DOI: https://doi.org/10.36094/sc.v91.2025.Pattern_of_Protein_Consumption_of_Animal.Mukhopadhyay.318

Research Communication

Sci. and Cult. 91 (5–6) : 318-325 (2025)

Pattern of Protein Consumption of Animal and Plant Origins - Possible Implications: A Study in Bengali Young Adult Educated Urban Females

***Abstract*: A balanced diet containing all the macro and micro nutrients in correct proportion is fundamental for achieving a good health. Protein is one of the macro nutrients which is linked with diverse anabolic functions of body and is particularly important for cell growth and defensive action. Report of recent study is indicating that the young adult females are at risk of dual burden of malnutrition, in which protein has a specific role to play. In this context, the present study highlights the protein choices and its consumption pattern among the Bengalee young adult females residing in greater Kolkata, West Bengal. The present study was carried out among 102 Bengalee young adult females in the age group of 18-24 years. Background information, anthropometric data and dietary intake values were obtained. Comparison has been made between recommended and average intake of protein, on a daily basis. Daily average intake of protein of the participants was 46.8g which was marginally higher than recommendation. Around 60% of consumed protein was coming from plant origin.**

Keywords: Tri

Good health is determined by intake of a balanced diet which contains all essential nutrients like proteins, carbohydrates, fats, minerals and vitamins in such proportions so as to meet the daily requirements of the body[1]. Carbohydrates, proteins and fats are the macronutrients providing energy and required in larger amounts whereas vitamins and minerals are the micronutrients which are equally important but required in smaller amounts. Among all the nutrients proteins hold a special significance for its diverse anabolic functions like growth of tissues, synthesis of essential body components like hormones and enzymes, fluid and electrolyte balance, defensive action and also act as a source of energy for the body. Almost all the activities taking place in a cell are intervened by proteins which are biomolecules and polymers made up of diverse sequence of a universal set of 20 different amino acids (Glycine, Alanine, Proline, Valine, Leucine, Isoleucine, Methionine, Phenylalanine, Tyrosine, Tryptophan, Serine, Threonine, Cysteine, Asparagine, Glutamine, Lysine, Histidine, Arginine, Aspartate and Glutamate). From these combinations different structural and functional properties of proteins are determined. Amino acids join covalently as peptide bonds to form proteins and peptides. Amino acid sequences decide the 3 – dimensional structure and functional properties of proteins. From nutritional point of view the amino acids are classified as essential, non-essential and conditionally essential amino acids. 9 out of 20 amino acids are essential which are not synthesized within the body and are required to be obtained from diet (tryptophan, threonine, histidine, valine, isoleucine, phenylalanine, methionine, leucine, and lysine). 6 of the amino acids are non-essential which are synthesized within the body in sufficient amounts (alanine, asparagine, aspartate, glutamate, glutamine, and serine). Rest 5 amino acids are conditionally essential which are required from diet when the precursors are not sufficiently accessible in the body (cysteine, tyrosine, arginine, proline and glycine). With regard to its immense significance, extensive validation is important to be achieved regarding proper and adequate consumption, especially in developing countries like India where the proportion of issues like stunting and wasting among children, maternal and child health related problems, prevalence of anemia and hunger are still significantly high[2]. Recommendations for adequate protein intake in India is based on the general requirements of the body which is specific for age, life stages, sex and like. The protein requirement is defined as the minimum intake of nitrogen that enables nitrogen equilibrium (zero nitrogen balance). Present scenario of various key indicators of health and nutrition reported that 35.5% and 19.3% of children under 5 years of age are stunted and wasted respectively. 18.7% of women have BMI below normal value (<18.5 kgm^{-2}) and 24% of women are overweight (BMI e" 25 kg. m^{-2}). Around 57% of non-pregnant-non-lactating women in the age group of 15-49 years are reported to suffer from anemia[2] indicating double burden of malnutrition. There is variation in so far protein consumption choices are concerned also: Vegetarianism

