crittenden & Schnorr 2017). With the advent of agriculture, people started settling down, and their relationship with nature changed permanently. Today, most communities consume primarily farmed foods, and very few foraging communities still depend entirely on wild foods (Headland & Blood 2002 and Crittenden & Schnorr 2017). In our time total dependence on the grain-based industrial food system makes us susceptible to many lifestyle diseases (Andrews & Johnson 2020).

Food habits and dietary practices, both in terms of quality and quantity, have a substantial impact on individuals' health status. Improper nutrition can lead to poor health, by increasing the risk of many non-communicable cardiovascular and metabolic diseases and reducing reproductive capacity (Freimer et al. 1983 and Frank et al. 2019). The exact dietary recommendations for a diversified, balanced and healthy diet depend on individual characteristics such as age, gender, physical activity, cultural context, locally available foods and dietary customs. Apart from dietary nutrient intake, nutrient absorption, energy storage, and control of oxidative metabolism vary from person to person (Frank et al., 2019). The physical and chemical processes in the gastrointestinal tract are associated with body composition and are related to body shape and size (Shridhar et al. 2015). In anthropology and allied disciplines, several anthropometric measures such as height, weight, waist and hip circumferences, mid-upper-arm circumference, skin fold thickness, and body mass index (BMI) are extensively used to assess nutritional status (Drywien et al. 2016).

Apart from BMI and other conventional indices, somatotype is a method to describe the shape, size, and composition of the human body (Sheldon et al., 1940). Researchers distinguish three basic somatotypes: endomorphy (relative fatness), mesomorphy (relative muscularity) and ectomorphy (relative linearity) (Sheldon et al., 1940; Carter & Heath, 1990; Drywein et al. 2017). Body shape and size partly reflect

inherent genetic predisposition but are influenced by several factors such as nutrition, age, gender, and physical activity (Raschka & Graczyk 2013 and Drywien et al. 2016). Somatotypes are distinguished by fat and muscle content of the human body, and these might be influenced by different dietary components to different extents (Drywien et al. 2017). Based on this conjecture, many researchers became interested in finding associations of somatotype with nutrient intake in recent years (Bolonchuk et al. 2000; Koleva et al. 2000; Raschka & Graczyk 2013; Raschka & Aichele 2014; Drywien et al. 2016 2017; Penggalih et al. 2017; Fitrani et al. 2019; Khairil-Shazmin & Wan Abdul Manan 2019; and Khairil-Shazmin et al., 2021).

Numerous studies have also been conducted to find out the relationships of somatotype with risk and incidence of lifestyle diseases such as hypertension (Herrera et al., 2004), digestive system diseases (Koleva et al. 2002), metabolic syndrome (Galić et al. 2016), diabetes mellitus (Yeung et al. 2010), blood pressure (Kalichman et al. 2004), abdominal adiposity (Ramos-Jiménez et al. 2019), and diseases with genetic predisposition such as Alzheimer disease (Buffa et al. 2007) and certain types of cancer (Bertrand 2013). Most of the studies on somatotypes conducted in India have investigated population variation among children, adolescents and women. Very few studies reported data from tribal populations (Gaur & Singh 1997; Bhasin & Jain 2007; Chandel & Malik 2012; Kaur et al. 2018; and Das et al. 2021). As numerous indigenous communities live across different ecological environments in India, it is essential to study their diverse dietary practices in the context of their body type.

1.1 People and Area

West Bengal has a sizable tribal population which constitutes 5.8 per cent of the total population of the state as per the last census (Census of India 2011). To determine the relationship of somatotype with intake of selected nutrients, we chose for our present study the Sabar (also *Savar/Savara/Shabar/Saora*) community, residing mostly in the jungle areas of Purulia, Jhargram, Medinipur, and Bankura districts of West Bengal. They have traditionally been forest dwellers, but with the gradual change in the landscape due to deforestation, environmental degradation and implementation of the Forest Protection Act, they are being displaced and settled in areas close to the jungle (Das et al. 2020a). They prefer to live in small groups of 20-30 houses on the outskirts of the villages and maintain a distance from neighbouring communities. Their low level of formal education and absence of any other earning opportunity force them to work mainly as wage labourers (Gupta 2011 and Das et al. 2019). In a recent study conducted on this community, Das et al. (2020b) reported that 85.1% of the participants were engaged as daily wage labour and per capita income for 72.8% of the participants came below Rs. 675.53. Almost half of them (49.1%) were found non-literate, 29.7% reported not having the electricity connection in their houses and 72.9% of them did not have the facility of sanitary latrine (Das et al. 2020b). They are socio-economically more marginalised than the other tribal groups living in West Bengal (Mukhopadhyay 1998; Gupta, 2011; and Das et al. 2020b). The shift from their traditional livelihood caused dietary changes, forcing them to substantially reduce their intake of various indigenous foods from the forest. Rice is their staple food, which they consumed two times a day with available seasonal vegetables like potato, cabbage, beetroot, cauliflower, eggplants, tomato, pumpkin, radish, raw papaya etc., collected from nearby market or forest produces like *baula* (*Mimusops elengi*), *birkundri* (*Solena hetarophylla*), *Kulamarshal* (*Nyctanthes arbor-tristis*), *khesari*

(*Actinoscirpus grossus*), etc. (Das et al. 2022). They also frequently use flesh items like fish, rats, chicken, snails, snakes etc. collected from nearby water bodies or agricultural field (Das et al. 2022). Sometimes use of wheat also seen among them mostly in winter season as its easy availability through public distribution system at a subsidised rate. Intake of alcoholic beverages (both local and traditional) was also found in common among them on regular basis (Das et al. 2022). In addition, the strenuous physical work as wage labourers also affected their health, resulting in much undernutrition among this group (Dhargupta et al. 2009; Ghosh et al. 2018; and Das et al. 2019, 2020a). Recently, Das et al. (2021) reported that Sabar males exhibited mesomorphic and ectomorphic features, meaning muscular as well as linear body types.

