CHAPTER 4

RESULTS AND DISCUSSION

The results of the present intervention study titled "Impact of lifestyle interventions on nutritional status, physical activity and sleep pattern of overweight and obese 18 to 25 year old women during Covid-19" are presented and discussed under the following heads:

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PHASE I

4.1 Validation of KAP questionnaire and pilot testing

Research tools, such as surveys, questionnaires, experiments, and data collection instruments, need to be validated for several important reasons including accuracy, generalizability, minimizing bias and error, comparability, and overall quality of the research tool. It advances not only the overall amount of knowledge in a particular field but also the credibility and accuracy of research findings.

To validate the Knowledge, Attitudes and Practices (KAP) questionnaire to be employed in this study, a pilot study was conducted among randomly selected 100 women, of which 50 had pre-requisite level of education in nutrition and 50 did not have any educational connection to the field of nutrition. Table 4.1 shows the age wise distribution of the participants who were between 18 to 25 years of age.

Table 4.1: Age and distribution of pilot KAP survey participants

Age (In years)	Nutrition Students (N=50)		Non-nutrition Students (N=50)	
	n	%	n	%
18-20	17	34	18	36
21-23	15	30	15	30
24-25	18	36	17	34
Total	50	100	50	100

Although the distribution of students was more or less homogenous in both the groups, the maximum number of pilot study participants came from the 24 to 25 years among the nutrition students while for the non-nutrition students, the highest number of participants came from the ages between 18 and 20. All the three sections of the pilot KAP questionnaire had 15 questions of one mark each, thereby making the total score, 45. The topics covered in the form of knowledge, attitudes and practices have been presented in section 3.3.2.3. For each of the three sections, the correct response was marked as one mark and the incorrect response was marked as zero. To study the effectiveness of the developed questionnaire, there were three steps carried out. In step one, the initial responses of the participants regarding managing obesity were recorded as pre-intervention KAP score. In step two, the participants were sent the presentations and educational modules developed in Phase III of the study methodology. After a period of one month, the questionnaire was readministered to record the participants' post-intervention KAP score as step three.

The average KAP scores of the hundred participants before and after the intervention to determine the validity and reliability of the pilot KAP survey is shown in Table 4.2.

Table 4.2: Pre and Post-awareness KAP scores of pilot survey participants

KAP Section	Nutrition Students (N=50) (Mean±SD)		Non-nutrition Students (N=50) (Mean±SD)		Total Difference	p_{value}
	Pre	Post	Pre	Post		
Knowledge (15)	12.0± 0.03	14.6± 1.04	8.5± 1.02	12.08± 1.02	6.18	<0.001*
Awareness (15)	11.6± 0.01	12.7± 0.19	8.6± 0.17	13.02± 0.05	5.52	<0.001*
Practices (15)	11.2± 0.04	13.1± 0.13	7.8± 0.18	13.51± 1.01	7.61	<0.001*
Total (45)	34.8± 0.06	40.4± 0.71	24.9± 0.11	38.5± 0.43	19.2	<0.001*

*Significant at 95% level of confidence

The average scores of the students from the nutrition background before the pilot intervention ranged from 11.2 to 12 points, making the total average score to be 34.8±0.06 points. For the non-nutrition students, the pre-pilot study average scores ranged from 7.8 to 8.6 points, making the total average score to be 24.9±0.11 points. It may be stipulated that the higher KAP scores as seen in the nutrition students, may be linked to their educational background and the lower KAP scores as the lack thereof in the case of the non-nutrition students. However, the average scores of the students from the nutrition background after the pilot intervention ranged from 12.7 to 14.6, slightly, yet significantly increasing the total average scores to 40.4±0.71. Among the non-nutrition students, the average scores ranged from 12.08 to 13.5 points, making the total average score to be 38.5±0.43 points. It can therefore, be observed that there is a pronounced and significant improvement in the KAP of students from the non-nutrition background after the pilot intervention. The total difference column in Table 2 indicates the statistical difference between the average pre- and post-KAP scores of all the hundred women pilot study participants.

To assess the whether the KAP questionnaire was valid to measure (construct validity) among all the participants equally (inter-reviewer reliability), the Cronbach's alpha (α) and the Pearson's coefficient (r) statistical correlations were used respectively, the results of which are given in Table 4.3.

Table 4.3: Validity and reliability of formulated KAP survey

KAP Section	Cronbach's α			Pearson's r		
	Nutrition Students (N=50)	Non-nutrition Students (N=50)	Overall (N=100)	Nutrition Students (N=50)	Non-nutrition Students (N=50)	Overall (N=100)
Knowledge (15)	0.67	0.84*	0.84*	0.75	0.84*	0.86*
Awareness (15)	0.65	0.83*	0.84*	0.66	0.84*	0.84*
Practices (15)	0.64	0.80*	0.80*	0.64	0.84*	0.84*
Total (45)	0.74	0.87*	0.87*	0.81*	0.90*	0.90*

*Significant at 95% level of confidence

As denoted by the asterisk (*) symbol, the pilot tested KAP questionnaire was found to have desirable levels of construct validity and inter-reviewer reliability which leads to $H_0 1$ being rejected. This is in agreement with other studies conducting validation for their KAP surveys in similar populations of age, education and existing knowledge levels (Reethesh *et al.*, 2019; Ritchie *et al.*, 2019; Al-Makhroumi *et al.*, 2022) and hence was utilised as a research tool in the present study. Existing guidelines for validating a questionnaire or survey have been elaborated by Taherdoost (2018). Considering those findings, it can be said that the developed, novel KAP questionnaire is adequately validated in terms of content and is reliable in terms of internal consistency to be used in the sample population of the present study.

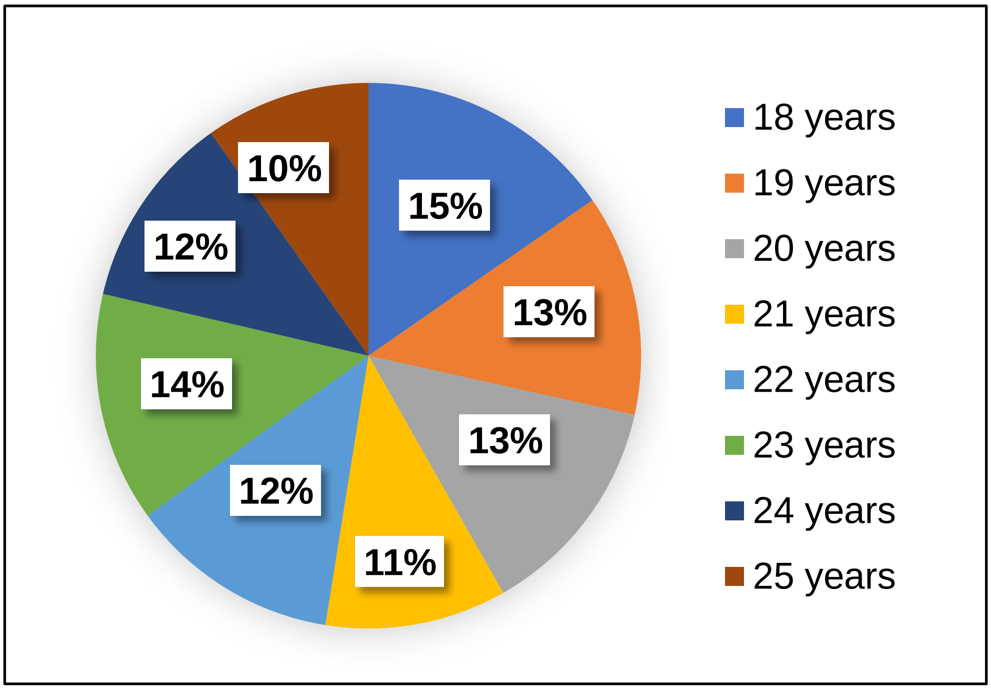
PHASE II

4.2 Background information and socio-economic profiling of subjects

4.2.1 Background information of subjects

Graph 4.1 shows the distribution of the study subjects as per their age at the time of the study period.

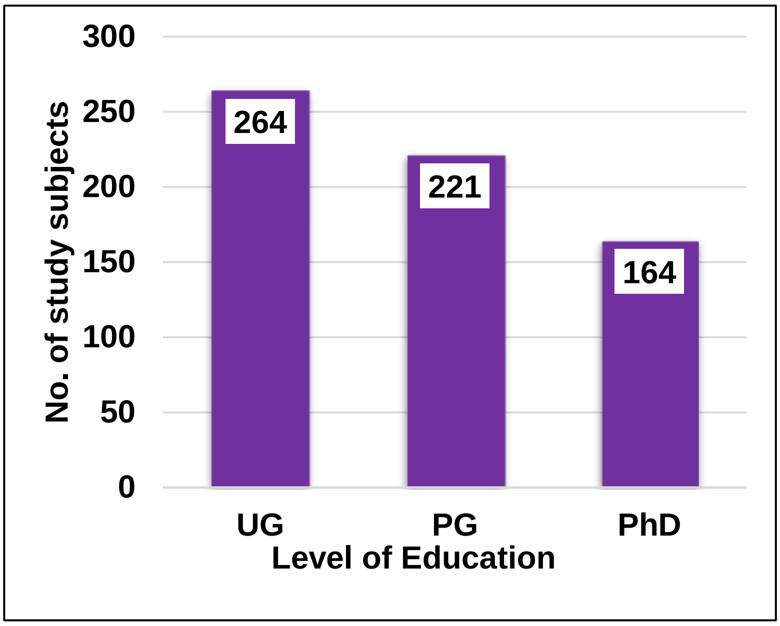
Graph 4.1: Distribution of study subjects as per age (N=632)



A majority of the 632 women participants of the study belonged to the subjects who were 18 years of age i.e., 15 percent while the least number of participants were 25 years old i.e., 10 percent.

Graph 4.2 displays the distribution of study subjects as per their education level at the time of the study period.

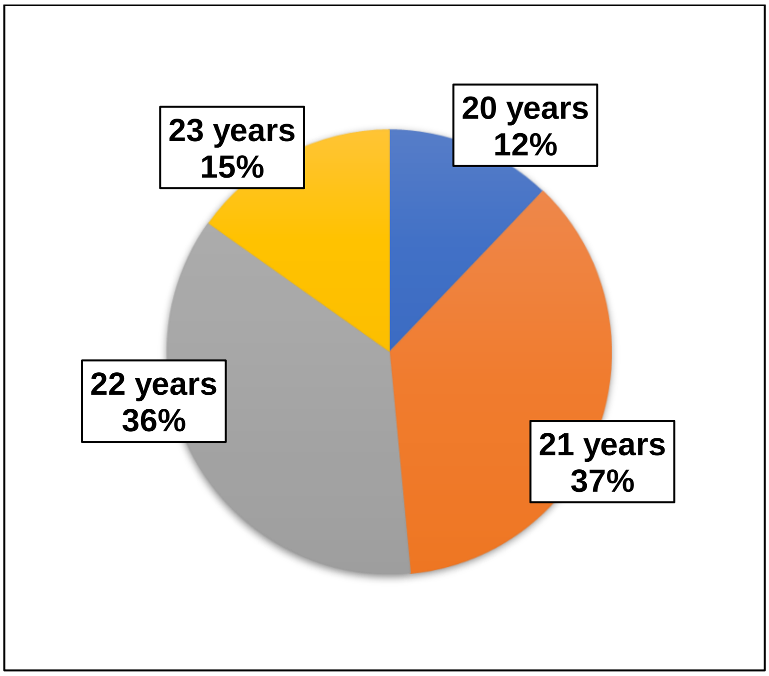
Graph 4.2: Distribution of study subjects as per education level (N=632)



When scrutinising the education level of the subjects, it was observed that most of them were either pursuing or had completed the graduation i.e., over 41 percent.

Graph 4.3 shows the distribution of study subjects as per their marital age at the time of the study period.

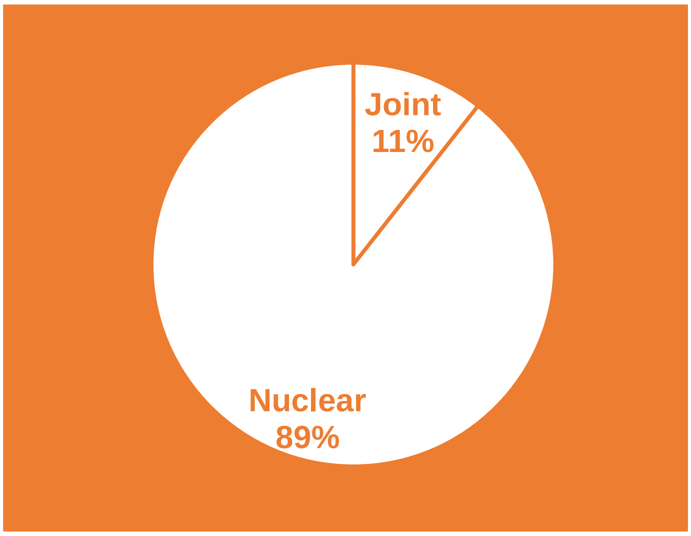
Graph 4.3: Distribution of study subjects as per marital age (N=33/632)



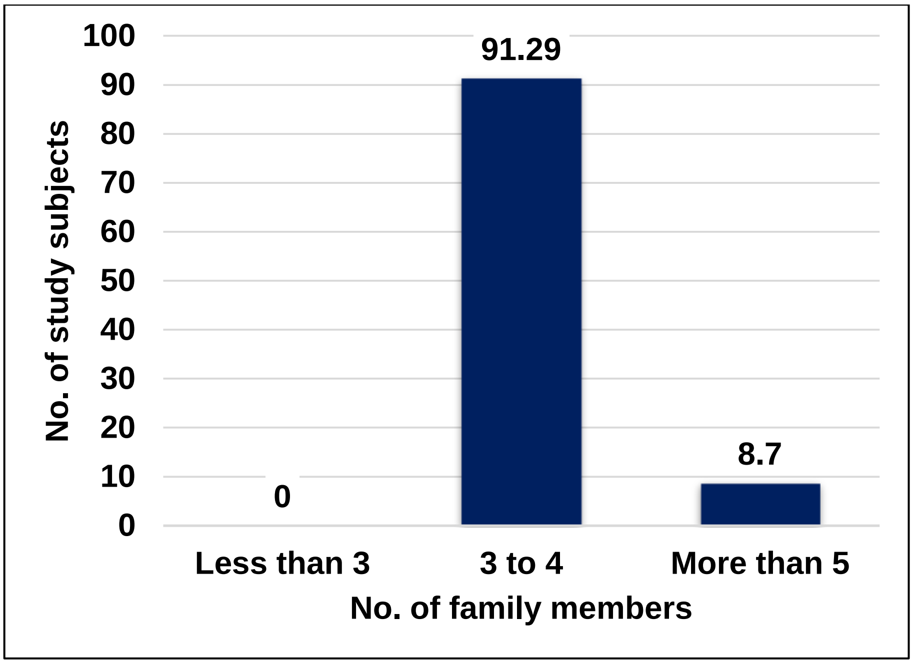
Although the age of marriage did not significantly affect this study and the interventions employed, it was interesting to note that there were 33 (5.2 percent) study subjects who were married. The pie chart indicates that there were 12 percent who were married below the age of 21 years while a 51 percent were married above 21 years.