refers to a whole range of variety in choices besides predominating plant-based diets which includ eabstaining from all meats and animal products (vegan), allowance to only milk and milk products (lactovegetarian), allowance to both eggs and milk (ovolactovegetarian), including only fish (pescetarian) and allowance to animal products only for some days in a week (semi vegetarian). Moreover, choice of protein sources at individual level is influenced by a numerous factors including food related factors (food quality, availability, physical and chemical properties, taste, appearance and nutritional significance); consumer related factors (hunger, thirst intention, emotions and attitudes) and environmental factors (family patterns, habits, lifestyle, household income, food production, distribution, religious belief, societal structure and traditions)[3]. Income is one of the drivers of protein choices. People with less income largely rely on staple sources like cereals and pulses. As the purchasing power improves, people tend to have proteins from more diverse sources like milk and meat[4]. Animal protein choices also depend on the ethnicity, religion and socio-cultural factors. Although a number of studies have been conducted on protein consumption in India even, there is lack of age, sex, ethnicity specific data on protein consumption especially that focus on the aspects related to protein quality. There is growth in number of people suffering from chronic kidney diseases in India, and a common strategy in its management inter alia include restricting consumption of protein of different sources. The present study, in this context, seeks to find out not only the quantum of daily consumption of proteins, but also the origin of the protein consumed in order to have an idea regarding the quality issues of protein consumption among young adult Bengalee educated urban females of Kolkata metropolitan area.

Methodology

Area and Population: The study was carried out on Bengalee (residing permanently in the state of West Bengal continuously for a period exceeding 10 years and Bengali being the mother tongue) [5-6]young adult females attending higher educational institutions (HEIs) located in urban areas of greater Kolkata. Initially the study requirements were explained and candidates showing interest on their own could enlist their names for participation. 102 females in the age range of 18-24 years residing in and around Kolkata constituted the study participants' set. Individuals either residing in or attending higher educational institutions in rural areas i.e. panchayat areas were excluded from the study purview. And those were having self - reported health issues for which were on continual medication or using oral contraceptives were also excluded from this particular study purview.

Collection of Background Information: On scheduled date and time, a face-to-face interview session was arranged for collecting information regarding socio-demographic profile of the study participants. Information about age (y), ethnicity, educational attainment, hours spent in educational institution, about general health, level of physical activity[7], and socio-economic status[8-9], was collected in a predesigned schedule. Systolic blood pressure (SBP) diastolic blood pressure (DBP) in mm Hg and pre-work heart rate (beats. minute^{-1}), were recorded by using and automated blood pressure monitor and/or sphygmomanometer.

Measurement of Anthropometric Parameters: Body height (cm) of the participants was measured by using an anthropometric measurement set (resolution: 0.1 cm) and body weight (kg) was recorded by using a pre-calibrated weighing scale (resolution: 0.1 kg) with subjects in socially acceptable minimal clothing. Mid-upper-arm circumference (cm) was measured midway between the olecranon and acromion process. Waist circumference (cm) was measured midway between the lowest ribs and iliac-crest and hip circumference was measured at the largest circumference around the buttocks. The circumferences were measured using non-elastic measuring tape (resolution: 0.1 cm)[10-11]. Body Mass Index (kg.m^{-2}) and Waist Hip Ratio were computed.

Assessment of Protein Intake: Data regarding dietary intake of the study participants were collected by using a validated food frequency questionnaire (FFQ)[12] containing questions on the usual frequency of food intake during the last one year. The subjects were asked about the portion and frequency of intakes of individual foodstuffs on daily, weekly, monthly, yearly or never basis and the accuracy of portion sizes were ensured by showing them the pictures of food portions of different foodstuffs and household cups, bowls, glasses, ladles and spoons. The portions were converted to daily equivalent (g and ml) and nutritional value of each food item was computed[13]. The average daily protein intake (g. d^{-1}) of the participants was separated and compared with the recommendation[14]. The average daily protein (g) availability for every kilogram of body weight was computed by dividing the total protein consumption by body weight of the participants and was compared with recommended safe intake values[14]. Percentage contribution of protein from animal and plant sources to total protein consumption across different ages was calculated.

Results

All the study participants were adults i.e. more than eighteen years of age, college goers i.e., had successfully completed their plus two-level education and were permanently residing and attending higher educational institutions in municipality or municipal corporation areas.

Table 1: Background Information of the Study Participants

Variables	Values
Number of study participants	102
Age (y)#	19.7 ± 1.05
Residential area	Urban
Level of physical activity (%)	
Low	21 (20)
Medium	61 (60)
High	20 (20)
SES	Upper middle
SBP (mm Hg)#	102.8 ± 11.67
DBP (mm Hg)#	69.2 ± 8.56
Pre work Heart Rate (beats.min^{-1})#	85 ± 12.2

AM ± SD

A total number of 102 females with mean age of 19.7 years participated in the study. 60% of the total participating individuals were having moderate physical activity. The participants were from urban areas of greater Kolkata and belonged to upper-middle socio-economic stratum.

The anthropometric profile of the study participants has been presented in table 2.

Table 2: Anthropometric Profile of the Study Participants

Variables	Values
Body height (cm)	158.1 ± 6.80
Body weight (kg)	58.4 ± 13.59
Mid-upper-arm circumference (cm)	26.8 ± 3.96
Waist circumference (cm)	83.6 ± 12.88
Hip circumference (cm)	96.6 ± 11.36

AM ± SD

In table 3, the distribution of body weight of the study participants across the sub groups in terms of age along with total number of participants belonging to the sub groups has been presented.