The changes in food habits, poor health conditions, and regular strenuous activities make it imperative to assess the dietary intake of the Sabar males living in the Purulia district and evaluate the relationship between their somatotype and nutrient intake, as a first step to find sustainable strategies to tackle their undernutrition.

2.3 Materials and Methods

In the present cross-sectional study, 350 adult Sabar males (18-60 years) were randomly selected from fifteen villages in five administrative blocks of Purulia district in West Bengal, India (Figure 1). Following the standard formula (see Charan and Biswas 2013), the estimated sample was considered as 350 with 95% level of confidence, 50% response rate and 5% margin of error. The detail distribution of the studied sample across different villages under selected blocks of Purulia district is given in table 1. In Purulia, located in the western part of West Bengal, 39.39 per cent of people were engaged in agricultural activities (Census of India 2011). This district has a sizable tribal population which constitutes 18.45% of the total population (Census of India 2011). The study was conducted in two phases: September-November 2018, and September 2019-January 2020. Persons with any form of disability, history of chronic diseases and following any dietary restriction were excluded from this study. The Research and Ethics Committee of Bangabasi College, University of Calcutta (CU) (No. 002/2017), and Institutional Ethical Committee for Bio Medical and Health Research involving Human Participants, CU (No. CUIEC/01/02/2022-23) granted the ethical approval to this study. Before commencement of the study, the objectives of the study were explained to the participants, and data were collected after taking their consent.

Table 1: Distribution of studied population across different villages, blocks under Purulia district

District	Purulia														Total
Sub-Division	Purulia Sadar					Manbazar									2
Community Development Block	Purulia-I					Manbazar-I		Manbazar-II		Bandwan		Puncha			5
Village	Akarbad	Kuda	Punru	Bamni	Jabla	Tamakhuni	Bisri	Popo	Mirgicharmi	Radhanagar	Burijhor	Damodarpur	Babuijhor	Balakdih	Bengthupi	15
No of participant	31	30	19	22	19	13	16	35	21	34	12	29	28	20	21	350

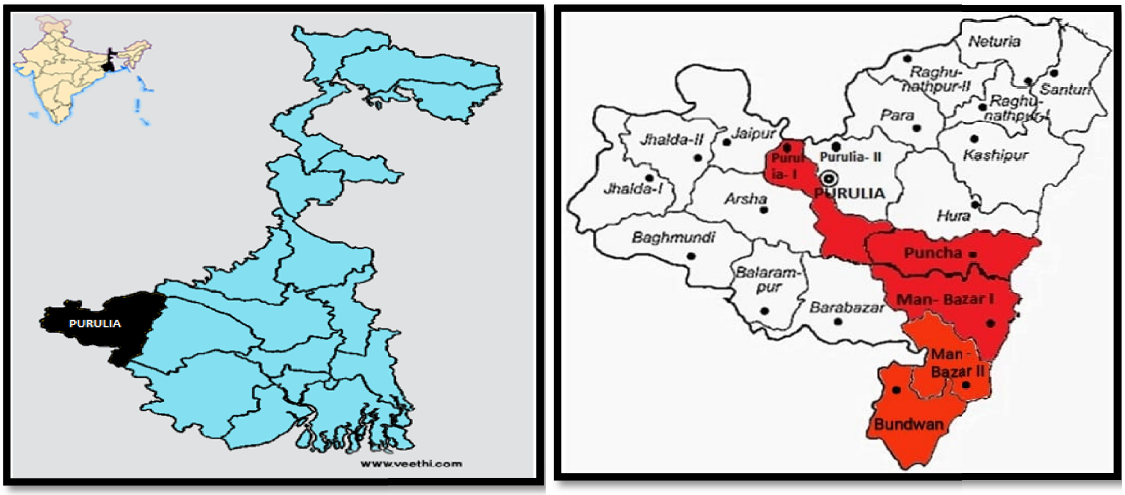

Figure 1: Location of the study area (Source: https://www.puruliaonline.in/city-guide/administration-of-purulia accessed on 10.04.2023 at 6.30 p.m.)

Anthropometric measurements, namely height (cm) and weight (kg), were taken following standard techniques (Lohman et al. 1988). Height was measured by Martin's anthropometric rod to the nearest 0.1 cm, and weight by digital weighing machine (OMRON HN 289) to the nearest 0.1 kg. The somatotype was determined by Rohrer's Index (RI) with Curtis key [weight (g)×100/height $(cm)^3$], and the participants were classified into three groups: ectomorphy (<1.28), mesomorphy (1.29-1.46), and endomorphy (>1.47) (Malinowski & Strzałko 1985).

Dietary information was collected from the participants using the 24-hour dietary recall method, and all food items consumed on the previous day were documented. Following the methodology used in the national-level Diet and Nutrition Survey by the National Nutrition Monitoring Bureau (NNMB) of the National Institute of Nutrition