Graph 4.4 shows the distribution of study subjects as per the type of family they lived in while Graph 4.5 shows the number of members in the families of the study subjects.

Graph 4.4: Distribution of study subjects as per family type (N=632)



Graph 4.5: Distribution of study subjects as per family size (N=632)



Examining the family type of the study subjects, it can see be seen that there were mostly nuclear families (89 percent) with only 11 percent belonging to joint families. Out of these nuclear and joint families, over 91 percent had at least three to four family members while there were no subjects with single parents and an eight percent with the number of family members exceeding five.

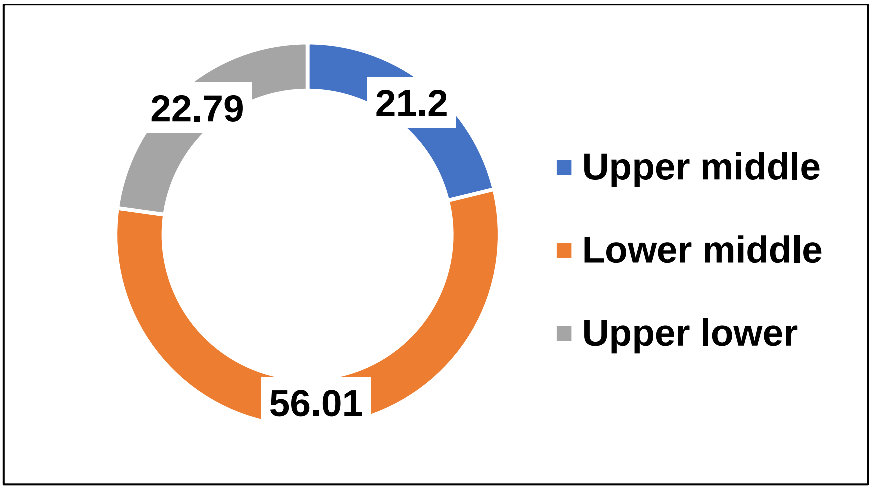
Prior research to identify the significance of socio-economic factors in the field of community research has been undertaken. Pampalon *et al.*, (2009) had established that area-based socio-economic variables are helpful in determining health inequities despite their drawbacks, and that they can be followed over time and for many geographic settings, and the inequalities they identify are significant, dependable, and constant. Recent research conducted across the age groups of the human lifecycle has also shown that there is noteworthy correlation between socio-economic status and the onset of childhood and adulthood obesity (Newton *et al.*, 2017), indicating the continuous effect that socio-economic variables may exert over health determinants in different populations across the globe. Recent research based on an Indian population that aimed to promote interdisciplinary research on the spatial and temporal dynamics of urban poverty and well-being in the light of the rising urbanization of cities in developing nations, suggests that socio-economic factors such as place of residence, housing types, source of incomes etc. can help to develop strategic slum management initiatives, from public distribution system enhancements to social interventions that increase or encourage movement and mobility (Roy *et al.*, 2018) which may include spaces in educational institutions or workplaces to promote a physically active lifestyle.

Other research studies conducted among or based on the Indian population has also extensively attributed the influence of socio-economic variables such as education, income, wealth indices based on assets, place of residence etc. on lifestyle factors including dietary and physical activity patterns which in turn affects the risk of obesity (Sengupta *et al.,* 2015; Little *et al.,* 2016; Purushotham *et al.*, 2023).

4.2.2 Socio-economic profiling of subjects

The modified Kuppuswamy scale for rural and urban households was used to identify the socio-economic profiling of the study subjects as reported by Sood & Bindra (2022). Graph 4.6 shows the distribution of study subjects as per their socio-economic profiles during the study period.

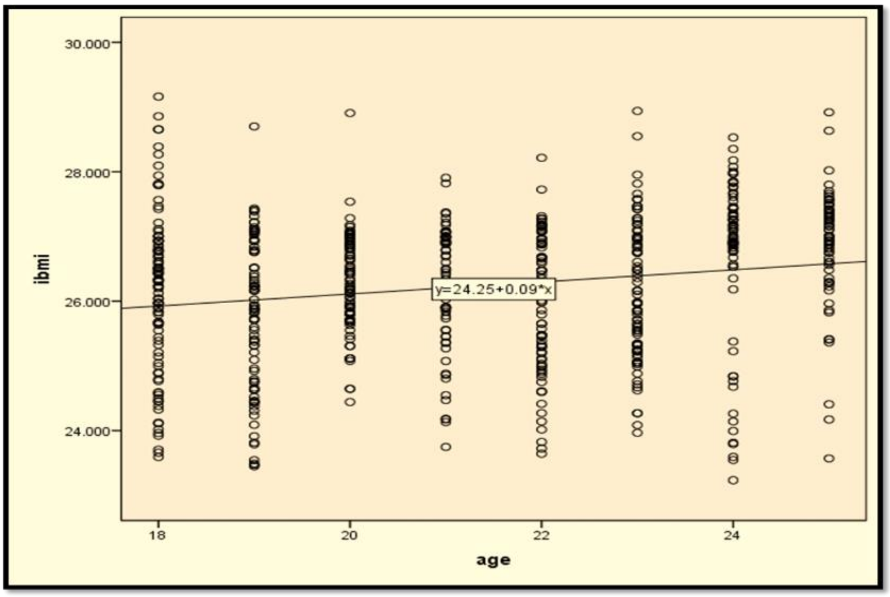
Graph 4.6: Distribution of study subjects as per socio-economic profiles (N=632)



The maximum of 56 percent of the study sample belonged to the lower middle-income category while the minimum of 21 percent belonged to the upper middle-income category. These categories were designated based on the information combined from age, education level, family type and size, practising religion, and type of residence.

Associating the socio-economic variables and the initial BMI of the study subjects revealed that there was a positive and statistically significant linear correlation (r=0.192; p<0.001) between the age and initial BMI of the study subjects. Graph 4.7 displays the scatter plot between the age and initial BMI of study subjects.

Graph 4.7: Scatter plot between the age and initial BMI of study subjects (N=632)

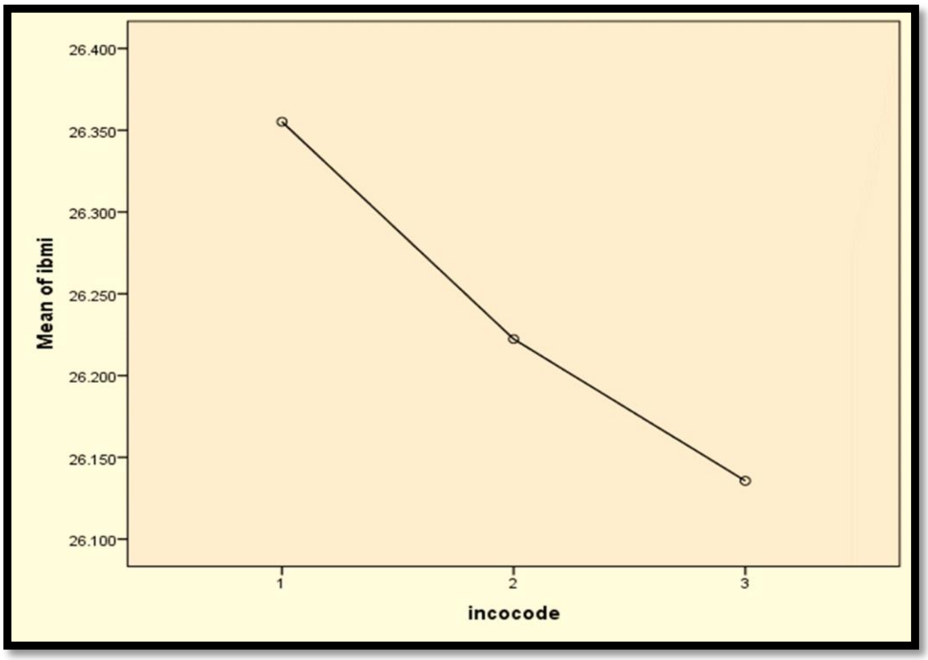


Description: Age of the subjects is represented on the X-axis while the initial BMI is represented by 'ibmi' on the Y-axis.

Other associations were also determined between the initial BMI category with the type of family (t=-1.187, p=0.236), with the family size (r=-0.028, p=0.476), but were not found to be statistically significant.

Graph 4.8 shows the graphical representation of the ANOVA test carried out between the initial BMI and the three income groups of the study subjects.

Graph 4.8: Plot of ANOVA between initial BMI and income groups of study subjects (N=632)



Description: Income code is represented by the ‘incocode’ on the X-axis while the initial BMI is represented by ‘ibmi’ on the Y-axis. ‘incocode1’ stands for upper middle-income group, ‘incocode2 stands for lower middle-income group and ‘incocode3’ stands for upper-lower income groups.

On assessing the relationship between the initial BMI levels and the income group of the study subjects, it was found that there was a positive and statistically significant relationship between the two variables (F=13.75, p<0.001). In other words, for the subjects of the present study, as their income level decreases, so does their degree of overnutrition.

Studies analysing the associations between socio-economic factors including age, education, family type and family income have also been previously conducted which have collectively mentioned that with increasing age, lower educational level and higher economic status, there was increased incidence of overweight and obesity (Fan *et al*., 2020; Islam *et al*., 2020; Shrestha *et al*., 2020; de Faria *et al*., 2023). According to the existing evidence, associations between socio-economic profiles of the population and the risk of developing obesity and other NCDs, is reportedly significant and valid and may contribute to early diagnosis of the disease and effective treatment interventions resulting in positive behaviour changes (Puzhankara & Janakiram, 2022; Mendge *et al.,* 2023; Purushotham *et al.*, 2023). Current research also proves that low to middle income status associated socio-economic profile is a detrimental contributing factor in the risk of developing obesity and other NCDs with the prevalence of obesity becoming increasingly high irrespective of the income status of the household (Templin *et al*., 2019; Reyes *et al*., 2020; Mahumud *et al*., 2021).

PHASE III

4.3 Nutritional status and lifestyle pattern of subjects

The results the collection of the initial or pre-intervention data of the study subjects related to their nutritional status as well their lifestyle pattern is presented as follows.

4.3.1 Nutritional status of subjects

The nutritional status of the subjects included the ABCD approach i.e., anthropometric, biochemical, clinical and dietary assessments which are as described in this section.

4.3.1.1 Anthropometric assessment of subjects

On analysing the anthropometric parameters of the study subjects including their height, weight, resultant body mass indices (BMI), waist circumference, hip circumference and result waist-to-hip ratio (WHR), it was seen that the average self-reported weight, BMI and WHR of the main study population was significantly higher than the standard as recommended by WHO (1995, revised in 2011) and ICMR-NIN (2020). Table 4.4 shows the anthropometric parameters of subjects before intervention.

Table 4.4: Anthropometric parameters of subjects before intervention (N=632)

Parameter	Standard	Mean±SD	t_{value}
Height (m)	1.62[a]	1.56±0.34	-1.19*
Weight (kg)	55[a]	64.35±4.25	2.58*
BMI (kg/m^2)	18.5-23.9	26.23±1.11	2.51*
WHR	0.80[b]	0.88±0.15	1.02*

[a] ICMR (2020), [b] WHO (2011)
* Significant at 95% confidence level

The average height of both the main and sub-sample subjects were significantly lower i.e., 1.56±0.34 m as compared to the standard 1.62 m of the Indian reference woman. The average weight of the women was higher by almost 10 kg as compared to the standard of 55 kg which in turn resulted in the average BMI also to be higher than the normal category as defined by the BMI cutoffs for Asians (Pan, 2008; WHO, 2011). The recorded WHR was also above the recommended levels (WHO, 2011) confirming the presence of overnutrition in the selected women population. The initial BMI and WHR were found to be slightly positively yet significantly correlated ($r=0.16$, $p<0.001$).

Research has proven that height is a hereditary factor which is sometimes expressed to its whole potential in the presence of ideal nutritional and other environmental factors, (McEvoy & Visscher, 2009; Stulp & Barrett, 2016; Wang *et al*., 2020). This could explain the deficit in the height parameter of the pre-intervention anthropometric assessment of the subjects in the present study. As elaborated in Chapter 2, the rising incidence of global and national obesity may also explain the elevated levels of body weight and BMI (Prasad *et al.*, 2013; IIPS-NFHS-4, 2017; IIPS-NFHS-5, 2021).

Table 4.5 presents the anthropometric measurements of the sub-sample subjects prior to the intervention.

Table 4.5: Anthropometric parameters of sub-subjects before intervention (N=164)

Parameter	Standard	Mean±SD	t_{value}
Height (m)	1.62[a]	1.56±0.002	-1.17*
Weight (kg)	55[a]	64.77±0.32	2.53*
BMI (kg/m^2)	18.5-23.9[b]	26.32±0.75	2.16*
WHR	0.80[b]	0.88±0.001	1.02*
SMM (kg)	16.8 – 20.5	17.35±0.74	2.19*
PBF (%)	18.0 - 28.0	31.30±0.11	3.16*
BMR (kcals)	1189 - 1371	1268.61±14.96	3.84*
Fitness Score[c]	70-79	54.34±0.17	2.35*

[a] ICMR (2020), [b] WHO (2011)
[c] Fitness score does not have a referral range
* Significant at 95% confidence level

From the extensive body composition analysis, the parameters considered for the present study include the skeletal muscle mass (SMM), the percentage of body fat (PBF), the basal metabolic rate (BMR) and the fitness score, as recorded by the InBody 720 (Seoul, South Korea) body composition analyser. It can be observed from Table 4.5 that even though the BMR of the subjects was within the referral range, it is near the lower limit of the range. SMM was also found to be near the lower level of the referral range. However, the PBF was higher than the recommended range, indicating that the majority of the subjects had more of fat percent in their bodies, i.e., they were overweight or obese. The initial BMI of the study subjects was positively and significantly correlated with the PBF ($r=0.623$, $p<0.001$) while it was not significantly correlated with SMM ($r=-0.11$, $p=0.887$), BMR ($r=0.075$, $p=0.342$) and fitness score ($r=0.041$, $p=0.606$).

Research has probed the extent of association of obesity with the measured body composition parameters of PBF and SMM and confirmed that elevated levels of PBF, and lowered levels of SMM and estimated BMR contribute to overweight and obesity among women (Völgyi *et al.*, 2012; Sullivan *et al.*, 2019). It can also be observed that the self-reported measurements and the ones measured by the investigator after adjusting for reliability and validation errors are in concordance, indicating the integrity of the data obtained through the Google forms, which was unavoidable due to the Covid-19 restrictions prevalent during the study period.

4.3.1.2 Biochemical assessment of subjects

Owing to the existing Covid-19 regulations at the time, the biochemical parameters were assessed for 164 subjects, i.e., the sub-samples of the study as presented in Table 4.6.