Table 3: Body Weight Along with the Number of Participants from Each of the sub Groups

Age in completed years (y)	Number of participants (%)	Body weight (kg)
18	10(9.8)	57.1 ± 13.48 (41.4 - 75.9)
19	37(36.4)	58.7 ± 14.81 (34.9 - 92.7)
20	34(33.3)	60.6 ± 12.68 (35.1 - 86.3)
21	15(14.7)	51.4 ± 9.76 (30.4 - 70.3)
22 and above	06(5.8)	66.1 ± 20.65 (40.0 - 85.4)
Total	**102(100)**	**58.4 ± 13.59 (30.4 - 92.7)**

AM ± SD (Range)

Table 4: Obesity Profile of the Study Participants

Variables#	Values
Body Mass Index	23.27 ± 5.02
Waist Hip Ratio	0.86 ± 0.08

AM ± SD

As the average value of the BMI computed was found to be more than 23, that is above the upper limit for being considered normal for the specific ethnic group, the status was further reviewed and findings presented in figure 1.

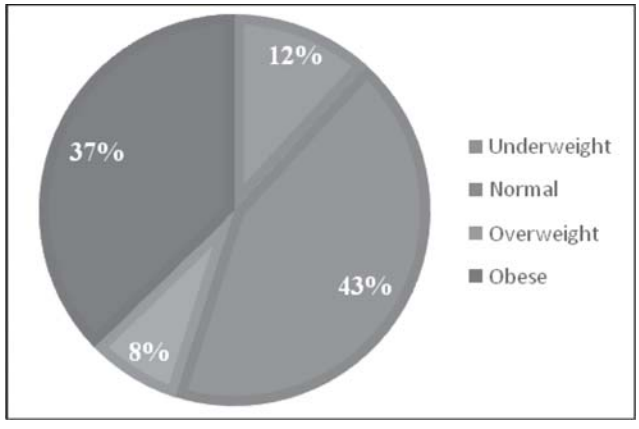

Fig. 1: Distribution of Study Participants in Different Levels of Adiposity in Terms of BMI

It may be observed that 12%, 43%, 8% and 37% of the individuals belonged to under-weight, normal, overweight and obese category respectively.

In table 5, the data on average protein consumption, along with average energy intake, in different categories of adiposity as categorized in terms of BMI has been presented. Protein Energy Ratio (PER) has been calculated.

In fig. 2, the comparison between daily estimated average protein intake of the participants and the recommended protein value for that age group has been presented. Average daily intake of protein was found to be higher, though marginally, than that recommended.

In fig. 3, the information on consumption of protein per kg body weight per day has been presented for different age groups.

Contribution of animal and plant sources of protein to the total protein intake of the study participants across different age groups has been presented graphically in fig. 4.

The figure made an interesting revelation that young females of age range 18-23 years are obtaining more than 50% of their protein from plant sources and in three sub groups-those completed 19, 20 and 21 years of age, it is more than sixty percent; it is to be further noted that at least 84% of the 102 study participants are having more than 60% of their protein consumption from plant sources.

In Fig. 5, the contribution of different food groups in fulfilling total protein requirement has been presented for each of categories of adiposity as defined in terms of BMI.

It is interesting to note that food group - cereals and millets - remains the major contributor of proteins in all groups suffering from any of the malnutrition be it a state of underweight or overweight or obesity.

Table 5: Protein Consumption and Energy Obtained Profile of the Study Participants Belonging to Different Categories of Adiposity

Categories of Adiposity in Terms of BMI (n)	Average Protein Consumption ($g.day^{-1}$)	Average Energy Obtained ($kcal.\ day^{-1}$)	PER
Underweight (12)	46.49 ± 14.43	1525.2 ± 423.77	0.122
Normal weight (44)	48.45 ± 14.82	1578.5 ± 409.48	0.123
Overweight (8)	49.59 ± 11.04	1709.3 ± 365.95	0.117
Obese (38)	43.63 ± 10.70	1359.5 ± 262.24	0.128
Total	**46.81±14.39**	**1484.2 ± 390.69**	**0.127**