(NIN), Hyderabad, India, the estimated portion sizes of the food consumed were recorded in as much detail as possible (NNMB 2009). The raw amount of all the ingredients used for any preparation was weighed (g) by an electronic digital kitchen weighing scale (SF-400). Then, the total cooked volume (ml) of each preparation was recorded by filling water in the standardised cups of different sizes (12 cups of 30-1400 ml) and spoons (a tablespoon of 15 ml and a teaspoon of 5 ml) as recommended and used by the NIN in their national-level diet and nutrition surveys (ibid.). After assessing the total cooked quantity of any preparation, the portion consumed by the study participant was assessed in terms of cups, following the cup size and volume accordingly. For calculating the raw food equivalent from individual cooked intake, a conversion factor (CF) for any ingredient is used [CF = weight of the raw food used (g)/total cooked quantity of that preparation (ml)] at first, then at the second stage, the individual intake of that ingredient (g) was recorded following the formula = CF (that ingredient)×volume of individual cooked food consumed (ml) (ibid.).Nutritional values for different food items were calculated from the food composition table of Gopalan et al. (2007). Except for energy, all the nutrients were classified into five groups: macronutrients (protein, carbohydrate, and fat), vitamins (Vit. A, thiamine, riboflavin, niacin, B6, folate, Vit. C, and choline), minerals (calcium, phosphorus, and iron), electrolytes (sodium, potassium, and magnesium), and trace elements (zinc, copper, manganese, chromium, and selenium). Vit. A is represented here as the form of retinol, as Vit. A was present in some animal foods and plant foods as retinol and carotenoids (β-carotene), respectively. A conversion factor of 1:8 was used to calculate Vit. A intake from carotenoids (Indian Council of Medical Research 2010). As most of the participants were found engaged in strenuous daily activities as wage-labourers, they have been categorised as men with moderate physical activity level (NNMB 2009). The Recommended Dietary Allowance (RDA) for Indians, as suggested by the ICMR Expert Committee, was used for nutrients (ICMR 2010, 2020). Their energy requirements were compared with the Estimated Energy Expenditure (EER) recommended by the ICMR Expert Committee for moderately active men (2710 Kcal/day for reference adult Indian man weighted 65kgs) (ICMR 2020).

All the analyses were performed using the statistical software package SPSS version 26.0 for Windows (SPSS Inc., Chicago, IL, USA). Descriptive statistics were performed, including mean, standard deviation (SD), minimum and maximum values, and quartile measures (25^{th}, 50^{th}, and 75^{th} percentile) for all the continuous variables. Each of the nutrients was categorised into four quartiles (Gr): Gr: I (very low intake), Gr: II (low intake), Gr: III (medium intake), and Gr: IV (high intake) for further analysis. Because the distribution of the dietary variables (nutrients) was skewed, the variables were transformed towards normality for further inferential statistical analysis in a two-step approach (Templeton, 2011). Chi square test was applied to examine the association between somatotype categories and different nutrient groups. Multivariate analysis of variance (MANOVA) followed by post hoc analyses (Tukey's HSD) was used to test for differences in mean intake of all the nutrients among the three somatotype categories and to determine between/within-group variation. Multivariate analysis of covariance (MANCOVA) was applied to examine how the mean intake of nutrients differed across different somatotype categories after controlling the effect of age. The level of significance was set at 0.05.

2.4 Results

Table 2: Descriptive statistics of the age, anthropometric profile, energy consumption and intake of selected nutrients among the studied population

Variables	Mean ± SD	RDA	Minimum	Maximum	Percentile		
					25th	50th	75th
N= 350							
Age (years)	38.92±12.89	-	18.00	60.00	27.00	39.00	49.00
Anthropometry							
Height (cm)	162.14±5.41	-	140.50	176.00	159.07	161.95	165.52
Weight (kg)	49.41±6.52	-	35.00	77.10	45.20	48.60	52.92
Rohrer Index	1.16±0.15	-	0.79	1.94	1.06	1.14	1.24
Nutritional information							
Energy (Kcal/d)	1660.97±200.77	2710.0*	1086.28	2261.25	1500.99	1630.93	1815.89
Macronutrients							
Protein (g/d)	57.02±21.21	54.0	5.32	118.65	40.69	54.49	73.29
Carbohydrate (g/d)	288.80±42.39	130.0	122.51	478.30	260.71	285.31	310.99
Fat (g/d)	32.68±11.26	30.0	13.16	174.51	26.39	32.04	37.56
Vitamins							
Vit. A (µg/d)	338.04±792.26	1000.0	22.67	7368.69	198.07	223.01	251.04
Thiamin (mg/d)	1.43±0.77	1.8	0.15	11.65	0.99	1.32	1.73
Riboflavin (mg/d)	1.06±0.85	2.5	0.15	10.99	0.59	0.87	1.27
Niacin (mg/d)	18.47±4.94	18.0	0.9	32.59	15.12	18.41	21.86
B6 (mg/d)	1.31±1.83	2.4	0.14	12.45	0.45	0.77	1.14
Folate (µg/d)	49.74±24.09	300.0	0.98	174.65	33.95	44.07	59.03
Vit. C (mg/d)	149.24±76.33	80.0	5.12	980.72	102.61	149.66	182.83
Choline (mg/d)	513.64±255.70	600.0	44.19	1383.12	270.85	526.32	695.55
Minerals							
Calcium (mg/d)	330.56±131.68	1000.0	90.82	1652.99	269.62	307.09	354.27
Phosphorus (mg/d)	814.01±180.19	1000.0	133.99	1567.10	690.69	776.32	896.09
Iron (mg/d)	17.91±11.58	19.0	1.23	131.16	11.76	15.96	20.17
Electrolytes							
Sodium (mg/d)	1084.38±351.62	2000.0	710.11	2402.38	824.70	955.08	1214.91
Potassium (mg/d)	896.77±183.36	3500.0	84.85	1694.07	802.06	896.77	991.56
Magnesium (mg/d)	470.91±80.99	385.0	38.08	931.46	425.75	467.37	519.32

Trace elements							
Zinc (mg/d)	6.39±1.33	17.0	2.06	11.36	5.48	6.17	7.09
Copper (mg/d)	1.68±0.99	2.0	0.04	16.62	1.25	1.60	1.97
Manganese (mg/d)	4.39±1.13	4.0	0.08	9.11	3.73	4.26	4.81
Chromium (µg/d)	0.26±0.47	50.0	0.02	5.45	0.05	0.08	0.18
Selenium (µg/d)	86.42±57.24	40.0	0.00	735.56	63.68	78.60	97.48

SD- Standard Deviation; RDA- Recommended Dietary Allowance;
*There is no RDA for Energy; energy is represented here as Estimated Energy Requirements (EER)

Table 2 represents the general characteristics of the 350 study participants. Mean energy intake (1660.97±200.77 kcal/d) was found lower than the estimated energy requirement (EER). In the case of macronutrients, low but satisfactory consumption of protein (57.02±21.21 g/d), and fat (32.68±11.26 g/d) were found, with much higher consumption of carbohydrates (288.80±42.39 g/d) according to RDA. Similarly, consumption of vitamin C (149.24±76.33 mg/d) among the vitamins, magnesium (470.91±80.99 mg/d) among the electrolytes, and selenium (86.42±57.24 µg/d) among the trace elements were noticeably higher than RDA. Intake of other nutrients was below the RDA, most notably vitamin A (338.04±792.26 µg/d), riboflavin (1.06±0.85 mg/d), folate (49.74±24.09 µg/d), calcium (330.56±131.68 mg/d), sodium (1084.38±351.62 mg/d), potassium (896.77±183.36 mg/d), zinc (6.39±1.33 mg/d), and chromium (0.26±0.47 µg/d).