Table 4.6: Biochemical parameters of sub-subjects before intervention (N=164)

Parameter	Standard	Mean±SD	t_{value}
RBG (mg/dl)	70-140	104.25±14.3	1.85*
Hb (g)	12.0-15.0	11.73±1.05	2.17*
T_3 (ng/dl)	70-204	100.89±3.53	2.10*
T_4 (mcg/dl)	4.6-12.0	5.61±0.33	3.17*
TSH (mc IU/ml)	0.35-5.5	4.50±0.261	1.24*

*Significant at 95% confidence level

Assessing the random blood glucose levels of the sub-sample subjects showed that the average (104.25±14.3 mg/dl) was well within the range considered normal. However, the same cannot be said about the content of haemoglobin among the subjects as the sub-sample average (11.73±1.05 g) was below the normal range. Assessing the serum thyroid levels through the thyroid function tests revealed them to be within the recommended ranges where the average levels of T_3 was 100.89±3.53 ng/dl, T_4 was 5.61±0.33 mcg/dl and TSH was 4.50±0.261 mc IU/ml.

The normal ranges of the biochemical parameters were set after confirmation from current studies carried out by Mathew & Tadi (2022) for random blood glucose, Pasupula & Reddy (2014) for serum haemoglobin, and Marwaha *et al.*, (2013) for serum thyroid levels respectively. Initial levels of BMI of the study subjects were not significantly correlated with any of the biochemical parameters, namely RBG (r=0.025, p=0.749), Hb (r=0.087, p=0.269), T_3 (r=0.027, p=0.733), T_4 (r=0.012, p=0.879) and TSH (r=0..007, p=0.934) which seem to suggest that the degree of obesity may not be related to elevated levels of random blood glucose, the level of haemoglobin or thyroid hormones in the human body. However, research carried out by Hruby *et al.,* (2016), Walczak & Sieminska (2019) and Klasson *et al.,* (2022) opposingly suggest that biochemical assessments including random blood glucose, haemoglobin and thyroid function tests have been used to previously diagnose and manage obesity.

4.3.1.3 Clinical examination of subjects

Outcomes of the initial clinical examination conducted for the sub-sample consisting of 164 women study subjects is presented in Table 4.7.

Table 4.7: Clinical symptoms of study sub-sample before intervention (N=164)

Sl. No.	Clinical symptoms	N	%
1	Tenderness of muscles	35	21.4
2	Mild anaemia	3	1.9
3	Nutritional oedema	18	10.9
4	Xerosis / pigmentation of cornea	23	14.1
5	Angular stomatitis	7	4.2
6	Red/glazed tongue	6	3.6
7	Bleeding gums	11	6.7
8	Dental caries	21	12.9
9	Pigmentation of skin	11	6.7
10	Dry / rough skin	12	7.3
11	No symptoms	17	10.3

It can be observed through the data indicated that the common symptoms recorded includes tenderness of muscles which was seen in 21.4 percent of the sub-sample, followed by xerosis or pigmentation of the cornea as seen in 20.7 percent and nutritional oedema which was visible in 14.6 percent of the sub-sample women. There was also a 10.3 percent that did not have any observable symptoms at the time of the initial clinical examination. These clinical symptoms and their associated nutritional deficiencies were the reason why the micronutrients mentioned below were selected to be analysed as part of the nutrient intake assessment of the subjects, as described in later sections of this chapter.

The clinical symptom of muscle tenderness has long been linked with vitamin D deficiencies. Research has suggested that the active form of vitamin D, 1,25-hydroxyvitamin D_3 (1,25$(OH)_2D_3$), is believed to possess a direct regulatory role in the growth and repair of skeletal muscle, as well as myogenesis, differentiation, proliferation, and protein synthesis control, and mitochondrial metabolism (Montenagro *et al.*, 2019; Charoenngam *et al.*, 2019).

Numerous reasons, including the loss of lumbar spinal stability due to insufficient stimulation of the lower spine stabilizing muscles including the multifidus muscle, through physical inactivity, can result in lower back discomfort, which has also been related to vitamin D deficiency (Dzik *et al.*, 2019). Incidence of the vitamin D deficiency has been documented in India in the past across different ages among both men and women (Garg *et al.*, 2018; Aparna *et al.*, 2018; Ramot *et al.*, 2022) and is also a reason that justified the selection of this nutrient in the present study.

Anaemia, including mild anaemia has been associated with iron deficiency over time in the country, especially in women (Thankachan *et al.*, 2007; Anand *et al.*, 2014; Natekar *et al.*, 2022). Studies conducted by Mawani *et al.* (2016) and others suggest that iron deficiency anaemia has many different causes, including hereditary and environmental factors. Among them are improper dietary habits, low socio-economic levels, high pregnancy parity, genetics, access to poor health, etc. Additionally, anaemia can lead to a number of negative consequences, including exhaustion, mental wellness issues, lack of focus, and negative foetal and neonatal outcomes, such as stillbirth, premature birth, and postpartum haemorrhages. Adopting measures including dietary diversity, biofortification, and supplementation are necessary for the prevention of iron deficiency anaemia and its numerous negative effects on health (Mirza *et al.*, 2018; Malhotra *et al.*, 2023). It can also be shown through prevalence studies and research carried out in finding emerging dietary strategies to end iron deficiency that the rate of anaemia has increased between the National Family Health Survey's fourth and fifth surveys, which is a serious cause for concern (IIPS-NFHS-4, 2017; IIPS-NFHS-5, 2021).

It is well recognized that a variety of oedema is caused by thiamine deficiency including localized oedema in muscles and cytotoxic and vasogenic oedema in the brain. Thiamine must be frequently consumed because it is essential for the body's energy metabolism. However, due to dependency on staple foods that are poor in thiamine, many communities are in danger of thiamine deficiency (Bourassa *et al.*, 2020; Tanaka *et al.*, 2021). Also, up to a third or more of children and women of childbearing age are affected by thiamine deficiency, which is widespread in many regions of Asia and Africa. Preventive measures, such as dietary diversity, fortification of foods, and/or supplementation for the population of children and women at risk, are dependent on local and regional characteristics (Koshy *et al.*, 2021; Keating *et al.*, 2023).

Pigmentation of the cornea has been associated with vitamin A and D deficiencies in India and the world. Conjunctival xerosis to severely blinding consequences such as keratomalacia are all examples of the ocular symptoms of vitamin A deficiency (Chander *et al.*, 2013). Numerous ocular illnesses have been researched in relation to vitamin D, including glaucoma, diabetic ocular engagement, dry eye syndrome, and optic nerve associated with multiple sclerosis (Cankaya *et al.*, 2018; Pellegrini *et al.*, 2020). Even though the prevalence of clinical vitamin A deficiency has dramatically decreased over time, the bulk of the globe's vitamin A deficient youngsters still live in India. Even though there has been a vitamin A supplementation program in place for over forty years, the inadequacy of the vitamin is still a major public health issue in India (Arlappa, 2023). Both mortality and myopia can be decreased by increasing dietary vitamin A intake or by administering vitamin A on a regular basis, while vitamin D deficiency in India requires strategies such as food fortification with Vitamin D and educational awareness programmes (Chander *et al.*, 2013; Aparna *et al.*, 2018).

Angular stomatitis, which is a condition characterized by inflammation and cracking at the mouth corners, has been reported to be associated with the deficiencies of iron and the group of B vitamins. Apart from fatigue, angular stomatitis, atrophic glossitis and irritability are common symptoms of iron deficiency (Jose & Sarika, 2023). The symptoms of riboflavin, niacin, and cobalamin insufficiency are said to include fissured and magenta-coloured tongues, recurring aphthous ulcerations, cheilitis, and angular stomatitis (Chandan & Rao, 2023). Although this clinical deficiency only been observed in young children and the elderly, the primary prevention of these deficiencies is still reported to be adequate dietary intake of both the vitamins (Blanck *et al.,* 2002; Sri *et al.,* 2023).

Glossitis or the glazed tongue, is where the tongue becomes swollen and inflamed and it has been associated to be a symptom of cobalamin deficiency. Benign migratory glossitis had a prevalence rate of 0.09% in South Indians and was more commonly observed in males at a much younger age than females (Ilankizhai & Chaudhary, 2021). Management of the symptom has been suggested to include enough nutrition, exercise, rest and supplements of the vitamin B_{12} to prevent the recurrence of glossitis (Chiang *et al.*, 2020). Bleeding gums is another term for scurvy and this clinical symptom has been associated with the deficiency of vitamin C. Clinical characteristics of scurvy include joint effusions, follicular hyperkeratosis, irritated and bleeding gums, and poor wound healing (Chandan & Rao, 2023). Despite the fact that vitamin C insufficiency is hardly ever recorded in affluent nations in the twenty-first century, there are still several people at risk for low vitamin C levels. Smokers, those who eat a diet with little diversity, people who have malabsorption problems, and people who have chronic illnesses have all been linked to low vitamin C levels. Since humans cannot synthesize vitamin C on their own, maintaining physiological functions while treating scurvy in affected persons requires a sufficient diet rich in fruits and vegetables (Dresen *et al.*, 2023).

Dental caries, are and often occur due to inadequate calcium and vitamin D intake in the diet. Calcium is necessary for tooth calcification and is crucial for controlling tooth development. However, Vitamin D regulates the production and calcification of hydroxyapatite crystals by promoting the absorption of calcium and phosphate, the deficiency of which can lead to dental caries (Dodhia *et al.*, 2021). Sugar consumption should be capped at four servings per day or less since higher a amount is associated with increased levels of caries. Hard cheeses, peanuts, whole-grain foods etc. are examples of foods that promote saliva secretion and are therefore preventive against caries. Chronic disorders linked to diet, including oral conditions like dental caries are further prevented by a diet rich in whole grains, fresh vegetables and fruits, and starches and less in extra sugar and fat (Tungare & Paranjpe, 2018).

Manifestations of symptoms of skin disorders include skin pigmentation and dry or rough skin that has been reportedly associated with the deficiencies of vitamin B_3, B_{12}, A, C, D and E. Vitamin level irregularities are being linked to skin disorders more and more frequently, and systemic and topical therapy has shown encouraging results. A few notable improvements have been made, but the wide range of results suggests that these illnesses are not just caused by a single deficit or fixed by giving a single supplement. Dietary sources to treat dry skin and skin pigmentation includes eggs, legumes, cheese, milk, nuts etc. (Elgharably *et al.*, 2023).

Assessing the initial morbidity pattern of all the women subjects revealed that the most common ailments were cold or cough, fever, vomiting or diarrhoea and food poisoning as presented in Table 4.8.

Table 4.8: Initial morbidity pattern of study subjects (N=632)

Morbidity status (up to 3 months)		Pre	
		N	%
Episodes of morbidity	Not sick up to 3 months	135	21.4
	Cold / cough	209	33.1
	Fever	234	37.0
	Vomiting / diarrhoea	33	5.2
	Food poisoning	21	3.3
Frequency of above episodes	No occurrence up to 3 months	137	21.78
	Once a month	163	25.8
	Once in two months	264	41.8
	Once in three months	68	10.8
	Rarely	-	-
Use of medicines during episodes	No medicines	512	81.01
	All the time	42	6.6
	Sometimes	78	12.34

Even though there is a 21.4 percent of the study samples who were not sick up to three months prior to the initiation of the study, and no subject contradicted the Covid-19 during the study period, there was a 33 percent who had cold or cough, and a 37 percent that had fever in the population. This could perhaps be attributed to the possibility that the subjects contracted the general symptoms of the virus, but not the virus itself; or that they had a higher case of morbidity due to a poor nutritional status which in turn affected their immunity status. The occurrence of food poisoning in three percent of the sample population was also concerning and also highlighted the need for a lifestyle and nutrition education intervention to choose better and healthier food choices. Another point to be considered is how episodes of these morbidities occur as frequently as once in two months to 41 percent of the study population. This could also be the reason why close to seven percent of the women preferred medicines to treat themselves during these bouts of sickness.

In a recent study that was conducted among women who were workers for a biscuit company, similar indicators of morbidity were analysed (Fathima & Daniel, 2023). As there are limited studies specifically assessing the morbidity pattern among young women of the age group of 18 to 25 years, other Indian studies i.e., with women belonging to an older age group or with women who had bouts of sickness other than the Covid-19 infection were analysed, and were found to exhibit similar parameters of assessment that accurately indicated the morbidity pattern of the selected population (Sarma *et al.*, 2021; Pathak *et al.*, 2022; Lewnard *et al.*, 2022). On considering the evidence that self-medication practices increased exponentially during the Covid-19 pandemic, findings of the present study contradicted the results of the literature survey. Reportedly, 29 to 46 percent of the world's population uses anti-cold and anti-allergy medicines at the first incidence of the symptoms of sore throat, cough or even fatigue (Ayosanmi *et al*., 2022; Shrestha *et al.*, 2022; Yasmin *et al.*, 2022). Therefore, as Saha *et al.,* (2022) notes, self-medication is extremely common among indigenous people, and the result is concerning; especially, the abuse of analgesics and antibiotics. Therefore, it was necessary to understand this pattern among the selected population and to raise public awareness of the harmful effects of self-medication and to put appropriate awareness measures into place.

4.3.1.4 Dietary pattern, food and nutrient intake of subjects

Dietary pattern before the intervention was collected from the subjects and is presented in Table 4.9.

Table 4.9: Dietary preferences of study subjects (N=632)

Indicator of dietary behaviour and preference		N	%
Food allergies	None	556	88.0
	Not known	34	5.4
	Yes	42	6.6
Type of food allergies	Fish	9	1.4
	Lactose	18	2.8
	Nuts	15	2.4
Food preferences	Vegan	20	3.2
	Vegetarian	297	47.0
	Ovo-vegetarian	139	22.0
	Non-vegetarian	176	27.8
Number of meals in a day	4 meals (3+1)	409	64.7
	5 meals (3+2)	72	11.4
	6 meals (1+3+2)	151	23.9

From the table, it can be observed that nearly seven percent of the study subjects had diagnosed food allergies of which lactose intolerance, allergies to nuts and fish were the most common. However, there were 5 percent of the subjects who reported having symptoms similar to that of allergic reactions post-consuming certain foods but did not get it clinically confirmed from a medical practitioner.

Food allergies have been reported in the Indian population as early as the year 2003 – however, it was reported that these allergies were limited to children (Gangal & Malik, 2003). An investigation into the occurrence and kinds of food specific allergic reactions in students from urban and rural China, Russia, and India highlighted the significance of early life exposures in influencing the progression of food sensitivity and allergy in children at elementary age, but not in adults (Li *et al.*, 2020). Presently, in a study that validated an egg and milk allergy detecting questionnaire, the scenario has remained unchanged and there is an increase in food allergies of chickpea, pea, lentil, and lupine among adults, thereby showing the necessity of precise medical diagnosis (Krishna *et al.*, 2020; Hildebrand *et al.*, 2021; Laha *et al.*, 2022). The risk of food allergies seems to be higher among individuals with obesity due to the pro-inflammatory immunological effects of adipose tissues especially if these individuals were exposed to microbial exposures, allergen exposure routes, environmental pollutants early on in their life (Guo *et al.,* 2020; Gu *et al.,* 2022; Zhang *et al.,* 2023).