AM±SD

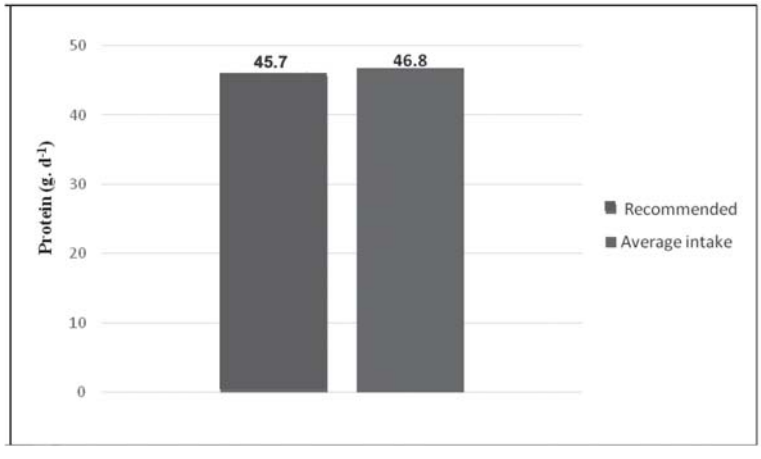

Fig. 2: Comparison Between Recommended and Daily Average Intake of Protein (g)

Discussion

Nutrition is one of the indicators of sound health and quality of life. Assessing the nutritional status especially among young adult women in the reproductive age, is particularly important to assess the overall health status of a nation as a whole. Malnourishment in this stage of life can affect the productive life years and also associated with mortality and morbidity. Anthropometric parameters are long been used as indicators of nutritional outcome[15-21]. The mean BMI of the participants in the present study was 23.27 $kg.m^{-2}$, indicating that the participants were falling under the category of overweight, which is in agreement with other studies carried out in similar age, sex and ethnic groups[22-30]. It may be also be noted that there is presence of under-weight (12%), normal (43%), overweight (8%) and obesity (37%) in the present study findings indicating a coexistence of dual burden of malnutrition. The findings of the present study in so far as the combined condition of overweightness, 45% is concerned, is more compared to data (27.9%) from NFHS 5 for urban females of age range 15 to 49 years. But it must be noted with a caveat that the results of the present study are based on the data of only 102 individuals. The status of underweight in the participating population was in tune with the NFHS-5, 2021, West Bengal[2]. Presence of underweight and overweight in the same population also indicating that this group of individuals is not free from dual burden of malnutrition. The mean WC and WHR of the participants were 83.6 and 0.86 respectively, indicating the participants had abdominal adiposity. The mean MUAC value, which is sort of function of protein and fat contents in

muscles[31], of the participants was 26.8 cm.

It is needless to mention that intake of adequate protein through diet is crucial for growth, development and maintenance of optimal health throughout the life. The average daily protein intake of the participants was 46.8g which was higher than the RDA (45.7 $g.d^{-1}$) although marginally. As per the latest revision of the RDA, the recommended dietary allowances for Protein for adult women is 0.83 g per day per kg body weight. In the present study it has been found to be 0.88, 0.77, 0.79, 0.91 g per day per kg body weight respectively for individuals completing 18, 19, 20, 21 years of age. It will possibly not be unreasonable to mention that RDA only depicts the minimum amount of protein required to supply indispensable amino acids, maintain optimum nitrogen balance and prevent deficiencies and muscle wasting and is not a measure of nutrient adequacy. RDA may be adequate to maintain the protein requirements of healthy and sedentary individuals but may be insufficient for certain group of individuals with higher requirements like for physically active individuals[32]. It may also be noted that insufficient intake of protein increases the appetite to get the required amino acids, and in many such situations, in place of increased protein intake, excess energy consumption takes place and cause a resultant weight gain, the most prevalent health issues of the particular age group[33]. In the present study it is observed that there is presence of overweight and obese individuals. However, not only proper nutrient intake, adequate amount of physical activity is also needed to cope up with obesity and associated disorders[34-43]. The average energy intake of 1484 kcal even is also falling short of estimated energy requirement of the adult females which is respectively 30, 39, 49 kcal per kg body weight per day that is amounting to 1650, 2145, 2695 kcal per day for female individuals of assumed body weight of 55kg sedentary, moderate and heavy lifestyle.