Table 3: Association between energy consumption and selected nutrients with somatotype categories

Variables	**Categories**	**Somatotype**			**Chi square**
		Endomorphy (N= 11)	**Mesomorphy (N= 55)**	**Ectomorphy (N= 284)**	
Energy (Kcal/d)	Gr: I	1 (9.1)	1 (1.8)	85 (29.9)	96.814^{***}
	Gr: III	0 (0.0)	7 (12.7)	81 (28.5)	
	Gr: II	2 (18.2)	8 (14.5)	78 (27.5)	
	Gr: IV	8 (72.7)	39 (70.9)	40 (14.1)	
Protein (g/d)	Gr: I	5 (45.5)	11 (20.0)	71 (25.0)	6.533^{NS}
	Gr: II	1 (9.1)	14 (25.5)	73 (25.7)	
	Gr: III	1(9.1)	13 (23.6)	74 (26.1)	
	Gr: IV	4 (36.4)	17 (30.9)	66 (23.2)	
Carbohydrate (g/d)	Gr: I	0 (0.0)	4 (7.3)	83 (29.2)	48.326^{***}
	Gr: II	1 (9.1)	6 (10.9)	81 (28.5)	
	Gr: III	3 (27.3)	16 (29.1)	69 (24.3)	
	Gr: IV	7 (63.1)	29 (52.7)	51 (18.0)	

Fat (g/d)	Gr: I	5 (45.5)	12 (21.8)	70 (24.6)	13.625*
	Gr: II	1 (9.1)	10 (18.2)	78 (27.5)	
	Gr: III	0 (0.0)	13 (23.6)	74 (26.1)	
	Gr: IV	5 (45.5)	20 (36.4)	62 (21.8)	
Vit. A (µg/d)	Gr: I	1 (9.1)	3 (5.5)	83 (29.2)	28.726***
	Gr: II	2 (18.2)	15 (27.3)	71 (25.0)	
	Gr: III	1 (9.1)	14 (25.5)	73 (25.7)	
	Gr: IV	7 (63.6)	23 (41.8)	57 (20.1)	
Thiamin (mg/d)	Gr: I	3 (27.3)	11 (21.2)	73 (26.2)	7.459NS
	Gr: II	3 (27.3)	8 (15.4)	74 (26.5)	
	Gr: III	1 (9.1)	15 (28.8)	70 (25.1)	
	Gr: IV	4 (36.4)	18 (34.6)	62 (22.2)	
Riboflavin (mg/d)	Gr: I	4 (36.4)	15 (27.3)	77 (27.1)	6.796NS
	Gr: II	2 (18.2)	7 (12.7)	71 (25.0)	
	Gr: III	1 (9.1)	16 (29.1)	71 (25.0)	
	Gr: IV	4 (36.4)	17 (30.9)	65 (22.9)	
Niacin (mg/d)	Gr: I	3 (27.3)	5 (9.1)	79 (27.8)	27.683***
	Gr: II	4 (36.4)	11 (20.0)	74 (26.1)	
	Gr: III	1 (9.1)	11 (20.0)	75 (26.4)	
	Gr: IV	3 (27.3)	28 (50.9)	56 (19.7)	
B6 (mg/d)	Gr: I	2 (18.2)	23 (41.8)	64 (22.5)	16.308**
	Gr: II	4 (36.4)	8 (14.5)	77 (27.1)	
	Gr: III	1 (9.1)	8 (14.5)	79 (27.8)	
	Gr: IV	4 (36.4)	16 (29.1)	64 (22.5)	
Folate (µg/d)	Gr: I	2 (18.2)	6 (10.9)	79 (27.8)	14.867**
	Gr: II	2 (18.2)	20 (36.4)	66 (23.2)	
	Gr: III	4 (36.4)	9 (16.9)	75 (26.4)	
	Gr: IV	3 (27.3)	20 (36.4)	64 (22.5)	
Vit. C (mg/d)	Gr: I	4 (36.4)	10 (18.2)	73 (25.7)	7.954NS
	Gr: II	1 (9.1)	14 (25.5)	73 (25.7)	
	Gr: III	1 (9.1)	13 (23.6)	74 (26.1)	
	Gr: IV	5 (45.5)	18 (32.7)	64 (22.5)	
Choline (mg/d)	Gr: I	1 (9.1)	7 (12.7)	79 (27.8)	16.013**
	Gr: II	6 (54.5)	17 (30.9)	65 (22.9)	