The majority of the study subjects were vegetarians i.e., 47 percent along with a 27.8 percent who were non-vegetarian. The recent trend in adopting a completely vegan diet, i.e., abstaining from consuming any sort of animal products as a personal preference or choice to preserve Earth and its resources (North *et al.*, 2021) also seems to be prevalent in nearly four percent of the selected women subjects.

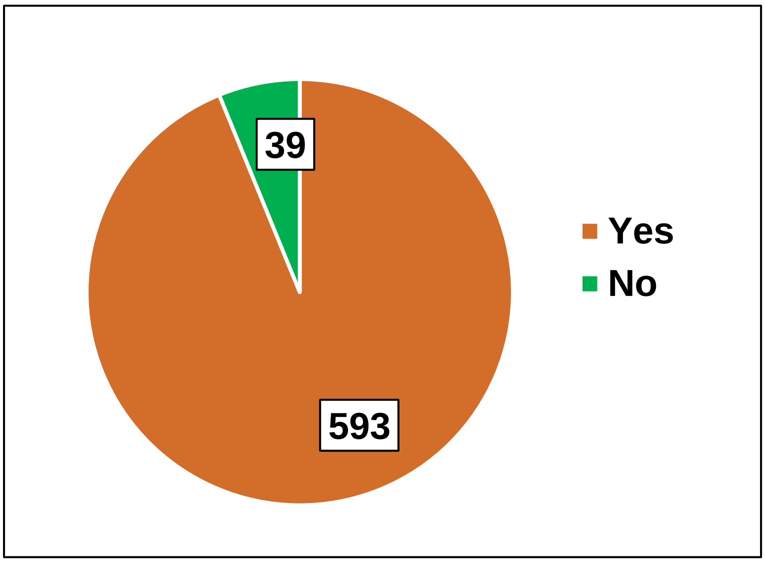
There has been research carried out to understand the prevalence of vegan diets across the world and India that suggests that the trend is increasing and vegan diets are being considered to combat against overnutrition, cardiovascular diseases, diabetes and other metabolic syndrome disorders as well as ensuring gut health (Sakkas *et al.*, 2020; Guha & Gupta, 2020; Marrone *et al.*, 2021; Pollakova *et al.*, 2021). However, literature review studies have shown that some vegan eating habits may make it difficult to meet the recommended nutritional needs in both children as well as adults (Lederer *et al.*, 2019; Gallagher *et al.*, 2022; Chouraqui *et al.*, 2023; Turaga, 2023).

The four-meal pattern was the most preferred by the subjects i.e., among 64.7 percent. It included three main meals i.e., breakfast, lunch, dinner and one snack / tea time. However, there were also a 23.9 percent who consumed six meals i.e., breakfast, lunch, dinner and two snack / tea times along with 'something light' prior to breakfast.

Association between the number of meals and health status, particularly healthy weight loss has been researched in the yesteryears to reveal the pros and cons of the same. While some studies mention that nutritional counselling, which includes eating more meals daily and emphasizing foods high in protein and energy, may help people improve their nutritional status and quality of life, others suggest that fewer meals per day, regular fasting and eating only two to three meals a day can have positive effects on the body's physiology, such as reduced inflammation, amplified circadian rhythmicity, enhanced catabolism, stress resistance, and improved gut flora (Nguyen *et al.*, 2019; Paoli *et al.*, 2019; Meessen *et al.*, 2022). In the Indian context, the ICMR-NIN (2011), in its guidelines to prevent overweight and obesity, encourages individuals to consume "small meals regularly at frequent intervals". Hence, understanding the meal pattern of the study participants was essential at this stage.

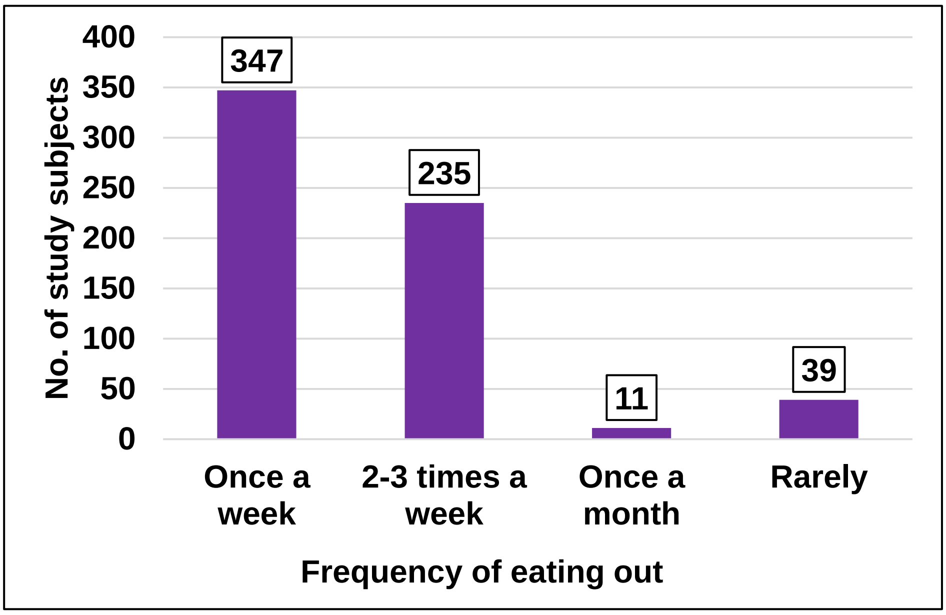
Graph 4.9 presents the preferences that the subjects had in terms of eating out of home, in the six months prior to initiation of the study. The majority of the subjects preferred eating out, and did not actively prefer consuming food from home or would rather eat out or order from fast food outlets.

Graph 4.9: Subjects' preferences of eating out 6 months prior to study initiation



Along with the tendency to eat out, the frequency of consuming food other than that made at home was also examined, as presented in Graph 4.10.

Graph 4.10: Frequency of eating out by subjects before study



It can be observed that the maximum of the subjects that preferred eating out, tended to do so, once every week. This was followed by two to three times a week and 'rarely'. 'Once a month' had the least number of subjects. Considering that this time period coincided with the time as that of the first wave of Covid-19, it was concerning to observe that individuals or families still preferred eating outside the home or ordering food from fast food outlets; yet another reason to orient the subjects towards making healthier food choices or to make their already existing home-made meals healthier.

Research previously conducted among over 500 adults to analyse their consumption of food away from home, they discovered that adults who were less than 30 years of age, also qualified graduates and/or employed, belonging to households with income above fifteen thousand rupees, went out for food at least once a month, usually celebrating holidays or occasions of significance with friends or family (Ali & Nath, 2013). Additionally, it was discovered that some adults thought it was advantageous to eat out because they had the chance to try new dishes that were challenging to prepare at home with the exact same taste and flavour as in a restaurant, demonstrating that eating out becomes more of a pleasure than a necessity and provides a certain amount of distraction and satisfaction (Kalita & Sarma, 2017). This continues to hold true in recent times, including during the Covid-19 pandemic when food delivery applications gained popularity and it was shown by

Selvan and Andrew (2021) and others that the eating in culture was slowly, but steadily replacing the dining out culture. Contradicting studies with nearly a thousand participants also reported that before the pandemic, only 36 percent of adults chose to consume food away from their homes which ranged from daily to five or six times a week. There were also the studies that compared changes in consumer dining out behaviour before and during COVID-19 that reported that restaurant trips significantly dropped compared to pre-COVID-19, whereas food delivery and meals prepared at home significantly rose. (Chopra *et al*., 2020; Ko *et al.*, 2023). These reasons justified the requirement to analyse the frequency with which the participants consumed food away from home.

After collecting the initial data obtained from the food frequency questionnaires, the average consumption frequency of food groups and processed foods of subjects were analysed. Cereals included whole grains or flours of wheat, rice, and millets, along with potato and tubers such as tapioca, yam, carrots, onions etc. Pulses included Dal (common name: *payaru* or *paruppu*), chickpea (common name: *sundal*), other pulses used in preparations of *sambaar* and chutneys etc. Since food preparations such as *dosa*, *idli* and other cereal-pulse foods are a combination of the above, the subjects were asked to indicate the frequency in both categories of cereals and pulses. Lean meat included poultry (duck or chicken) and fish. Other meat included egg, mutton, beef etc. Milk included milk and milk products including tea, coffee, paneer, cheese, curd etc. Fats included cooking oil, mayonnaise, ghee, butter etc. and finally, sugar included white (refined) and brown sugar, honey, jaggery etc. Table 4.10 displays the average frequency of consumption of food groups and processed foods of the study subjects.

Table 4.10: Average consumption frequency of food groups and processed foods of subjects (N=632)

Food Items	Frequency of consumption – N (%)					
	Daily	Weekly	Monthly	Occasionally	Rarely	Never
Food Groups						
Cereals	632 (100)	-	-	-	-	-
Pulses	221 (34.9)	283 (44.7)	128 (20.2)	-	-	-
Milk & Milk Products	612 (96.8)	-	-	-	-	20 (3.2)
Lean meat	19 (3.0)	124 (19.6)	138 (21.8)	35 (5.5)	-	317 (50.2)
Other meat	-	121 (19.2)	139 (21.9)	48 (7.6)	7 (1.1)	317 (50.2)
Vegetables	632 (100)	-	-	-	-	-
GLV	5 (0.80)	98 (15.5)	137 (21.7)	284 (44.9)	108 (17.1)	-
Fruits	112 (17.7)	138 (21.8)	169 (26.7)	122 (19.3)	91 (14.5)	-
Fats	632 (100)	-	-	-	-	-
Sugar	632 (100)	-	-	-	-	-
Processed Foods						
Pastry items	-	72 (11.4)	211 (33.4)	313 (49.5)	36 (5.7)	-
Fried foods	44 (6.9)	54 (8.6)	56 (8.9)	421 (66.6)	57 (9.0)	-
Spreads	-	41 (6.5)	70 (11.1)	392 (62.0)	129 (20.4)	-
Pickles	91 (14.5)	177 (28.0)	158 (25.0)	183 (28.9)	23 (3.6)	-
Frozen foods	-	-	29 (4.6)	316 (50.0)	280 (44.3)	7 (1.1)
Ice-cream	-	82 (12.9)	198 (31.4)	214 (33.8)	138 (21.9)	-
Chocolates	108 (17.1)	217 (34.3)	299 (47.3)	8 (1.3)	-	-
Sweets	-	-	32 (5.1)	552 (87.3)	48 (7.6)	-
Carbonated drinks	-	46 (7.3)	108 (17.1)	385 (60.9)	91 (14.4)	2 (0.3)

It could be observed that the food groups of cereals, vegetables, fats, sugar were consumed daily by all the subjects. Milk and milk products were also mostly consumed daily except by the subjects who were vegan while pulses were mostly consumed weekly or monthly. Meat, owing to most of the subjects being vegetarian (nearly fifty percent did not consume meat), was mostly consumed monthly or weekly by the subjects. While green leafy vegetables were mostly consumed occasionally, while most of the study subjects were consuming fruits on a monthly basis.

Consumption pattern of young adults has been studied in the past, as reported by Sharma *et al.*, (2020) and others. The researchers found that whole grains had a much higher calorie share of the diet as compared to legumes, meat, eggs, fish, vegetables, and fruits, which all have a significantly lower calorie share. This meant that regardless of their income levels, the average Indian household consumes more calories from processed foods than from fruits. Additionally, Indians consume too many cereals and too few proteins, fruits, and vegetables. A wide variety of domestic and foreign cuisines are readily available to consumers in India, where the food environment is gradually changing. One of the reasons influencing the food environment was mentioned as the presence of Western cuisine and culture, not just in terms of food but also in terms of values of going out and eating processed or pre-prepared foods (Kumar *et al.*, 2022). Reportedly, the growth in NCDs in India is caused by altered eating behaviours and longer workdays that encourage a more sedentary lifestyle, thereby warranting careful monitoring of food consumption behaviour. According to the ICMR-NIN MyPlate (2017) recommendations, cereal consumption should make up a maximum of 40% of total calories; however, 17% of calories may come from eggs, lentils, and animal protein. Total fat consumption should be kept to a minimum of 30% and should not exceed 300ml per day for milk and milk products. The recommended daily consumption of vegetables, including green leafy vegetables, is 350 grams while it should be 150 grams and 30 grams of fruits and nuts (Cena & Calder, 2020; Sharma, 2022).

Pastry items included breakfast cereals like corn flakes or *Chocos*® etc., biscuits, cookies, cakes, puffs etc. Fried foods included all types of snack items that were fried in any way i.e., deep, shallow or air fried such as vada, chips, mixture, samosa, banana fry. Sweets included gulab jamun, jalebi, barfi and the like. Spreads included mayonnaise, *Nutella*®, jam etc. Frozen foods included packaged frozen vegetables, fruits or pre-fried foods (nuggets, patties, wedges etc.) while fast food chains included foods from outlets outside of the home.

Most of the subjects either consumed pickles occasionally, weekly or monthly and chocolates were consumed by a majority of the subjects monthly once or twice while pastry items were consumed either monthly or occasionally, and this pattern was observed to be similar in the case of fried foods, spreads, frozen foods, ice-cream, sweets, and carbonated drinks. However, it is also important to note that a very similar percentage of study subjects also consumed these food groups monthly, suggesting that these food groups may actually be consumed more than how they are being indicated by the food frequency questionnaire responses.

Over the years, studies have suggested links between a diet rich in energy and fats and elevated body mass index levels, among children and adults alike, irrespective of geographical area and ethnicity (Pesta & Samuel, 2014; Bowen *et al.,* 2015; Jian *et al.,* 2022). Correspondingly, there have been studies that associate energy-restricted, high protein and low-fat diets with weight loss and reduction in body mass index levels in healthy non-athlete adults (Fernando *et al.,* 2019) and studies that have observed the positive effects of time-restricted eating on metabolic diseases (Moon *et al.*, 2020). Since the diet of today's population includes, higher oil (fried foods), sweet and salt content, along with a reduction in the quality proteins of healthful components such as fibre, legumes, fruits, vegetables and coarse grains (Popkin, 2011), it was necessary to understand the consumption frequency of these food groups in the present study participants. Table 4.11 shows the average initial food intake of the study subjects.

Table 4.11: Average initial food intake of subjects (N=632)

Food Groups	Standard (ICMR, 2020)#	Food Intake (Mean±SD)	Excess / Deficit	t_{value}
Cereals (g)	270	283.45±55.1	13.45	4.96*
Pulses (g)	60	42.51±5.12	-17.49	8.53*
Milk & Milk Products (g/ml)	300	210.31±4.27	-89.69	15.71*
Animal food (g)	60	53.6±4.01	-6.4	4.24*
Vegetables (g)	200	51.21±12.6	-148.79	101.1*
GLV (g)	100	17.43±9.10	-82.57	73.4*
Roots and Tubers (g)	200	124.12±15.6	-75.88	2.61^{NS}
Fruits	100	106.1±21.8	6	2.69^{NS}
Fats and oils (g)	20	23.1±5.1	3.1	28.04*
Sugar and jaggery (g)	20	17.9±3.6	-2.1	16.8*

Recommended Dietary Allowances (ICMR, 2020),
*Significant at 95% confidence level, ^{NS}Not significant

It displays how vegetables, green leafy vegetables and milk and milk products are among the least consumed food groups among the study subjects, which indicated the need for the nutrition education to promote a more balanced food consumption pattern. It also displayed how even though a majority of the subjects were vegetarians by choice, the consumption of pulses was much below the recommended levels.