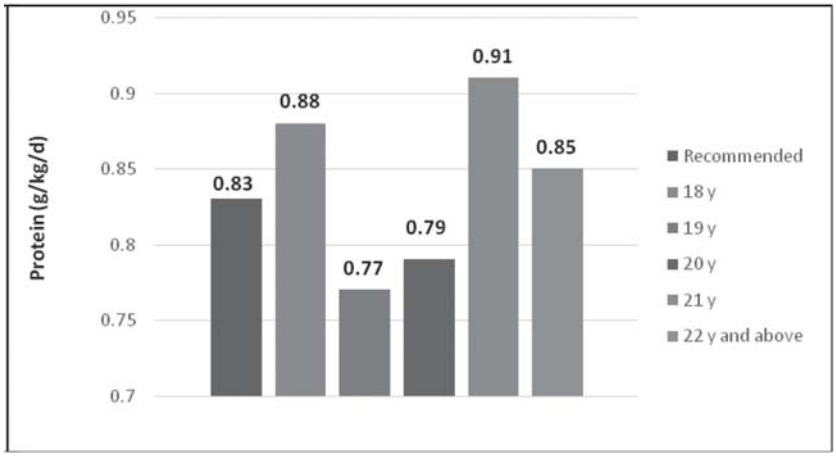

Fig. 3: Comparison Between Recommended Safe Intake and Average Daily Intake of Protein (g/kg/day)

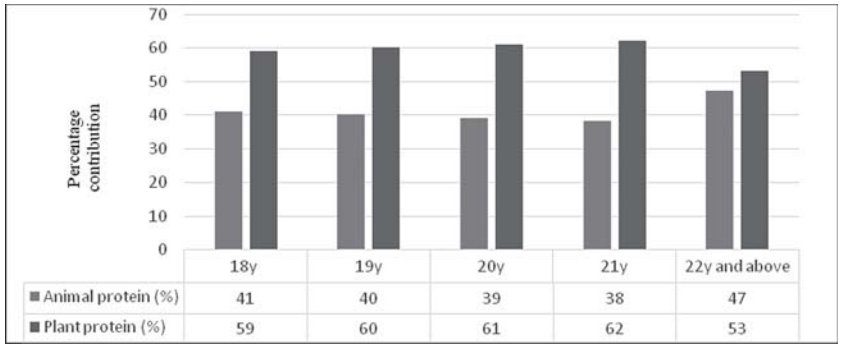

Fig. 4: Percentage Contribution of Animal and Plant Protein Sources to Total Protein Intake Across Different Ages.

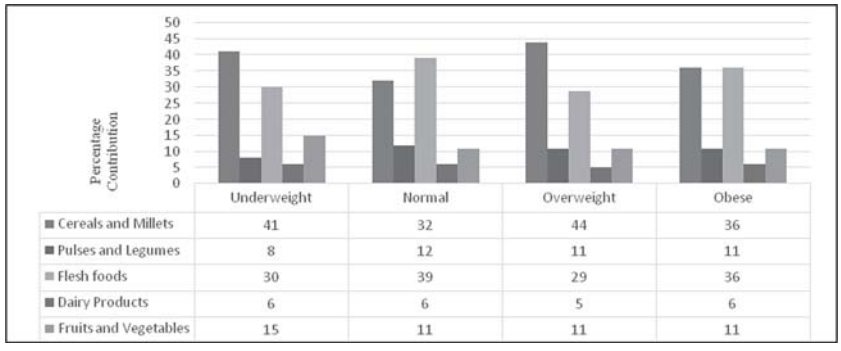

Fig. 5: Percentage Contribution of Different Food Groups to Total Protein Intake for each of the Adiposity Category

Utilization and deposition of protein within human body is dependent on adequate intake of energy which is expressed as protein energy ratio (PER) that is the ratio of energy from protein to total energy intake. PER is a measure to assess the protein contribution in the diet and can be used to evaluate the risk of dietary protein deficiency by comparing the actual PER of diet with the reference value. The mean PER for female adult in urban areas in India has been reported to be 0.107[44]. In the

present study the mean PER of the diet has been found out to be 0.127(0.117 - 0.128). While the recommended protein intake is fixed based on body weight regardless of physical activity, energy requirement varies. Therefore, when protein adequacy in diet is expressed as PER, it is important to consider the factors that influence energy requirement. However, in the calculation of reference PER, the effect of physical activity and/or energy requirement does not get considered. Supply of adequate energy from diet is essential for protein to be utilized properly in the body and in absence of sufficient energy protein requirements increases[14], it may be noted.

Along with quantity the quality of proteins needs special consideration**.** Depending on indispensable amino acid (IAA) protein can be of two types low quality and high-quality protein. Plant proteins are generally considered as low-quality protein as they deficit in one or more IAA and animal proteins contain all IAA hence are of high biological value. Habitual Indian diets are predominantly based on cereals and 60% of the protein in Indian diets is derived from cereals which is of poor quality and digestibility. Findings of the present study indicated that out of total protein content in the diet around 60% was obtained from plant sources. The finding of the present study is in line with a study carried out in India which stated that most of the dietary protein in both urban and rural population was derived from plant origin specifically from cereal sources[45]. It has been observed in the present study that except for participants in normal category, cereals are the main source of protein providing about 40% of total protein; the findings are in agreement with an earlier study that cereals provide the maximum, but in case of the earlier one it is in the order of 60% and contribution of flesh is around 10% only; the latter may be attributable to demographic and ethnic issues for the present study confined itself to urban Bengalee young females and not a pan India study (Fig. 5).