	Gr: III	1 (9.1)	11 (20.0)	76 (26.8)	
	Gr: IV	3 (27.3)	20 (36.4)	64 (22.5)	
Calcium (mg/d)	Gr: I	2 (18.2)	9 (16.4)	76 (26.8)	9.530^{NS}
	Gr: II	2 (18.2)	13 (23.6)	73 (25.7)	
	Gr: III	1 (9.1)	16 (29.1)	72 (25.4)	
	Gr: IV	6 (54.5)	17 (30.9)	63 (22.2)	
Phosphorus (mg/d)	Gr: I	0 (0.0)	0 (0.0)	87 (30.6)	47.798^{***}
	Gr: II	0 (0.0)	9 (16.6)	79 (27.8)	
	Gr: III	5 (45.5)	24 (43.6)	59 (20.8)	
	Gr: IV	6 (54.5)	22 (40.0)	59 (20.8)	
Iron (mg/d)	Gr: I	4 (36.4)	9 (16.4)	74 (26.1)	6.612^{NS}
	Gr: II	1 (9.1)	12 (21.8)	75 (26.4)	
	Gr: III	2 (18.2)	17 (30.9)	69 (24.3)	
	Gr: IV	4 (36.4)	17 (30.9)	66 (23.2)	
Sodium (mg/d)	Gr: I	1 (9.1)	3 (5.6)	76 (26.8)	42.126^{***}
	Gr: II	0 (0.0)	5 (9.3)	39 (13.7)	
	Gr: III	3 (27.3)	8 (14.8)	90 (31.7)	
	Gr: IV	7 (63.6)	38 (70.4)	79 (27.8)	
Potassium (mg/d)	Gr: I	1 (9.1)	5 (9.1)	99 (35.0)	55.448^{***}
	Gr: II	0 (0.0)	2 (3.6)	68 (24.0)	
	Gr: III	1 (9.1)	17 (30.9)	51 (18.0)	
	Gr: IV	9 (81.8)	31 (56.4)	65 (23.0)	
Magnesium (mg/d)	Gr: I	1 (9.1)	5 (9.1)	81 (28.5)	36.332^{***}
	Gr: II	0 (0.0)	8 (14.5)	80 (28.2)	
	Gr: III	2 (18.2)	19 (34.5)	67 (23.6)	
	Gr: IV	8 (72.7)	23 (41.8)	56 (19.7)	
Zinc (mg/d)	Gr: I	0	5 (9.1)	83 (29.2)	35.690^{***}
	Gr: II	1 (9.1)	6 (10.9)	82 (28.9)	
	Gr: III	4 (36.4)	23 (41.8)	59 (20.8)	
	Gr: IV	6 (54.5)	21 (38.2)	60 (21.1)	
Copper (mg/d)	Gr: I	1 (9.1)	6 (10.9)	84 (29.6)	27.283^{***}
	Gr: II	1 (9.1)	14 (25.5)	72 (25.4)	
	Gr: III	3 (27.3)	10 (18.2)	74 (26.1)	
	Gr: IV	6 (54.5)	25 (45.5)	54 (19.0)	

Manganese (mg/d)	Gr: I	1 (9.1)	7 (12.7)	80 (28.2)	30.722^{***}
	Gr: II	1 (9.1)	6 (10.9)	83 (29.2)	
	Gr: III	2 (18.2)	21 (38.2)	63 (22.2)	
	Gr: IV	7 (63.6)	21 (38.2)	58 (20.4)	
Chromium (µg/d)	Gr: I	2 (18.2)	15 (27.3)	104 (36.6)	5.291^{NS}
	Gr: II	3 (27.3)	12 (21.8)	73 (25.7)	
	Gr: III	3 (27.3)	11 (20.0)	42 (14.8)	
	Gr: IV	3 (27.3)	17 (30.9)	65 (22.9)	
Selenium (µg/d)	Gr: I	1 (9.1)	9 (16.4)	77 (27.1)	22.482^{**}
	Gr: II	2 (18.2)	7 (12.7)	79 (27.8)	
	Gr: III	1 (9.1)	22 (40.0)	65 (22.9)	
	Gr: IV	7 (63.6)	17 (30.9)	63 (22.2)	

Gr: I (very low intake), Gr: II (low intake), Gr: III (medium intake), and Gr: IV (high intake); Percentages are presented in parentheses; ***p< 0.001, **p< 0.01, *p< 0.05

The association between nutrients and somatotype categories is seen in table 3. Consumption of each nutrient was categorised into quartiles (Gr: I-IV), then the distribution within different somatotype categories was observed. Chi square test revealed that somatotype categories were significantly associated with energy (χ^2= 96.814, p< 0.001), carbohydrate (χ^2= 48.326, p< 0.000), fat (χ^2= 96.814, p< 0.05), vitamin A (χ^2= 28.726, p< 0.001), niacin (χ^2= 27.683, p< 0.001), B6 (χ^2= 16.308, p< 0.01), folate (χ^2= 14.867, p< 0.01), choline (χ^2= 16.013, p< 0.01), phosphorus (χ^2= 47.798, p< 0.001), sodium (χ^2= 42.126, p< 0.001), potassium (χ^2= 55.448, p< 0.001), magnesium (χ^2= 36.332, p< 0.001), Zinc (χ^2= 35.690, p< 0.001), copper (χ^2= 27.283, p< 0.001), manganese (χ^2= 30.722, p< 0.001), and selenium (χ^2= 22.482, p< 0.01). Other nutrients were found not significantly associated with somatotype. It has also been noticed that the number of individuals gradually decreases in the ectomorphy category and increases in mesomorphy and endomorphy from Group: I to IV for energy, carbohydrate, vitamin A, niacin, phosphorus,potassium, magnesium, zinc, copper, manganese, and selenium. No such trends were observed for fat, B6, folate and choline though they expressed statistically significant (p<0.05) association with somatotype.