Vitamin C consumption levels were above the recommended levels, which could be because of the extent of importance given to the vitamin during the times of Covid-19 for its anti-oxidant and immunity boosting properties (Abobaker *et al.*, 2020; Carr, 2020; Milani *et al.,* 2020). This was because people looked for strategies that may protect themselves from the coronavirus (2019-nCoV) outbreak or to lessen its consequences once they had been diagnosed with the viral infection. One such method that was being promoted in the media and online was the intake of vitamin C, which supposedly had advantages for preventing COVID-19 (Banerjee *et al.,* 2020; Dutta *et al.,* 2022).

However, similar to the low pulse consumption, the protein consumption among the subjects was almost 20 percent below the recommended level, which could be attributed to the often-reported poor consumption of protein rich foods in Indian diets, as proved by studies conducted early on in the 1970s (Sukhatme, 1970), as well as recently (Sharma *et al.,* 2020). Additionally, nutrients such as calcium, and vitamin A, as well as the B-group vitamins were also lesser than the advised amount. This could be due to the presence of leafy greens lacking in the diet of the subjects along with vegetables and milk or milk products, as mentioned by recent studies (Natesh *et al.,* 2017; Arasaretnam *et al.,* 2018; Kumar *et al.,* 2020) and others which were elaborated in the sections above.

Table 4.12 shows the average initial nutrient intake of the study subjects.

Table 4.12: Average initial nutrient intake of subjects (N=632)

Nutrients (per day)	Standard (ICMR, 2020)#	Nutrient Intake (Mean±SD)	Excess / Deficit	t_{value}
Macronutrients				
Energy (kcals)##	1660	2786.75±74.6	67.87	12.75^S
Protein (g/kg body weight)	36.3	29.16±13.12	-19.66	24.17^S
Carbohydrate (g)	130	309.41±32.37	138.00	34.13^S
Fat (g)	20	50.3±10.4	151.5	23.12^S
Micronutrients				
Iron (mg)	15	13.8±4.1	-5.33	37.26^S
Calcium (mg)	800	702.01±101.82	-12.25	17.25^S
Vitamin A (mcg RAE)	840	741.21±12.19	-11.76	16.41^S
Vitamin B_1 (mg)	1.4	1.21±1.1	-13.57	19.92^S
Vitamin B_2 (mg)	2.0	1.41±0.61	-29.5	15.68^S
Vitamin B_{12} (mg)	2.0	0.89±0.41	-55.5	26.7^S
Total folate (mcg)	180	151.0±38.51	-16.11	23.2^S
Vitamin D (mcg)	10	8.3±7.25	-15.92	17.2^S
Vitamin C (mg)	55	72.13±33.2	31.14	7.43^S

#Recommended Dietary Allowances, 2020
##EER – estimated energy requirement since energy has no recommended dietary allowances
*Significant, ^{NS}Not significant

Based on the responses recorded from the twenty-four-hour recall questionnaires, it was observed that the subjects' average intake of energy, carbohydrates, fat, were above recommended levels while most of the vitamins was below the recommended level. This may be attributed to usual or overconsumption of foods that are rich in calories, but not adequate enough in terms of the nutrient content.

Analysing the data received from the three day twenty-four-recall forms, the average overall calorie intakes of the subjects have been reported in Table 4.13.

Table 4.13: Overall calorie intake of subjects among intervention groups before the intervention (N=632)

Group	EER* (ICMR, 2020)	Calorie Intake (kcals) (Mean±SD)	Excess / Deficit	F_{value}	t_{value}
Group 0	1660 kcals	2784.30±71.14	+74%	1.981 (p=0.14)^{NS}	1.45^{S}
Group 1		2787.13±73.36	+74.1%		1.75^{S}
Group 2		2783.85±83.54	+73.9%		1.53^{S}
Group 3		2793.01±69.80	+74.5%		1.81^{S}

*EER – estimated energy requirement since energy has no recommended dietary allowances
^{S}Significant at 95% confidence level, ^{NS}Not significant

It can be seen that even group wise, there is a consistent nearly 74-75 percent excess in the calories consumed which was statistically verified through the repeated measures of analysis of variance. The excess in calories describe the requirement to improve the subjects' awareness of the need in consuming a nutritionally balanced diet and making informed choices when purchasing foods. Initial BMI and initial overall calorie intake were positively correlated (r=0.113, p<0.001).

There have been studies that analyse the factors affecting the point of purchase of healthy foods (i.e., the factors being considered by individuals just before choosing to buy them or place them back on the shelf of the grocery stores) to increase the awareness of individuals to make healthier food choices through adopting different practices such as reading the nutrient labels or the ingredient lists, or trying to understand the approximate nutritive values of essential and non-essential nutrients before purchasing the food product (Volkova & Ni, 2015; Sutton *et al.,* 2019; Karpyn *et al.,* 2020; Grandi *et al.,* 2021). However, the lack of uniform guidelines on the same and the consequent lacunae in the knowledge levels of the customers enforce the need of awareness programmes on healthy purchasing behaviour.

4.3.2 Lifestyle pattern of subjects

The lifestyle pattern of the students including their physical activity pattern, sleep quality and their Knowledge, Attitudes and Practices (KAP) related to obesity management, at the initiation of the study period are explained in this section.

4.3.2.1 Physical activity pattern of subjects

The exercise habits of the subjects at the time of study initiation have been shown in Table 4.14.

Table 4.14: Exercise habits of study subjects (N=632)

Exercise habit indicator		N	%
Frequency of exercising	Not regular	261	41.3
	Daily	149	23.6
	2-3 times a week	222	35.1
Preferred area to exercise	Indoors	239	37.8
	Outdoors	308	48.7
Preferred time of day to exercise	Early morning	281	44.5
	Morning	207	32.8
	Evening	58	9.2
	Night	1	0.2
Types of preferred exercise	Stretching	158	25.0
	Walking	176	27.8
	Yoga	83	13.1
	Jogging	44	7.0
	Cycling	48	7.6
	Dance / Zumba	38	6.0

From the table, it can be observed that most of the subjects (41 percent) did not have the practise of exercising regularly – neither two or three times per week, nor daily. Even though there are guidelines in place that encourage the need of being physically active for at least 30 minutes per day or 150 minutes per week (ICMR, 2011), the pattern of physical inactivity seen among the subjects warranted an intervention plan where the importance of being physically active was conveyed to the subjects, in order to motivate and encourage them to imbibe sustainable habits of physical activity in their daily lives.

Although physical inactivity has long been associated with morbidity and non-communicable diseases (Anderson & Durstine, 2019), currently, the trend of physical activity is only headed in a downward direction, with the prevalence of physical inactivity increasing globally, and nationally, especially among women, as compared to men (Anjana *et al.,* 2014; Smith & Smith, 2016; Hui *et al.,* 2021). This called for increasing the physical activity and exercising behaviour among the participants of the present study.

There were a 44 percent of the women subjects that said that they preferred to exercise in the early mornings or before their day starts, which could be attributed to their daily student schedules that may not allow for evening recreations with regard to physical activity. Considering that taking up goals of being physically active requires time and a consistent approach for healthy outcomes, the intervention needed to be feasible and practical for all the women participants.

A recently published study in the journal of *Obesity*, having over 5000 subjects suggests that the best time to exercise would be between 7 am and 9 am. This was because in comparison to participants who attended more than half of their training sessions between 3 and 7 pm i.e., mid-day or evening, those who attended more than half of their training sessions in the morning experienced a larger loss of body mass and fat mass (Ma *et al.,* 2023). Other studies have also encouraged exercises to be carried out in the morning suggesting that it improves metabolic control and muscle performance on the subsequent day (Gomez *et al.,* 2015; Aoyama & Shibata, 2020). However, as the authors did not specify that exercise was to be done only in the morning hours for optimal health, it signifies the importance of allowing the participants of the current study to choose their own timings to exercise instead of recommending a time that would not fully ensure compliance to the study intervention.

The types of preferred exercise included stretching, walking, yoga, jogging, cycling, and dance or Zumba and the most preferred among the subjects was observed as ‘walking’ while ‘dancing’ was the least preferred. This observation supported the need for an intervention that incorporated dance or the combination of different exercises to encourage participation among the women subjects of the study.

It has been reported that as compared to a single exercise, structured exercise participation in terms of physical activity highly influences the important factors of ageing even in older adults (Izquierdo *et al.,* 2021). Research also suggested that the exercises that were initiated during the pandemic season needed to extend even after the pandemic effect decreased. For this, it was deemed essential that building a habit, which usually takes approximately 10 weeks, people need to try exercising in some capacity (moderate to vigorous intensity) every day (Nyenhuis *et al.,* 2020).

Table 4.15 shows the initial GPAQ scores of the study subjects across the control group and the three intervention groups.

Table 4.15: Initial GPAQ scores of the study subjects across intervention groups (N=632)

Group	Standard#	Mean±SD	Excess / Deficit	F_{value}
Group 0	> 600	314.97±8.10	- 47.50	2.896^NS (p=0.218)
Group 1		315.06±8.09	- 47.49	
Group 2		319.11±8.04	- 46.81	
Group 3		316.23±8.30	- 47.29	
All Groups		316.34±8.28	- 47.27	

#WHO (2002), NSNon-significant

Analysing the data from the Global Physical Activity Questionnaires (GPAQ) at the initiation of the study, it was observed that all of the subjects did not meet the global recommendations of physical activity as their scores were nearly 50 percent lesser than the recommended with an average of 316.34±8.28 as the score for the GPAQ among all the subjects. This was verified by the statistically insignificant difference between the control and experimental groups. The scores, corresponding to their sedentary occupations and mode of transport indicated the need for inclusion of physical activity in their daily schedules. Initial BMI and GPAQ scores were negatively but insignificantly correlated (r=-0.125, p=0.899).

Studies assessing physical activity using modified versions of the GPAQ have been carried out in the world and in India. The tool has been found to effectively measure the average physical activity of the study subjects so as to recommend interventions towards better health (Mengesha *et al.,* 2019; Lee *et al.,* 2020; Devi *et al.,* 2020; Jalal *et al.,* 2021; Sathish & Mathews, 2023), thereby justifying its validity to be used in the selected population of women in the present study.

4.3.2.2 Sleep quality of subjects

The scores obtained from the initial assessment of the subjects' sleep patterns through Pittsburgh sleep quality index (PSQI) have been listed groupwise in Table 4.16.

Table 4.16: Initial PSQI scores of the study subjects across intervention groups (N=632)

Group	Standard#	Mean±SD	F_{value}
Group 0	1 - 5: Good 6 - 15: Average 21 - 25: Poor	19.16±1.41	0.206 (p=0.892)^NS
Group 1		19.05±1.25	
Group 2		19.14±1.22	
Group 3		19.07±2.0	
All Groups		19.11±1.50	

#WHO (2002), NSNon-significant

It can be observed that all of the subjects had a poor sleeping pattern according to the PSQI standard of scoring with the average of the PSQI scores being 19.07±2.0 for all the subjects. No significant correlation was determined between initial BMI levels and the sleep quality of the study subjects (r=0.014, p=0.728).

PSQI has been used to assess sleep quality and as an accompaniment to psychiatric research ever since it was first created (Buysee *et al,* 1989; Manzar *et al.,* 2018; Javed *et al.,* 2023). In India, the use of PSQI ranges from studies of validation in specific populations or being associated with NCDs and BMI levels or as a method of assessing the prevalence of poor sleep behaviours seen among certain populations aiming to provide improved interventions for better sleep (Shad *et al.,* 2015; Anwar & Mahmud, 2018; Cherubal *et al.,* 2020), which warrants the need to include this tool to assess the importance of sleep quality as a lifestyle factor in the present population.

Although interventions for better sleep include research on mobile application interventions, caffeine intake, relaxation techniques, behaviour changes as the workplace, educational institutions etc., (Shin *et al,* 2017; Friedrich & Schlarb, 2018; Redeker *et al.,* 2019), exercise has long been associated with better sleep, and more and more research is showing how productive it is as a "non-pharmacologic sleep disorder treatment" (Logue *et al.,* 2012; Kline *et al.,* 2013; Martinez *et al.,* 2020; Tai *et al.,* 2022). Presently, there is also research to suggest that a poor sleep pattern may be attributed to the stressful conditions existing during the Covid-19 at the time, such as increased screen time and being physically inactive along with negative influences on mental health during Covid-19 (Deng *et al.,* 2021). Seeing as the National Health Policy (2017) does not address the critical issue of the requirement of adequate sleep for the population as a whole, Akhtar & Mallick (2019) advocated the need for a National Sleep Policy to improve the health outcomes due to a lack of quality sleep. According to them, as many as 33% of persons in India report having sleeplessness, irrespective of the guidelines of proper sleep among adults being seven to eight hours of sleep every night. For optimum health and longevity, since getting enough sleep of high quality is vital, PSQI was selected to measure the sleep quality of the over nourished women participants of the study.

4.3.2.3 Knowledge, attitudes and practices of subjects

Analysis of the initial data of the subjects regarding their knowledge, attitudes and practices regarding the management of obesity has been reported in Table 4.17.

Table 4.17: Initial KAP scores of the study subjects across intervention groups (N=632)

Group	Standard[#]	Mean±SD	Excess / Deficit	F_{value}
Group 0	45	12.46±1.67	-72.31	0.874 (p=0.454)[NS]
Group 1		12.41±1.67	-72.42	
Group 2		12.51±1.79	-72.20	
Group 3		12.70±1.70	-71.78	
All Groups		12.51±1.71	-72.20	

[#]WHO (2002), [NS]Non-significant

Out of the whole 45 points that was allotted to each KAP questionnaire, the average of all the women subjects was only nearly 13 on 45, indicating the immense need to improve the existing knowledge, attitudes and practices regarding the effective management of the global epidemic. The scoring methods and the percent of the subjects who got each answer correct and incorrect has been attached in the Annexure-XIV. From which it can be observed that all of the subjects only had some extent of the knowledge, especially when it came to the awareness of the attitudes and practices that can be included in their daily schedules required to counter against and manage obesity effectively. Initial degree of overnutrition and KAP of the study subjects were negatively but not significantly correlated (r=-0.023, p<0.567).

Knowledge, attitudes and practices surveys have often been used to assess the existing level of awareness of the participating populations that range from paediatrics to geriatrics. Studies have mentioned that assessing KAP is the primary step to develop educational modules, as the KAP responses helps to identify the suitable content to be utilised in achieving better understanding of a disease and its management (Lau *et al.,* 2019; Reethesh *et al.,* 2019; Laar *et al.,* 2020; Sharaf *et al.,* 2021). Although the method of developing and validating a KAP survey is not novel, the fact that a new KAP questionnaire was developed as a part of this study solely to tailor to the over nourished overweight and obese women participants that was used after pre-testing and validation among a similar population is to be recognised as a highlight of the present study.