Cereals are deficient in lysine, an IAA, and have poor digestibility and quality. On the other hand, another important source of plant protein, legumes are high in lysine, while limiting in Sulphur containing IAA, methionine. Hence, for those who largely depend on plant sources to achieve the demand of IAA to a desirable level, should have an admixture of different plant protein sources in an appropriate ratio. But a recent study has suggested that cereal-legumes complementation may not sufficiently improve the protein quality for children and women and to achieve the required quality the quantity of the food protein need to increase which may result in excess energy intake[46]. Therefore, a diet solely based on plant protein may be at a greater risk of protein inadequacy in terms of quality. On the other hand, along with of high quality, animal proteins also contain saturated fats and cholesterol in good amounts and obtaining all the required proteins from animal sources may increase the risk of cardiometabolic diseases. A study has indicated that diets high in animal protein increased the risk of diabetes in adults[47]. For the past few decades there has been a significant rise in the demands for meat that brings about health issues like CVD and cancer risks and environmental sustainability issues. It has been estimated that a huge area of land and about 6 kg of plant proteins are needed to produce 1 kg of animal protein[48]. Recently a global awareness on the significance of vegetarian diets is seen as an aid for climate change and thus ensuring food security[49]. Vegetarian diets are more environment friendly as they contribute to the lowest greenhouse gas emissions and it also lowers the risk of various non-communicable diseases. While in Western countries more people (~5% of the population) are choosing vegetarianism in adulthood voluntarily driven by increased concerns about animals and ethical and moral principles regarding animal slaughter, personal health and environmental sustainability; in India with a significantly large number of people being vegetarian (35% of Indian population) - mainly driven by family traditions, religious and cultural systems, the moral aspects and attitudinal variations still remains[50]. A judicious choice of protein sources that allow both animal and plant protein is thus useful in addressing the issues. Combination of cereals, pulses and milk in the proportion of 3:1:2.5 can provide a good quality protein with all Indispensable Amino Acids[14]. Hence, presence of different sources of protein in diet may complement each other and the digestibility of protein from mixed diet also get improved than that of a single source diet which is specifically important for economically compromised country like India.

Conclusion

It may be concluded from the present study that the daily average intake of protein (g) was marginally higher in the young adult females of urban region. Importantly they were obtaining about sixty percent of the protein from plant sources, that are having some quality issues. Incidentally the individuals were found to have marginally inadequate energy intake but in some cases falling under the overweight category. The study highlighted a few interesting observations, but a sample size of just hundred plus calls for more elaborate studies with higher

number of participants for further validation of the initial results. ❐

SHREYA MUKHOPADHYAY
SWEETY BARDHAN
SAMBARAN MONDAL
SAYANTIKA SAHA
SUDIPTA BANERJEE
NEEPA BANERJEE
SHANKARASHIS MUKHERJEE*

*PHAU, Department of Food and Nutrition,
West Bengal State University,
Kolkata 700126, India