Table 4: Results of MANOVA and MANCOVA (after controlling age) showing the effect of somatotype on energy consumption and intake of selected nutrients

Dependent Variables	**Somatotype (Rohrer Index)**	
	MANOVA	**MANCOVA**

	F	**Sig**	**Partial Eta Squared**	**Post hoc test**	***F***	**Sig**	**Partial Eta Squared**
Energy (Kcal/d)	45.683	0.000	0.219	Ec vs Me (-220.844*) Ec vs En (-307.023*) Me vs En (-86.179)	43.403	0.000	0.211
Protein (g/d)	3.054	0.049	0.018	Ec vs Me (-6.819) Ec vs En (7.019) Me vs En (13.839)	2.909	0.056	0.018
Carbohydrate (g/d)	24.778	0.000	0.132	Ec vs Me (-38.480*) Ec vs En (-36.673*) Me vs En (1.807)	22.914	0.000	0.124
Fat (g/d)	2.126	0.121	0.013	Ec vs Me (-2.883) Ec vs En (3.853) Me vs En (6.736)	1.489	0.229	0.009
Vit. A (µg/d)	12.711	0.000	0.073	Ec vs Me (-502.697*) Ec vs En (-637.946*) Me vs En (-135.249)	11.713	0.000	0.067
Thiamin (mg/d)	0.903	0.406	0.006	Ec vs Me (-0.139) Ec vs En (0.133) Me vs En (0.272)	0.580	0.560	0.004
Riboflavin (mg/d)	2.292	0.103	0.014	Ec vs Me (-0.186) Ec vs En (0.421) Me vs En (0.607)	2.112	0.123	0.013
Niacin (mg/d)	12.619	0.000	0.072	Ec vs Me (-3.479*) Ec vs En (0.118) Me vs En (3.598)	11.217	0.000	0.065
B6 (mg/d)	0.217	0.805	0.001	Ec vs Me (0.173) Ec vs En (0.151) Me vs En (-0.021)	0.220	0.803	0.001
Folate (µg/d)	4.799	0.009	0.029	Ec vs Me (-10.639*) Ec vs En (-3.961) Me vs En (6.677)	4.522	0.012	0.027
Vit. C (mg/d)	2.372	0.095	0.014	Ec vs Me (-23.337) Ec vs En (6.240) Me vs En (29.577)	2.008	0.126	0.013
Choline (mg/d)	5.460	0.005	0.033	Ec vs Me (-116.834*) Ec vs En (66.492) Me vs En (183.326)	5.167	0.006	0.031
Calcium (mg/d)	2.577	0.078	0.016	Ec vs Me (-40.208) Ec vs En (-43.459) Me vs En (-3.251)	1.978	0.140	0.012
Phosphorus (mg/d)	20.110	0.000	0.110	Ec vs Me (-145.417*) Ec vs En (-166.646*) Me vs En (-21.229)	18.574	0.000	0.103
Iron (mg/d)	3.175	0.043	0.019	Ec vs Me (-4.132*) Ec vs En (1.708) Me vs En (5.840)	2.585	0.077	0.016

Sodium (g/d)	10.687	0.000	0.062	Ec vs Me (-219.994*) Ec vs En (-187.512) Me vs En (32.481)	7.109	0.000	0.062
Potassium (mg/d)	18.922	0.000	0.104	Ec vs Me (-140.347*) Ec vs En (-176.921*) Me vs En (-36.574)	13.248	0.000	0.109
Magnesium (mg/d)	19.818	0.000	0.109	Ec vs Me (-57.292*) Ec vs En (-99.943*) Me vs En (-42.650)	18.230	0.000	0.101
Zinc (mg/d)	14.545	0.000	0.082	Ec vs Me (-0.947*) Ec vs En (-1.042) Me vs En (-0.096)	13.164	0.000	0.075
Copper (mg/d)	8.034	0.000	0.047	Ec vs Me (-0.499*) Ec vs En (-0.718) Me vs En (-0.219)	6.944	0.001	0.041
Manganese (mg/d)	9.515	0.000	0.055	Ec vs Me (-0.629*) Ec vs En (-0.842) Me vs En (-0.213)	8.239	0.000	0.048
Chromium (µg/d)	2.030	0.133	0.012	Ec vs Me (-0.141) Ec vs En (-0.002) Me vs En (0.139)	1.826	0.163	0.011
Selenium (µg/d)	7.103	0.001	0.042	Ec vs Me (-25.628*) Ec vs En (-43.364) Me vs En (-17.736)	6.743	0.001	0.040
Wilks' Λ= 0.674; *F* (48, 604) = 2.884; p= 0.000; partial η^2= 0.179					Wilks' Λ= 0.680; *F* (48, 602) = 2.807; p= 0.000; partial η^2= 0.176		

Ec= Ectomorphy, Me= Mesomorphy, En= Endomorphy; *p< 0.05

In table 4, MANOVA and MANCOVA (after controlling the effect of age) revealed how the mean intake of nutrients differed across the three somatotype categories. Wilks' lambda test for both MANOVA (Wilks' Λ= 0.674; *F* (48, 604) = 2.884; p= 0.000; partial η^2= 0.179) and MANCOVA (Wilks' Λ= 0.680; *F* (48, 602) = 2.807; p= 0.000; partial η^2= 0.176) demonstrated statistically significant differences in mean intake of most nutrients between somatotype categories. In the MANOVA test, only fat, thiamine, riboflavin, vitamins B6 and calcium, and chromium do not differ significantly between somatotypes. In the next step, a series of post hoc analyses (Tukey's HSD) were performed to examine mean differences between somatotype categories. Among the nutrients, mean values of energy, carbohydrate, vitamin A, potassium and magnesium were found different between the ectomorphy and mesomorphy groups and between the ectomorphy and endomorphy groups. Niacin, folate, chlorine, iron, sodium, zinc, copper, manganese and selenium showed significant (p< 0.05) mean differences between the ectomorphy and mesomorphy group only, possibly because the small size of the endomorphy group was insufficient for statistically significant results. Similarly, MANCOVA did not reveal age effect on the intakes of fat, thiamine, riboflavin, vitamins B6 and C, calcium, iron, and chromium across somatotype categories.