PHASE IV

4.4 Validating intervention methods

In this section, the results of validating the intervention methods including the pilot testing of the identified exercise routines and the nutrition education modules are discussed. As the developed diet plans were already recommended by the ICMR-NIN in their publication 'Dietary Guidelines for Indians' (2011), they were not separately validated before being used among the women subjects in the present study.

4.4.1 Validating exercise routines

Once the exercise routines were identified by the investigator, they were tested among 100 women students aged between 18-25. For drawing comparisons in the identified routine's validity, half of the pilot study participants were those who had an educational background in physical education while the other half consisted of those who did not. The age and distribution of participants for pilot testing of formulated exercise routines are displayed in Table 4.18.

Table 4.18: Age and distribution of participants for pilot testing of formulated exercise routines (N=100)

Age (years)	Physical education student ts (N=50)		Non-physical education students (N=50)	
	N	%	N	%
18-20	16	32	21	42
21-23	18	36	13	26
24-25	16	32	16	32
Total	**50**	**100**	**50**	**100**

Prior studies that have validated exercise routines as an intervention, included developing a routine, pilot testing it among a representative target population, evaluation of the administered routine and finally modifying it to suit the target population (Jones *et al.,* 2021; Wang *et al.,* 2023). Among the representative population, the developed exercise routines were administered for a specific number of sessions that were timed and observations were recorded. Post the pilot testing period, the observations were analysed to validate the developed exercise routine for its structure, ease of comprehension, frequency, variations, suitability to the target population, and medium of instruction (Santos-Rocha *et al.,* 2020). Sometimes, these steps were repeated over different rounds to understand the effect of timelapse on the KAP level of the representative population (Varela-Vásquez *et al.,* 2022). These steps were also utilised in the present study, which justifies the method of validation for the exercise routines developed as an intervention method. However, it is to be noted that the techniques used to validate the identified exercise routine as in intervention in the present study is unprecedented in its approach.

Two YouTube videos had been identified as part of the initial screening by the investigator that was tested for its content, presentation and probability of compliance by the prospective study participants as presented in Table 4.19.

Table 4.19: Screening of YouTube videos with selected exercise routines (N=100)

Evaluation Criteria	Physical education students (N=50)		Non-physical education students (N=50)	
	Video 1	Video 2	Video 1	Video 2
Clarity of instruction (10)	6.8	7.2	7.3	8.8
Execution / demonstration (10)	8.8	9.0	9.0	9.2
Probability of compliance (10)	9.0	9.4	9.1	9.8
Total (30)	**24.6**	**25.6**	**25.4**	**27.8**

As observed, Video 2 had the greater acceptability due to its improved instruction clarity, demonstration of exercise, and the probability of whether the prospective study subjects would follow the identified exercise routines, among both the categories of pilot subjects and was hence selected to be used in the present study as out of the thirty total points, Video 2 scored above twenty-five points.

Testing the construct validity and inter-reviewer reliability of the developed exercise routine for its clarity, demonstration and probability of compliance set one month apart have been summarized in Table 4.20.

Table 4.20: Validity and reliability of identified exercise routines

Selected Exercise Routine (35 minutes)	Cronbach's α			Pearson's r		
	Ph. Ed. Students (N=50)	Non-Ph. Ed. Students (N=50)	Overall (N=100)	Ph. Ed. Students (N=50)	Non-Ph. Ed. Students (N=50)	Overall (N=100)
Clarity of instruction (10)	0.82*	0.88*	0.88*	0.82*	0.88*	0.88*
Execution / demonstration (10)	0.80	0.82*	0.86*	0.88*	0.88*	0.90*
Probability of compliance (10)	0.84*	0.88*	0.90*	0.84*	0.82*	0.88*
Total (30)	**0.81***	**0.85***	**0.88***	**0.85***	**0.88***	**0.90***

Ph. Ed. – Physical education students, * - Significant at 95% level of confidence

As part of the validation of the identified exercise routines the results obtained are recorded in the table below. The routines were tested to check if it changes the amount of time an individual would dedicate to exercising on a daily basis. For this, the subjects were asked to follow the video and exercise five days a week for three weeks which was a shorter period than the study intervention but similar in its approach. The total difference column in the table below denotes the sum of the differences between the initial (week zero) and final (week three) exercise timings of both the categories of pilot study students.

Table 4.21 presents the initial and final exercise timings of the participants of pilot testing phase with formulated exercise routines.

Table 4.21: Pre and post-exercise timings of participants of pilot testing with formulated exercise routines (N=100)

Week	Physical education students (N=50)		t_{value}	Non-physical education students (N=50)		t_{value}	Total Diff.#
	Pre	Post		Pre	Post		
1	33.21 ±5.40	40.51 ±5.32	3.81* (p=<0.001*)	8.41 ±4.17	30.12 ±2.17	97.12*	27.01
2	40.3 ±3.17	45.25 ±2.43	2.75^{NS} (p=0.218)	30.42 ±2.13	35.12 ±3.27	37.18*	9.8
3	45.12 ±8.13	45.51 ±6.23	-1.67^{NS} (p=0.109)	35.12 ±5.12	36.5 ±3.12	2.54^{NS}	-10.22
Total	**119.63 ±17.1**	**120.27 ±14.35**	**1.32^{NS} (p=0.318)**	**74.65 ±11.42**	**101.74 ±8.56**	**98.35***	**28.02**

*Significant, ^{NS}Non-significant,
#Sum of the pre and post differences in exercise durations of students from physical education and non-physical education backgrounds.

From the table, it can be observed that among the physical education students, the average minutes spent for exercise was nearly 33 minutes at the first week of the pilot testing period which increased to 45 minutes by week three. A similar but statistically significant increase was observed among the non-physical education students, where their initial time spent for exercise at week one started with less than 10 minutes of physical activity and ended at 36 minutes by the third week. The difference in the time spent on exercise among physical education students and non-physical education students may be justified owing to the probability that the physical education students may be physically active for more amount of time than their counterparts, apart from following the prescribed video that was pilot-tested.

It can be observed through the results of the pilot study (Table 4.21) that the exercise routine increased the overall time spent doing physical activity by the women from both non-physical education backgrounds and physical education backgrounds. However, it was more prominent in the former group of the participants of this pilot study, as statistically determined utilising the paired samples t-test, and was hence utilised in the present study.

4.4.2 Validating nutrition education modules

The developed nutrition education modules were tested in the same manner as the KAP survey tool (section 4.1 of this chapter) among 50 women from an educational background in nutrition and 50 women from other educational backgrounds. Each developed module was tested for its likelihood of imparting knowledge, subject clarity and ease of understanding by prospective study subjects. All ten modules that were developed were found to be reliable and valid to be used in the present study as denoted in Table 4.22.

Table 4.22: Validity and reliability of formulated nutrition education module

Nutrition Education Modules	Cronbach's α			Pearson's r		
	Nutrition Students (N=50)	Non-nutrition Students (N=50)	Overall (N=100)	Nutrition Students (N=50)	Non-nutrition Students (N=50)	Overall (N=100)
Module 1: RDA	0.79	0.83*	0.86*	0.80	0.83*	0.82*
Module 2: Water	0.80	0.88*	0.88*	0.80	0.82*	0.82*
Module 3: Food Measuring	0.79	0.86*	0.82*	0.80	0.83*	0.82*
Module 4: Physical Activity	0.80	0.86*	0.88*	0.80	0.82*	0.81*
Module 5: DM1-Fibre	0.81*	0.86*	0.88*	0.78	0.82*	0.82*
Module 6: DM2-Protein	0.80	0.88*	0.88*	0.78	0.81*	0.81*
Module 7: DM3-Sugar & Salt	0.80	0.88*	0.88*	0.80	0.83*	0.82*
Module 8: DM4-Essential Fats	0.79	0.88*	0.88*	0.80	0.84*	0.82*
Module 9: DM5-Processed Foods	0.80	0.82*	0.82*	0.78	0.86*	0.86*
Module 10: Cooking Methods	0.79	0.86*	0.88*	0.76	0.86*	0.88*
Total	**0.80**	**0.85***	**0.90***	**0.82***	**0.85***	**0.90***

Among the research carried out in the Indian population, KAP surveys have been crucial in developing nutrition education modules aimed at increasing awareness about dietary behaviour, food choices, physical activity, sports nutrition, healthy food preparations aimed at better nutritional quality of household meals, and the management of NCDs such as hypertension, cardiovascular diseases and obesity (Elias *et al.,* 2018; Moitra *et al.,* 2021; Al-Makhroumi *et al.,* 2022; Cheikh Ismail *et al.,* 2022). Therefore, the present study recognized the need to validate the developed KAP questionnaires and the developed educational modules to be used as an intervention among the women over nourished subjects to facilitate their awareness on managing the epidemic of obesity.

4.4.3 Validating sample diet plans

The sample diet plans that were used were already validated and promoted by the Indian Council of Medical Research (ICMR-NIN, 2010) in their publication, “Dietary Guidelines for Indians: A Manual” (in their Annexure 2b, page 88). Hence, although the recommended sample diet was modified to include non-vegetarian meals, additional steps to validate them were not taken.

PHASE V

4.5 Assessing impact of interventions on subjects

In this section, the observable impact of the imparted interventions on the subjects of the present study has been detailed.

4.5.1 Impact of intervention on nutritional status of subjects

This section discusses the post-intervention nutritional status of the subjects including their anthropometric parameters, their biochemical parameters, their clinical assessments, morbidity pattern and their dietary intake.

4.5.1.1 Anthropometric parameters of subjects

As the tables 4.23 and 4.24 (next page) below summarise, it can be seen that the self-reported anthropometric parameters such as weight, BMI and WHR have changed since the intervention period.

Table 4.23: Anthropometric parameters of subjects after intervention (N=632)

Parameter	Standard	Mean±SD	t_{value}
Weight (kg)	55[a]	59.54 ± 5.13	4.15*
BMI (kg/m^2)	28.5-23.9	24.27 ± 1.81	2.52*
WHR	0.80[b]	0.83 ± 0.28	3.12*

[a] ICMR (2020), [b] WHO (2011), * Significant at 95% confidence level

The average weight is still higher than the recommended levels while both the BMI and the WHR have decreased.

Table 4.24 shows the inter-group changes in the anthropometric parameters as a result of the imparted intervention. It can be observed that group zero had little to no changes in their anthropometric parameters while Group 1 had an approximate seven kilograms weight loss and a three-point reduction in the BMI levels. Group 2 had an approximate of four kilograms weight loss and a two-point BMI level reduction. The most changes, i.e., nine kilograms weight loss and a four-point reduction in the BMI levels were seen in Group 3. The WHR was a consistent 0.06 point reduction in the experimental Groups 1 and 3 while it was a 0.04 point reduction in Group 2. All the observed changes have been statistically determined to be significant in the experimental groups.

Table 4.24: Impact of interventions on anthropometric parameters of subjects (N=632)

Group	Group 0 (N=158)			Group 1 (N=158)			Group 2 (N=158)			Group 3 (N=158)		
	Pre	Post	t_{value}	Pre	Post	t_{value}	Pre	Post	t_{value}	Pre	Post	t_{value}
Weight (kg)	63.31± 4.08	63.96± 4.42	-11.30	64.68± 3.71	57.47± 3.56	-51.17*	64.64± 4.81	60.92± 3.89	-18.27*	64.78± 4.81	55.80± 4.31	-65.21*
BMI (kg/m^2)	26.08± 1.21	26.34± 1.24	-11.38	26.39± 1.03	23.45± 1.05	-24.11*	26.31± 1.02	24.79± 1.01	-21.73*	26.13± 1.15	22.51± 1.06	-29.15*
WHR	0.881± 0.01	0.880± 0.17	0.164	0.885± 0.01	0.822± 0.01	-2.39*	0.886± 0.01	0.845± 0.12	-2.21*	0.888± 0.15	0.825± 0.01	-2.76*

*Significant at 95% level of confidence

Table 4.25 shows the anthropometric parameters of sub-subjects after intervention.

Table 4.25: Anthropometric parameters of sub-subjects after intervention (N=164)

Parameter	Standard	Mean±SD	t_{value}
Weight (kg)	55[a]	60.07 ± 0.42	32.41*
BMI (kg/m^2)	18.5-23.9	24.42 ± 0.14	31.61*
WHR	0.80[b]	0.83 ± 0.002	43.10*
SMM (kg)	16.8 – 20.5	20.61 ± 0.13	-24.16*
PBF (%)	18.0 - 28.0	28.66 ± 0.21	22.27*
BMR (kcals)	1189 - 1371	1351.57 ± 4.95	26.33*
Fitness Score[c]	70-79	68.51± 1.13	-33.12*

[a] ICMR (2020), [b] WHO (2011),
[c] Fitness score does not have a referral range
* Significant at 95% confidence level

Among the subset samples, that had their post-intervention anthropometric parameters measured with the body composition analyser, it can be observed that except for the SMM parameter, all other anthropometric parameters have the measurements above the recommended range among all the subjects.

However, when considering the intergroup variability, it can be seen that there are statistically significant changes in all the three experimental groups, as shown in Table 4.26.

Table 4.26: Impact of interventions on anthropometric parameters of sub-subjects (N=164)

Parameter	Group 0 (N=41)			Group 1 (N=41)			Group 2 (N=41)			Group 3 (N=41)		
	Pre	Post	t_{value}	Pre	Post	t_{value}	Pre	Post	t_{value}	Pre	Post	t_{value}
Weight (kg)	64.71± 3.77	65.50± 4.17	0.015	65.00± 4.06	57.83± 3.82	-61.31*	65.03± 3.97	61.26± 3.68	-50.48*	64.33± 4.72	55.70± 4.51	-31.94*
BMI (kg/m^2)	26.38± 0.91	26.7± 0.94	0.273	26.47± 0.97	23.55± 0.93	-64.73*	26.34± 0.98	24.81± 0.97	-64.01*	26.10± 1.00	22.62± 1.25	-26.89*
WHR	0.885± 0.14	0.885± 0.17	0.139	0.88± 0.15	0.82± 0.14	-50.82*	0.88± 0.15	0.86± 0.14	-58.07*	0.88± 0.16	0.82± 0.14	-5.92*
SMM (kg)	19.35± 0.92	19.34± 0.92	0.287	19.29± 1.10	21.78± 1.42	24.4*	19.42± 0.89	19.42± 0.88	-2.11	19.33± 0.91	21.89± 1.40	20.27*
PBF (%)	31.37± 1.25	31.88± 1.33	0.191	31.5± 1.52	27.45± 1.55	-17.63*	31.39± 1.47	29.31± 1.41	2.53	30.93± 1.61	26.02± 2.16	-22.29*
BMR (kcals)	1410.99± 71.42	1391.23± 56.02	0.381	1296.48± 53.67	1355.55± 53.15	10.04*	1356.72± 52.12	1322.96± 46.42	37.97*	1265.62± 60.49	1357.16± 56.01	26.33*
Fitness score	53.15± 0.88	54.17± 2.46	0.15	55.17± 2.15	82.56± 2.71	62.82*	54.80± 2.68	54.80± 3.01	0.171	54.22± 2.36	82.51± 5.45	-33.20*

*Significant at 95% level of confidence

In terms of body weight, there was an average decrease of eight kilograms in Group 1 while there was an average decrease of four kilograms in Group 2 and an average decrease of nine kilograms for Group 3, indicating that the more statistically significant degree of weight loss may have occurred with the combined intervention of exercises and nutrition education. The degree of overweight/obesity was negatively correlated with SMM ($r=-0.545$, $p<0.001$), BMR ($r=-0.723$, $p<0.001$) and fitness score ($r=-0.736$, $p<0.001$) while it was positively correlated with PBF ($r=0.964$, $p<0.001$).