Email: msasish@yahoo.co.in

Received: 12 September 2023

Revised: 10 June, 2024

Accepted: 2 July, 2024

References

1. Y.J. Par, S. Chung, J. T. Hwang, J. Shon, A. Kim, *Nutr Res Pract*. Suppl 1, S37-S46, (2022).
2. International Institute for Population Sciences (IIPS) and ICF. 2021. National Family Health Survey (NFHS-5), India, 2019-21: Mizoram. Mumbai: IIPS
3. E.B. Zieliñska, Polish J Food Nutr Sci.**15/56** (4), 379-384 (2006).
4. V. Andreoli, M. Bagliani, A. Corsi, V. Frontuto, *Sustainability.***13** (7399), (2021) doi.org/10.3390/su13137399
5. S. Kundu, N. Banerjee, T. Santra, S. Chatterjee, S. Mukherjee, In *User centered design and occupational wellbeing*. 328-331, (2014).
6. S. Bhattacharjee, N. Banerjee, S. Chatterjee, S. Chatterjee, A. Chatterjee, S. De, S. Mukherjee, In *Proceedings of the international conference on humanizing work and work environment*. pp. 404-410, (2015).
7. M. L. Booth, *Res.Q.Exerc.Sport.***71**, 114-120 (2000).
8. P. Sood, S. Bindra,*Int J Community Med Public Health.***9**, 3841-4 (2022).
9. T. Santra, S. Chatterjee, S. Chatterjee, S. Bardhan, N. Banerjee, B. Pal,S. Gangopadhyay, S. Mukherjee, In: Ergonomics for Design and Innovation. HWWE 2017 (ISBN Print: 978-3-030-94276-2, Online: 978-3-030-94277-9), Springer, Cham 391, pp 1423–1433. (2022). DOI: https://doi.org/10.1007/978-3-030-94277-9_122
10. O. Savolainen, B. Fagerberg, M. Vendelbo Lind, A.S. Sandberg, A.B. Ross, and G. Bergstro¨m, *Plos One*, **12**(7), e0177738, (2017).
11. A. Chatterjee, S. Chatterjee, N. Banerjee, S. Mukherjee, *J Comp & Alt Med*. **2**, 171-180 (2020). DOI: 10.32474/OAJCAM.2020.02.000142
12. V. Sudha, G. Radhika, RM. Sathya A. Ganesan V. Mohan, *Int J Food SciNutr.***57**, 481-93 (2006).
13. C. Gopalan,b. v. Rama Sastri S. C. Balasubramanian, Nutritive Value of Indian Foods. Revised and updated by Narasinga Rao BS, Deosthale YG and Pant KC., National Institute of Nutrition, Hyderabad, 1996.
14. ICMR-NIN, Recommended Dietary Alloiwances and Estimated Average Intake Nutrients requirements for Indian - 2020. Department of Health Research. Ministry of Health and Family Welfare, Government of India (2020).
15. S. Chatterjee, N. Banerjee, T. Santra, S. Chatterjee, A. Chatterjee, S.Bhattacharjee, S. Mukherjee, *Sci Cult* (ISSN 0036 8156).**83** (11-12) (2017).
16. S. Chatterjee, N. Banerjee, S. Bhattacharjee, T. Santra, A. Chatterjee, S. Chatterjee, S. Mukherjee, *Int J Current Advanced Res.***6**, 2341 –2346 (2017).
17. N. Banerjee, S. Chatterjee, S, Bhattacharjee, S. Chatterjee, A. Chatterjee, T. Santra S. De, K. Ghosh, S. Mukherjee, *Int J Res Med Basic Sci* (ISSN 2455-2569). **3**, 18-28 (2017).
18. A. Bhattacharya, B. Pal, S. Mukherjee, S. K. Roy, *BMC Public Health.***19** (1), 1-9 (2019). doi.org/10.1186/s12889-019-7372-2
19. A. Chatterjee, N. Banerjee, S. Chatterjee, S. Chatterjee, S.Mukherjee, *Int J InnovKnowl Concepts* (ISSN: 2454-2415). **7**, 238-243 (2019).
20. N. Banerjee, P. Biswas, S. Chatterjee, T. Santra, S. Chatterjee, S. Mukherjee, Ergonomics for improved productivity. Design science and innovation. Springer Nature, Singapore. 921-929, (2021).
21. A. Briend, M. Garenne, B. Maire,O. Fontaine,K. Dieng,*Eur J ClinNutr.* **43**, 715–726 (1989).
22. N. Banerjee, S. Chatterjee, s. Chatterjee, S. Bhattacharjee, S. De, S. Mukherjee, Ergonomics for Improved Productivity (ISBN 978-93-86724-25-0). Excel India 40, (2017).
23. N. Banerjee, S. Chatterjee, S. Chatterjee, S. Bhattacherjee,S. De, S. Mukherjee, Ergonomics for improved productivity, Design science and innovation. Springer Nature, Singapore 911-920 (2021).
24. N. Banerjee, T. Santra, S. Chatterjee, S. Mukherjee,Ergonomics for Rural Development (ISBN 978-93-5174-905-9).89-96, (2015).
25. N. Banerjee, S. Chatterjee, S. Chatterjee, K. Ghosh, S. De, S. Mukherjee, *Int Physiol*. **3**(1), 11–15 (2015).
26. S. Chatterjee, N. Banerjee, S. Chatterjee, A. Chatterjee, B. Chakraborty, D. Banerjee, S. Mukherjee, *Int Physiol.* **3**, 23 – 28 (2015).
27. S. Bhattacharjee, N. Banerjee, S. Chatterjee, A. Chatterjee, S. Chatterjee, S. Mukherjee, Molecular Physiological and Nutritional Responses during Patho-physiological Alteration of Cell Function, AP. 22-34 (2017).
28. N. Banerjee, S. Chatterjee, S. Chatterjee, K. Ghosh, S. Mukherjee, *Int J Gen Med Pharm* ISSN(P): 2319-3999 ISSN(E): 2319-4006. **6**, 7-16 (2017).
29. S. Bhattacharjee, T. Santra, S. Chatterjee, A. Chatterjee, K. Ghosh, S. Chatterjee, N. Banerjee, S. Mukherjee,*Sci Cult*. **83** (7- 8), 247-252 (2017).
30. S. Bhattacharjee, N. Banerjee, S. Chatterjee, S. Chatterjee, S. De, S. Mukherjee, *Int Physiol*. **3** (1), 41–47 (2015).
31. A. Das, G.Saimala, N. Reddy,P. Mishra, R. Giri, A. Kumar,A. Raj,G. Kumar, S. Chaturvedi, S. Babu, S.Srikantiah, T. Mahapatra,*Public Health*. **179**, 68-75 (2020).
32. D. T. Thomas, K. A. Erdman, L. M. Burke, *J. Acad. Nutr. Diet*. **116**, 501–528 (2016).
33. C.E. Berryman, S. Agarwal, H. R. Lieberman, V. L. Fulgoni, S. M.Pasiakos, Am. J. Clin. Nutr. **104**, 743–749 (2016).
34. N. Banerjee, T. Santra, S. Bardhan, S. De, S. Mukherjee, Ergonomics for Design and Innovation. HWWE 2017 (ISBN Print: 978-3-030-94276-2, Online: 978-3-030-94277-9),