Table 5: Pearson correlation between Somatotype (Rohrer Index, RI) with energy consumption and selected nutrients

Nutritional Variables	Pearson correlation coefficient (r)	Sig
Energy (Kcal/d)	0.711	0.000
Protein (g/d)	0.115	0.032
Carbohydrate (g/d)	0.518	0.000
Fat (g/d)	0.229	0.000
Vit. A (µg/d)	0.400	0.000
Thiamin (mg/d)	0.208	0.000
Riboflavin (mg/d)	0.159	0.003
Niacin (mg/d)	0.286	0.000
B6 (mg/d)	0.019	0.717
Folate (µg/d)	0.201	0.000
Vit. C (mg/d)	0.213	0.000
Choline (mg/d)	0.179	0.001
Calcium (mg/d)	0.231	0.000
Phosphorus (mg/d)	0.455	0.000
Iron (mg/d)	0.122	0.022
Sodium (mg/d)	0.389	0.000
Potassium (mg/d)	0.473	0.000
Magnesium (mg/d)	0.530	0.000
Zinc (mg/d)	0.448	0.000
Copper (mg/d)	0.376	0.000
Manganese (mg/d)	0.369	0.000
Chromium (µg/d)	0.169	0.002
Selenium (µg/d)	0.274	0.000

The Pearson's correlations between somatotype and nutrients are presented in table 5. There were statistically significant positive relationships of somatotype with all nutrients except B6 (r= 0.019, p= 0.717) among the studied population. Most nutrients showed a weak positive relationship with somatotype, whereas, carbohydrate (r= 0.518), Vit. A (r= 0.400), phosphorus (r= 0.455), sodium (r= 0.389), potassium (r= 0.473), magnesium (r= 0.530), zinc (r= 0.448), copper (r= 0.376), and manganese (r= 0.369) presented moderate positive relations. Only energy (r= 0.711) showed a strong relationship with somatotype through a firm linear rule.

2.5 Discussion

The present work studied the relationship between nutrient consumption and somatotypic characters of 350 randomly selected Sabar males of West Bengal. Their mean body weight of 49.41±6.52 kg was low. This was matched by a low mean energy intake of 1660.97±200.77 kcal/day, well below the EER (ICMR, 2020). Interestingly, the low energy consumption contradicted the satisfactory consumption of carbohydrates (288.80±42.39 g/d), protein (57.02±21.21 g/d) and fat (32.68±11.26 g/d) (table 2).

Protein consumption could play a key role in inducing satiety and a negative energy balance in the studied population. The idea of satiety, precisely the inhibitory effect of dietary consumption on appetite, was conceptualised and proposed by Blundell et al.

(1987). This conceptual framework is dependent on the metabolic effects of nutrients in the gut and intestine, which combines the physiological events controlling appetite with the simultaneous behaviours and physiological experiences that are integral to the eating process as well as lower calorie intake as a key outcome (Chambers et al., 2015; Amin & Mercer, 2016; Carreiro et al., 2016; Forde, 2018). Previous studies have shown a close association between the higher consumption of macronutrients and satiety, where specific high protein and carbohydrate meals induce satiety, and therefore, reduced body weight, resulting in negative energy balance (Soenen & Westerterp-Plantenga 2008 and Pesta & Samuel 2014). Thus, the low energy consumption among the studied population raised the possibility that unintentional negative energy balance may be induced by increased energy expenditure and decreased energy intake (hypocaloric diet) and weight loss.

The Sabar of West Bengal is not the only tribal community with low energy consumption. In a recent study on tribal communities living in south Rajasthan, India, Saxena et al. (2020) revealed the presence of satiety and negative energy flow as an outcome measure to combat the household food insecurity. Other studies speculated that indigenous people's diet comprises primarily local plant and animal foods with possibly satiety-promoting properties (Azam et al. 2014; Heim & Pyhala, 2020; and Ghosh-Jerath et al. 2021). Another striking point noted in the present study is the minimal use of sugar among the studied community. In fact, refined carbohydrates rich in sugar promote resistance to satiation. The foods with high glycemic index having an immediate satiating effect that however doesn't last long, because of the rapid but transient flush of sugar and incretins (Harvard T.H. Chan School of Public Health 2022). In contrast, foods with low glycemic index contains fibre and sometimes fat and protein, therefore, keeps them in the stomach longer and retards nutrient absorption (Roberts, 2003). Actually, the food satiation signal to the brain is logically related to ingestion of whole food with little sugar (Zucoloto 2011).

In the present study, 15 nutrients out of 22 have shown significant association with somatotype categories which were consistent with previous studies (Bolonchuk et al. 2000; Koleva et al. 2000; Raschka & Graczyk 2013; Raschka & Aichele 2014; Drywien et al. 2016 2017; Penggalih et al. 2017; Fitrani et al. 2019; Khairil-Shazmin & Wan Abdul Manan 2019; and Khairil-Shazmin et al. 2021).

The present study confirmed relationships between somatotype and mean nutrient intake using MANOVA and MANCOVA. The mean energy consumption significantly varied among somatotype categories and revealed the age effect, which is in agreement with previous studies (Koleva et al. 2000; Raschka & Graczyk 2013; and Drywien et al. 2017). In this context, it is to be mentioned that Das et al. (2021) had already demonstrated changes in body composition with ageing among the Sabar adult males of West Bengal, where the number of ectomorphy changed significantly across different age groups. Like energy, mean carbohydrate intake also showed significant variation, which was consistent with other studies (Fefelova et al. 2016 and Drywein et al. 2017). There were no significant differences in the mean intake of protein and fat between different somatotype categories. This is similar to Drywein et al.'s (2017) results with females from Poland. On the other hand, differences in mean intake of energy and carbohydrate were observed between the somatotypes. With higher intake of energy and carbohydrate, the frequency of ectomorphy decreased, and the frequency of endomorphy and mesomorphy increased. This is in good agreement with the work of Fitranti et al. (2019), where positive correlation between energy intake and endomorph and mesomorph was found among adult women of

Indonesia; but there are some disagreements in this field, with some stating that carbohydrate intake is inversely associated with lower weight gain (Merchant et al. 2009 and Sartorius et al. 2018).