In previous studies, there has been no focus on the role of lifestyle interventions such as physical activity or dietary modifications in women who do not have any underlying diseases. In a 2015 study that aimed to find the difference in the effectiveness of weight loss interventions among men and women, it was noted that even thought at first glance it seemed as if the male subjects lost more weight in comparison to the female subjects, there was no significant differences that suggested different weight loss strategies for either gender. Rather, the evidence suggested that both men and women can lose weight by moderately restricting their caloric intake and exercising (Williams *et al.,* 2015). In another case–control intervention study that examined the effect of weekly motivational talks and aqua aerobic classes as interventions among obese, pregnant women, it was found that the intervention program was successful in preventing weight gain throughout the pregnancy which had no impact on the delivery process or the health of the newborn (Claesson *et al.,* 2008). Studies that have probed upon the influence of lifestyle interventions on the risk of body weight on diabetes among Indian women indicate that future interventions to lower diabetes risk should concentrate primarily on weight loss. This was because, among the 495 participants of the study, those who improved their physical activity, had a 44 percent of lowered risk of diabetes. Similarly, an intense lifestyle intervention of at least 150 minutes of physical activity per week has a comparable effect to a pharmacological intervention on reducing the incidence of diabetes among women who had a history of the said NCD (Hamman *et al.,* 2006; Ratner *et al.,* 2008).

In terms of body mass indices (BMI), there was an average decrease of three kilograms per meter square in Group 1 while there was an average decrease of two kilograms per meter square in Group 2 and an average decrease of four kilograms per meter square for Group 3, indicating that the more statistically significant degree of BMI reduction may have occurred with the combined intervention of exercises and nutrition education.

In a similar study, the first and biggest community-based weight reduction intervention study, known as the ‘My Body is Fit and Fabulous at home’ (MyBFF@home), that had been carried out in Malaysia targeting overweight and obese housewives, it was found that a combined intervention of exercise regimes of minimum 30 minutes in duration as well as a reduced calorie diet following an education programme led to improvements in the BMI levels of the over nourished women (Mohamad *et al.,* 2018; Fazliana *et al.,* 2018). Meta analysis studies have also derived that utilising a combination of resistance training or aerobic training, along with calorie restrictive diets yielded higher a percentage of improvements in fat mass and overall BMI levels, of the overweight and obese subjects of the study (Arslan, 2011; Zouhal *et al.,* 2020; Lopez *et al.,* 2022).

When it came to the waist-to-hip ratio (WHR), there was a 0.06 average reduction observed in Group 1 and Group 3. However, the average reduction in Group 2 was 0.02. This difference observed may be due to the increased effect of exercise on the WHR of the women subjects as compared to the effect of nutrition education. The final BMI and WHR were found to be slightly positively and significantly correlated ($r=0.603$, $p<0.001$).

A study by Srivastava *et al.,* (2021) suggests that recognizing physical activity as a method of reducing comorbidities is necessary since increased physical activity has been associated with proportional declines in WHR of men and women. Additionally, although there aren’t many studies that emphasise the possible role of educational interventions on the WHR of over nourished individuals, a recent study described how a nutritional education-based intervention for addressing the issue of obesity in adults led to weight loss, dietary changes, and a decrease in fat intake. Better eating practices and a lower risk of cardiovascular disease was also linked to increased nutritional awareness due to the intervention (López-Hernández *et al.,* 2020). Considering both of these studies, the current assumption regarding the observed changes among the intervention groups in the present study may be held true, as stated above.

In terms of skeletal muscle mass (SMM), there was an average increase of two kilograms in Groups 1 and 3. However, the SMM for Group 2 did not change from the initial average measurement of the subjects. This difference observed may be due to the more pronounced effect that exercise intervention has on the SMM of the subjects as compared to the nutrition education intervention. A study that exclusively focused on the effect of exercise on the skeletal muscle mass among overweight individuals reported that regular exercise can improve SMM, irrespective of whether the subjects were diagnosed with chronic obstructive pulmonary disease (Li *et al.,* 2021). Prior studies that have examined the effect of nutritional interventions and resistance exercise on the regulation of skeletal muscle mass have noted that exercise training improves musculo-skeletal health while increasing muscle mass. This effect seems to increase when there is an adequate consumption of vitamin D, essential amino acids and milk proteins through the diet (Candow *et al.,* 2012; McGlory *et al.,* 2019). This highlighted the need for incorporating physical activity and nutrition education interventions for improving SMM, in a metabolically healthy, yet over nourished population of young women.

Considering percent body fat (PBF) or body fat percentage, there was an average four percent reduction in Groups 1 and 3 while it was a two percent reduction in Group 2. Similar to the WHR and SMM observations, this observation could also be due to the increased effect of exercise over nutrition education as the intervention method. This has been supported by the studies discussed previously such as Lopez *et al.,* (2022), Zouhal *et al.,* (2020) and Arslan (2011) which report that physical activity when carried out regularly, i.e., for at least eight weeks can have beneficial effects on the levels of percent body fat of the study subjects who were majorly middle-aged women with sedentary lifestyles.

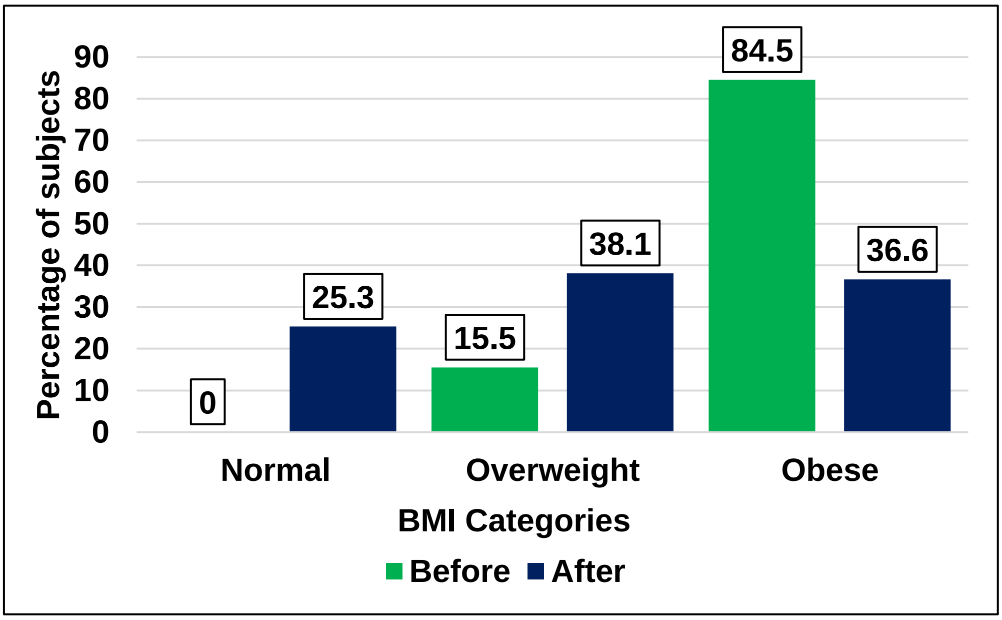
In terms of basal metabolic rate (BMR), there was an average increase of about 59 kilocalories among the Group 1 subjects while there was an average decrease of 39 kilocalories in Group 2 and an average increase of 92 kilocalories in Group 3. The combined effect of the exercise and nutrition education intervention could be the reason why there is more effect among the women subjects of Group 3. There have been studies that observed the relationship between exercise, nutrition education and changes in the BMR of study subjects with and without other NCDs such as diabetes or cancer (Arslan, 2011; Trestini *et al.,* 2021). In these studies, similar to the observed results of the present study, it was reported additional health related education as compared to exclusive concurrent training resulted in reduction of body weight and improvements of the BMR, of the obese women subjects of the study (Srivastav *et al.,* 2021 Sullivan *et al.,* 2021; Huang *et al.,* 2023).

In terms of the fitness score observed among the subjects, there was an average increase of about 27 points among the subjects of Group 1 intervention group while it did not change for the subjects of the intervention Group 2. There was a higher i.e., a 28 point increase in the BMR of the subjects in the intervention Group 3. Since the fitness score is an arbitrary score generated by the body composition analyser at the time of the analysis, combining all the indicators such as PBF, SMM, BMI, WHR and the weight of an individual, it can be stipulated that the combined effect of interventions of exercise and nutrition education is what caused the 1 point increase as compared to the other two intervention groups.

As observable from the results above, it is Group 3 that had the most changes in the measured anthropometric parameters after the intervention period, indicating that the better intervention out of the two methods would undoubtedly be a combination of the two, instead of one over the other. This is also in agreement with the findings from research studies that are recent or have been conducted over the years that state the additive effect of exercises and nutrition education interventions or health intervention programs towards reducing the extent of over nourishment in young women (Choi & Kim, 2006; Lee *et al.,* 2010; Bandyopadhyay, 2022).

As depicted in the graph below (Graph 4.11), it can be understood that at the end of the intervention period, there was a complete change in the BMI levels of the subjects.

Graph 4.11: Impact of intervention on BMI categories of study subjects (N=632)



There is a 47 percent reduction in the obese category while a 22 percent increase is visible in the overweight category along with a 25 percent increase in the normal category. The increase in the overweight category can be attributed to the shifting of subjects from the obese BMI category to either normal or overweight BMI categories as a result of the interventions of exercise and nutrition education.

4.5.1.2 Biochemical parameters of subjects

The biochemical parameters were assessed only for the 164 women sub-samples due to the Covid-19 restrictions prevalent at the time, the results of which are presented in Table 4.27.

Table 4.27: Biochemical parameters of sub-subjects after intervention (N=164)

Parameter	Standard	Mean±SD	t_{value}
RBG (mg/ dl)	70-140	107.39 ± 14.2	<0.001*
Hb (g)	12.0-15.0	15.06 ± 2.98	<0.001*
T_3 (ng/dl)	70-204	88.81 ± 2.31	<0.001*
T_4 (mcg/dl)	4.6-12.0	4.67 ± 0.46	<0.001*
TSH (mc IU/ml)	0.35-5.5	0.933 ± 0.33	<0.001*

*Significant at 95% confidence level

Although the RBG levels are within the normal range, it is the haemoglobin content that needs to be noted, which is above the recommended range for the subjects, suggesting a link between exercise and nutrition education and the increase in haemoglobin. Final BMI levels and post-intervention biochemical parameters such as RBG ($r=0.133$, $p<0.001$) and Hb ($r=0.946$, $p<0.001$) were positively correlated while the thyroid parameters such as T_3 ($r=-0.169$, $p<0.001$), T_4 ($r=-0.198$, $p<0.001$) and TSH ($r=-0.188$, $p<0.001$) were negatively correlated.

Table 4.28 presents the impact of interventions on the biochemical parameters of sub-subjects.

Table 4.28: Impact of interventions on biochemical parameters of sub-subjects (N=164)

Parameter	Group 0 (N=41) (Mean±SD)			Group 1 (N=41) (Mean±SD)			Group 2 (N=41) (Mean±SD)			Group 3 (N=41) (Mean±SD)		
	Pre	Post	t_{value}	Pre	Post	t_{value}	Pre	Post	t_{value}	Pre	Post	t_{value}
RBG (mg/ dl)	105.87± 13.82	108.33± 13.87	2.051	103.44± 14.17	106.73± 14.07	70.52*	101.75± 15.05	104.21± 15.09	58.07*	105.92± 13.53	110.28± 13.56	98.91*
Hb (g)	11.96± 1.14	12.12± 1.15	0.942	11.68± 1.00	12.02± 1.01	23.73*	11.81± 0.96	13.89± 2.21	38.05*	11.48± 1.06	13.62± 1.06	97.91*
T_3 (ng/ dl)	98.94± 2.27	97.62± 1.50	1.016	102.04± 3.73	89.49± 2.38	-58.77*	102.27± 3.66	89.67± 2.21	-53.99*	100.3± 3.28	86.45± 2.46	-36.89*
T_4 (mcg/ dl)	5.72± 0.26	5.64± 0.30	0.041	5.70± 0.34	4.68± 0.47	-22.05*	5.73± 0.32	4.68± 0.04	-23.68*	5.72± 0.33	4.66± 0.46	-20.52*
TSH (mc IU/ml)	4.34± 0.24	4.74± 0.23	0.418	4.57± 0.25	1.03± 0.35	-64.88*	4.60± 0.21	1.05± 0.32	-48.30*	4.48± 0.26	0.90± 0.33	-52.48*

*Significant at 95% confidence level

The considerable high amount of variance in the standard deviation of the random blood glucose levels can be explained when Table 4.28 is studied. It is because there is little change in the measurements of Group zero which remains at the initial 11-12g of haemoglobin, that lowers the cumulative average of all the groups. It should also be emphasised that there was an observed increase in the RBG levels, in all the intervention groups, i.e., almost an increase of three milligram per decilitre in Group 1 and Group 2, and an increase of five milligram per decilitre in Group 3, which may suggest a connection in between increased physical activity and improved glucose uptake throughout the body. Studies conducted by Röhling *et al.,* (2016), Myers *et al.,* (2019), Yang *et al.,* (2019) and Nagarathna *et al.,* (2020) support the present study's findings while also noting that there are multiple signalling pathways responsible for improvements in glucose metabolism and uptake and the resulting increases in the serum glucose levels due to exercise, over a period of time.

Regarding the haemoglobin levels of the women subjects, Group 1 had a 0.4 gram increase as compared to the intervention Group 2 that had a 2.0 gram increase and the 2.2 gram increase in Group 3 which were statistically significant improvements. The maximum increase in the third intervention group may be due to the combined approach of both the interventions of exercise and nutrition education. Previous studies that have analysed the associations between improved serum haemoglobin and physical activity include the work of Kriswanto *et al.,* (2021), who state that there can be an improvement of serum Hb levels up to an extent of 28.6 percent by following exercise routines for 24 weeks.

Considering the thyroid levels, there was a consistent reduction in all the three parameters i.e., T_3, T_4 and TSH across the experimental groups. In the levels of triiodothyronine (T_3), there was a marked 13 nanogram per decilitre reduction in Group 1 and Group 2 while there was a marked 14 nanogram per decilitre reduction in Group 3. The one-point increase of the third group as compared to the other two groups could be due to the combined effects of both exercise and nutrition education interventions. In the thyroxine or tetraiodothyronine levels (T_4), there was a uniform 1.1 microgram per decilitre reduction across all the three intervention groups which may suggest that serum T4 levels are not subjectable to change due to an exercise or educational intervention. The changes in the serum thyroid stimulating hormone (TSH) levels were similar to the pattern as observed in the T_3 levels. Group 1 and had an average reduction of 3.54 micro international units per millilitre while the second intervention group i.e., Group 2 had an average reduction of 3.55 micro international units per millilitre and Group 3 had an average reduction of 3.58 micro international units per millilitre.