Springer, Cham 391, 1521-1529. (2022). DOI: https://doi.org/10.1007/978-3-030-94277-9_130

35. N. Banerjee, S. Chatterjee, S. Bhattacharjee, S. Mukherjee, *Indian J Clin Anat Physiol*. **1** (1), 29-33 (2014).

36. S. Mukherjee, N. Banerjee, S. Chatterjee, B. Chakrabarti, *Sci Cult*. **79** (11-12), 503-506 (2013).

37. N. Banerjee, S. Chatterjee, S, Chatterjee, S. Bhattacharjee, B. Bhattacharya, S. Mukherjee, *Sci Cult*(ISSN 0036 8156). **84**, 339-343 (2018).

38. L. Borges, M. E. P. Passos, M. B. B. Silva, V. C. Santos, C. M. Momesso, T. C. Pithon-Curi, R. Gorjão, S. R. Gray, K. C. A. Lima, P. B. de Freitas, E. Hatanaka, *Mediators Inflamm*. **2019** (2924818), (2019).

39. S. Mukherjee, N. Banerjee, S. Chatterjee, *Indian J Biol Sci*. **18**, 9-15 (2012).

40. S. Chatterjee, N. Banerjee, S. Chatterjee, S. Mukherjee, Ergonomics for Rural Development (ISBN 978-93-5174-905-9). 461 – 467 (2015).

41. A. Chatterjee. S. Chatterjee. N. Banerjee, S. Mukherjee. *Holistic Approach Environ*. **10**(2020), 100 – 108 (2020)

42. N. Banerjee, S. Chatterjee. S. Chatterjee, S. Mukherjee, *Am J Sports Sci*. **2**(6), 19-23 (2014).

43. N. Banerjee, S. Chatterjee, S. Bhattacharjee, P. Biswas, S. De, S. Mukherjee, *Int Phy EducSports Health* (P-ISSN: 2394-1685 E-ISSN: 2394-1693). **5**, 25-29 (2018).

44. National Nutrition Monitoring Bureau (1984) Report on urban population (1975-80). NNMB Technical Report. Hyderabad: NIN, ICMR.

45. S. Swaminathan, M. Vaz, A. V. Kurpad,*Br J Nutr*.**108**, S50-8 (2012). doi: 10.1017/S0007114512002413. PMID: 23107548.

46. S. Kashyap, A. Varkey, N. Shivakumar, S. Devi, T. Thomas, T. Preston, A. V. Kurpad, A. V. *Am J ClinNutr*. 110 (4), 873-882 (2019). doi.org/10.1093/ajcn/nqz159.

47. I. Sluijs, J. W. Beulens, D. L. van der A, A. M. Spijkerman, D. E. Grobbee, Y. T. van der Schouw,*Diabetes Care*. **33**(1), 43-8 (2010).

48. A. Drewnowski,A E.Mognard, S. Gupta, M. N. Ismail, *Nutrients*, **12** (1530),(2020); doi:10.3390/nu12051530.

49. N. Banerjee, S. Chatterjee, B. Bhattacharjee, S. Chatterjee, A. Chatterjee, S. Bhattacharjee, S. Mukherjee, *Indian Agriculturis*t (ISSN: 0019-4336).**63**, 11-17 (2019).

50. M. B. Ruby, S. J. Heine, S. Kamble, T. K. Cheng, M. Waddar,*Appetite*, **71**, 340-348(2013).