In case of vitamins, significant associations with somatotype categories have been seen for vitamin A, niacin, B6, folate and choline; where 63.6% endomorphic and 41.8% mesomorphic subjects consumed a higher amount of Vit. A (Gr IV) (table 3). On the other hand, 50.9% of mesomorphic subjects consumed a higher amount of niacin than other body physique types. A recent study on a sample of 154 female students from a university in Warsaw, Poland, revealed that endomorphic women had comparatively low consumption of vitamin A, thiamine, and B6 (Drywien et al., 2016). Khairil-Shazmin and Wan Abdul Manan (2019), in their study on government employees from Malaysia, reported that endomorphy components show an inverse relationship with vitamins C, B6 and cobalamin, whereas mesomorphy showed an inverse relationship with vitamin E, and ectomorphy components had a positive correlation with cobalamin. The concentration of vitamins has been found to be correlated with the level of serum leptin which maintains the constancy of adipose tissue mass through the regulation of food intake and energy expenditure; therefore, it is clear that deregulation of vitamin metabolism, mainly, folate and vitamin B12 are associated with diverse metabolic alterations (García et al., 2009; Semmler et al., 2010; Araghi et al., 2021). Leptin most likely is a proxy measure for adiposity. Fat people have higher leptin level than thin people, which compensates for leptin resistance of the target tissues. This is similar to insulin, which is higher in fat people and which compensates for fat people's insulin resistance (García et al. 2009 and Araghi et al. 2021).

Among the minerals, calcium and iron were very weakly correlated with RI, but no significant differences in mean intake were observed among the somatotype categories. An earlier study, on students at the University of Valencia, Spain had shown a deficit of calcium intake across all somatotype categories (Leonardo Mendonca et al., 2012). On the other hand, Khairil-Shazmin & Wan Abdul Manan (2019) demonstrated that calcium and iron intake of government employees in Malaysia, are inversely related with mesomorphy and positively with ectomorphy. Bolonchuk et al. (2000) reported that endomorphy was inversely correlated with iron intake among adult men lived at United States. It is relevant in this context to mention that many cross-sectional and longitudinal studies revealed associations of dietary minerals, especially calcium and iron, with metabolic syndrome, obesity regulation, and variation in body composition though the actual causal explanation was not established (Jacqmain et al. 2003; Ausk & Ioannou 2008; and Aeberli et al. 2009). Only phosphorus was significantly different between the somatotype categories and showed a significant age effect in the present study. Endomorphic subjects had higher phosphorus consumption than other body physique types, similar to Drywien et al. (2017). Though phosphorus intake in the present study shows a moderate relationship with somatotype, other studies, particularly conducted among adults from US and Brazil produced no consensus regarding the relationship of phosphorus with metabolic activities (Beydoun et al. 2008 and Pereira et al. 2013). However, the calcium-phosphorus relationship ratio might influence an individual's metabolic activities and obesity (Pereira et al. 2013).

All electrolytes and trace elements except chromium varied with the somatotype categories, with a significant age effect (table 4). Again, the highest potassium, and magnesium consumption was found significantly among the most endomorphic Sabar

males who were 81.8 %, and 72.7 %, respectively (table 3). In their study, Leonardo Mendonca et al. (2012) revealed a high sodium intake and a deficit of potassium and magnesium intake across all the somatotype categories among the students at the University of Valencia, Spain. Higher sodium consumption among mesomorphic and endomorphic Sabar males in the present study indicated a worrisome finding as endomorphy is generally associated with a slow metabolism, therefore easier to gain weight and other metabolic disorders (Navia et al. 2014). Plenty of studies have worked on the association of sodium intake with body composition, weight gain and morbid obesity and demonstrated that the higher intake of sodium could contribute to ingestive behaviour and obesity (Navia et al. 2014 and Oh et al., 2015). At the same time, Bonfils et al. (2013) did not observe any significant change in lean or morbidly obese individuals during higher intake of sodium. But the higher potassium intake among endomorphs in the present study revealed an intriguing result as it is well established that sodium and potassium are interconnected but have opposite effects on the body for maintaining physiological balance, where high sodium intake increases blood pressure along with slowing down the metabolic rate, while higher intake of potassium can help relax blood vessels and excrete extra sodium (Harvard T.H. Chan School of Public Health 2021). On the other hand, the highest consumption of all trace elements except chromium was found among endomorphs and lowest among ectomorphs. Like other micronutrients, trace elements can lead to nutritional disorders, and their presence in excess can cause obesity, though, were not associated directly with lifestyle disorders until associated with other factors (National Research Council 1989 and Wada 2004).

Pearson's correlation test between RI and nutrients in the present study showed weak correlation except for energy ($r=0.711$, $p=0.001$) (table 5), similar to the findings of Khairil-Shazmin and Wan Abdul Manan (2019), where the strength of the correlation ranged between -0.1 to +0.2 indicating week relationships between dietary intake and somatotype categories among a cohort of 308 males and females from Malaysia.

2.6 Conclusion

The present study is probably the first attempt to explore the relationships between somatotype components and intake of energy, macronutrients, vitamins, minerals, electrolytes and trace elements among any indigenous community living in West Bengal, India. This study also identified that ectomorphy is the dominant somatotype followed by mesomorphy component and the nominal presence of endomorphy possibly due to the changes in their dietary practice, lifestyle, etc., which may indicate a future trend of obesity among the Sabar males. At the same time, significant associations of several nutrients with somatotype components were found. Further, there is a near-perfect relationship between somatotype and energy intake. So, it may be proposed that the Rohrer index may be considered as a potential indicator of body composition, offering an alternative method for assessing nutritional status. But it should be used in combination with other variables like specific nutrients intake and total energy intake to get a more comprehensive picture of an individual's nutritional status.Most of the earlier studies of indigenous communities of India determined either somatotype components or dietary intake but not both. The present study addresses a potential requirement for personalized assessments of nutritional status, taking into account ethnic variations. The findings of this study can play a pivotal role in shaping a more tailored and effective dietary policy for the formulation of a sustainable health strategy. Recognizing the diverse nutritional needs within different ethnic groups can enhance the precision and inclusivity of health

initiatives, contributing to the development of comprehensive and culturally sensitive approaches that promote sustainable well-being.

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Conflict of interest

The authors declare no conflict of interest.

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