Prior research states that individuals with thyroid dysfunction benefit from regular physical activity (Sabini *et al.,* 2015) and even though there is research that states that being physically active is inversely related to the thyroid hormone levels (Klasson *et al.,* 2022), research also states that thyroid hormones and overall physical activity are not shown to be correlated (Roa *et al.,* 2021). Besides this, in the same population, mixed findings were seen from weight change therapies targeting thyroid function (Kouidrat *et al.,* 2019). Furthermore, where the influence of diet on thyroid function was examined, it was determined that there were significant effects of dietary intake on thyroid function (Croce *et al.,* 2021). Thus, as supported by some recent research in this field as cited above, the changes observed in the present study may warrant a link between increased physical activity and thyroid function improvement.

4.5.1.3 Clinical parameters of subjects

The post-intervention clinical assessment of the subjects was conducted for the 164 sub-sample women which revealed that there was a 38 percent of the subjects who did not have any of the symptoms by the end of the study period as compared to what they had previously listed at the beginning of the study period. This has been presented in Table 4.29.

Table 4.29: Clinical symptoms of study sub-sample after intervention (N=164)

Sl. No.	Clinical symptoms	N	%
1	Tenderness of muscles	23	14.1
2	Mild anaemia	1	0.61
3	Nutritional oedema	17	10.3
4	Xerosis / pigmentation of cornea	16	9.8
5	Angular stomatitis	3	1.83
6	Red/glazed tongue	2	1.22
7	Bleeding gums	4	2.44
8	Dental caries	21	12.7
9	Pigmentation of skin	8	4.9
10	Dry / rough skin	6	3.7
11	No symptoms	63	38.4

It can also be observed that are reductions in the number of women experiencing these symptoms, the most notable of which is where seven percent of the women felt that the physical activity and/or mindful eating they had participated in reduced the tenderness of their muscles. Examining the post-intervention clinical symptoms among the 164 women subjects from Table 4.29, it was revealed that there was a 7.4 percent of the women who reported a reduction or complete withdrawal in the tenderness of muscles symptom as compared to the initiation period of the study. There have been reports of prior research that suggests that increased or improved physical activity levels of an individual can help with muscle tenderness. Physical activity has been shown to have positive impacts on the musculoskeletal system since it helps to ease back pain, general muscular soreness, and ankle sprains (Yang, 2019). Meta analysis of research that studied the association of non-specific low back pain and total and domain-specific physical activity among adults revealed an inverse association between physical activity and lower back pain (Alzahrani *et al.,* 2019).

In terms of the clinical symptoms of mild anaemia, there was a 1.3 percent reduction among the women subjects as compared to the initiation period of the study. Research has suggested that a balanced diet has the potential to alleviate the symptoms of mild anaemia. A review on the existing scenario of nutritional anaemia by Bhadra and Deb (2020), has suggested that anaemia can be avoided by changing one's eating habits, and that eating nutritious, wholesome diet can treat anaemia. While Swaminathan *et al.,* (2019) asserts that the weak correlation between dietary iron intake and anaemia explains why there aren't many successful iron fortification measures in India, other research has also suggested that unlocking the health benefits of food and hygiene habits to lower anaemia requires integrating behavioural change components such as nutrition educational interventions or improvement in consumption of iron rich foods through home gardens (Sujatha & Kowsalya, 2018; Baliki *et al.,* 2023).

Nutritional oedema decreased from 10.9 percent to 10.3 percent i.e., a 0.6 percent reduction which can be due to a combination of the physical activity and nutrition education interventions. This is supported by recent research that states that the symptoms of nutritional oedema in an individual, apart from having other causes, may recede in the presence of regular exercise and a balanced diet consumption. Prior research conducted in a similar population, i.e., among non-athletic young obese women suggested that aerobic exercise for 8 weeks was useful in lowering PMS symptoms, including nutritional oedema (Samadi *et al.,* 2013). Apart from this, improved intake of dietary protein has also been associated with reduced symptoms of nutritional oedema (Wu, 2016; Keith *et al.,* 2020; Singh & Revand, 2022) i.e., the more the intake of dietary protein, the less chances of lower-limb oedema being expressed, which is in concordance with the present study's findings.

The clinical symptom of corneal pigmentation was reduced by a 4.3 percent among the women subjects which may be attributed to the nutrition education intervention and the subsequent improvement in dietary practices and healthy consumption. The findings of the present study re-establish existing research that suggests that dysfunction of the eye including mild corneal pigmentation can be controlled or even reversed by incorporating a diet rich in long chain omega three polyunsaturated fatty acids into the daily lifestyle (Francisco *et al.,* 2020; Britten-Jones *et al.,* 2023).

The symptoms of angular stomatitis or angular cheilitis was also observed to have reduced by a 2.4 percent among the women subjects of the study. Research carried out by Bidyasagar *et al.,* (2019) and others (Akmal *et al.,* 2021; Rajendran & Pandurangan, 2021) evidentially suggests the contribution of a balanced diet or a diet that meets the adequate amounts of the vitamin B_{12} in the effective management of angular stomatitis.

The glazed tongue that has been previously associated with nutritional deficiencies of iron and vitamin B_{12} (Nuraeny, 2019; Chaudhary, 2019) had reduced by a 2.4 percent by the end of the intervention period from 3.6 percent to 1.2 percent, thereby suggesting a link between improved dietary practices and reduced observation of the glazed tongue symptom.

The clinical symptom of bleeding gums was observed to have reduced by 4.3 percent among the subjects by the end of the study period. Although research suggests that scurvy was abolished in the country, long ago, there have been reports that point-out the possibility that the deficiency symptom has not completely disappeared as a public health concern, especially among school aged children (Kaur & Goraya, 2021; Rahayu & Pangarungan, 2021). This could also be the reason why clinical studies still promote good dietary practices as the best prevention tactic towards handling this symptom related to the deficiency of vitamin C (Dresen *et al.,* 2023) which is also in agreement with the results of the present study.

Dental caries may be a symptom of excess consumption of foods containing sugar and starch along with poor oral hygiene as established by prior research (Islam *et al.,* 2007; Foley & Akers, 2019; Hancock *et al.,* 2020). After the intervention period, it was observed that the symptom of dental caries had reduced by a 0.2 percent. Reportedly, although dental caries is irreversible once they progress deep inside the tooth, research states that the early signs of tooth decay are reversible through mindful eating and judicious consumption of foods containing sugar and starch (Carounanidy & Sathyanarayanan, 2009; Sivapathasundharam & Raghu, 2020). It is to be noted that the results of the present study that pertained to this could be attributed also to the nutritional education intervention (Module 7) provided to the women participants of this study.

The clinical symptoms of skin pigmentation and rough skin decreased by a percentage of 0.2 percent and 1.8 percent respectively after the intervention period which could be a combined effect of the exercise and nutrition education intervention. This finding is supported by prior research that had concluded that a balanced diet including essential oils and fats along with healthy lifestyle behaviours including physical activity may be beneficial against the symptoms of skin diseases such as dry skin and pigmentation of the skin (Kaur *et al.,* 2019; Cao *et al.,* 2020; Faria-Silva, *et al.,* 2020).

Finally, it can be said that there was an increase in the women subjects from 10.3 percent to 38.4 percent i.e., a 28.1 percent increase that reported no symptoms towards the end of the intervention period. Therefore, as understood from the above results that have been supported by studies done across the globe, among women and other populations, the possibility that nutrition education and physical activity could have influenced the betterment of these nutritional deficiency symptoms cannot be negated completely.

Assessing the post-intervention morbidity pattern for the entire study sample revealed that there was an improvement in the episodes of morbidity, especially food poisoning among the study participants after the study period, as represented in Table 4.30.

Table 4.30: Final morbidity pattern of subjects (N=632)

Morbidity status (up to 3 months)		Post	
		N	%
Episodes of morbidity	Not sick up to 3 months	303	47.9
	Cold / cough	126	19.9
	Fever	181	28.6
	Vomiting / diarrhoea	17	2.7
	Food poisoning	5	0.8
Frequency of above episodes	No occurrence up to 3 months	226	35.8
	Once a month	88	13.9
	Once in two months	131	20.7
	Once in three months	184	29.1
	Rarely	2	0.3
Use of medicines during episodes	No medicines	461	72.9
	All the time	16	2.5
	Sometimes	155	24.5

A marked improvement was also seen with respect to how the frequency of the above-mentioned morbidities occurred less in the months following the intervention. The change in subjects shifting from a monthly morbidity frequency to a once in three months frequency is also notable. A change was also observed in the way the study subjects sought medication for these episodes. By the end of the study period, there was a decrease in those who hadn't preferred taking medicines during bouts of sickness as well as those who preferred medicines each time they fell ill. However, there was an increase in those who wanted medicines for some of their morbidity episodes.

Obesity and a number of diseases are known to be associated, although targeting any disease independently becomes difficult to prevent, due to the probability of them having complex comorbidities. Hence, there is a need to investigate the relationship between obesity-related disorders, the role that the epidemic plays in the emergence of such complex multimorbidity, and obesity as a shared contributory factor for common diseases (Kivimäki *et al.*, 2022; Sharma *et al.*, 2023).

4.5.1.4 Dietary pattern, food and nutrient intake of subjects

Table 4.31 shows the average food intake of the study subjects, post the study intervention.

Table 4.31: Average final food intake of subjects (N=632)

Food Groups	Standard (ICMR, 2020)#	Food Intake (Mean±SD)	Excess / Deficit	t_{value}
Cereals (g)	270	273.17 ± 51.2	3.17	3.12*
Pulses (g)	60	53.1 ± 4.81	- 6.9	1.32^{NS}
Milk & Milk Products (g/ml)	300	231 ± 29.2	- 69	2.81*
Animal food (g)	60	47.4 ± 6.12	- 12.6	3.43*
Vegetables (g)	200	72.4 ± 15.9	- 127.6	2.81*
GLV (g)	100	24.7 ± 11.17	- 75.3	2.93*
Roots and Tubers (g)	200	132.61 ± 11.7	- 67.39	2.17^{NS}
Fruits (g)	100	128.3 ± 7.12	28.3	2.89*
Fats and oils (g)	20	19.2 ± 3.53	- 0.8	36.12*
Sugar and jaggery (g)	20	15.2 ± 2.74	- 4.8	19.21*

#Recommended Dietary Allowances, 2020

*Significant, ^{NS}Not significant

On understanding the table, it can be seen although most of the food groups were still being consumed lesser than the recommended levels, and that there was a reduction in the extent of percent deficit of the consumption of the food groups as compared to the start of the study period. This is most notable in the consumption of pulses, fats and oils as well as sugar and jaggery.

This change can be further observed among the control and experimental groups when studying Table 4.32.

Table 4.32: Impact of interventions on food intake of subjects (N=632)

Food Group	Group 0 (N=158)			Group 1 (N=158)			Group 2 (N=158)			Group 3 (N=158)		
	Pre	Post	t_{value}	Pre	Post	t_{value}	Pre	Post	t_{value}	Pre	Post	t_{value}
Cereals (g)	283.17± 51.01	286.21± 51.47	2.16	315.29± 47.81	332.41± 46.13	2.51	307.19± 59.47	263.17± 27.12	261.7*	287.43± 61.8	265.21± 30.15	400.12*
Pulses (g)	41.68± 8.23	42.47± 12.81	1.27	43.17± 5.63	44.61± 8.23	1.39	43.59± 6.13	53.2± 4.75	303.51*	44.12± 8.23	59.12± 4.32	472.61*
Milk & Milk Products (ml/g)	200.73± 4.12	200.61± 3.25	1.31	209.81± 3.57	214.76± 4.16	1.26	213.61± 5.41	230.81± 9.81	254.9*	202.69± 5.21	232.51± 2.72	416.31*
Animal foods (g)	53.17± 3.12	56.12± 4.13	0.98	58.27± 3.72	59.81± 2.89	2.41	54.12± 4.19	44.81± 3.14	313.74*	52.17± 3.29	41.31± 3.18	430.57*
Vegetables (g)	51.34± 11.94	50.89± 12.31	1.15	53.57± 9.83	54.12± 7.83	1.12	55.61± 7.81	71.81± 4.16	213.84*	52.41± 8.23	73.51± 7.12	430.13*
GLV (g)	19.21± 8.57	15.16± 4.18	1.61	21.12± 7.51	22.37± 5.42	2.16	23.17± 8.12	31.62± 6.39	302.61*	22.19± 6.29	33.18± 7.28	412.71*
Roots & Tubers (g)	131.01± 14.16	129.81± 15.41	2.71	121.61± 13.71	123.14± 6.81	2.09	120.51± 2.61	139.37± 6.51	316.71*	135.59± 11.31	141.69± 8.31	400.91*
Fruits (g)	103.17± 5.12	104.51± 5.17	1.29	110.60± 2.13	112.61± 21.7	1.06	127.84± 4.17	132.41± 3.12	270.91*	103.41± 12.27	138.53± 4.12	361.73*
Fats (ml/g)	26.12± 5.17	28.12± 5.95	1.86	23.12± 6.19	24.15± 6.52	2.18	25.16± 2.41	17.81± 2.16	350.41*	23.12± 4.72	21.2± 3.13	376.41*
Sugar (g)	17.92± 3.12	19.31± 2.12	1.36	21.34± 7.01	21.31± 5.21	2.13	19.12± 3.12	13.12± 2.13	384.71*	23.12± 6.12	14.15± 2.17	412.51*

*Significant at 95% confidence level

Considering the consumption of cereals, there was increase in the consumption in Group 1 by 17 grams, while there was a reduction of 44 grams in Group 2 and 22 grams in Group 3. Regarding pulses, there was an increase of 1.5 grams in the first intervention group while there was a 9.7 gram increase in the second and a 15 grams increase in the third intervention group. The consumption of milk and milk products increased uniformly among the three intervention groups. It increased by 5 millilitres or grams in Group 1, by 17 millilitres or grams in Group 2 and by 30 millilitres or grams in Group 3. Similarly, the vegetable consumption among the women subjects increased by approximately 10 grams in Group 2 and Group 3 while it did not increase pronouncedly in the first intervention group. In the case of green leafy vegetables, there was a 1.2 gram increase among the subjects of Group 1, while there was an increase by 8.5 grams in Group 2 and 11 grams in Group 3. The consumption of roots and tubers also increased among the three intervention groups - by 1.5 grams in Group 1, 19 grams in Group 2 and 6 grams in Group 3. Fruits was the food group that had the highest improvement in terms of food choices because there was an increase of 35 grams in Group 3 as compared to the 2 grams and 5 grams increase in Group 1 and 2 respectively. While the intake of fats and oils increased slightly in Group 1, it lowered to 7.3 millilitres or grams in Group 2 and only slightly decreased in Group 3. This could be due to the nutrition education intervention method among the subjects of Group 2 that encouraged the subjects to cut down their intake of the food group. However, the same cannot be said about the subjects of Group 3 since it is probable that they cut down on, but replaced their usual sources of fat with healthier options.

This has also been supported by Karpińska *et al.,* (2022) and Kumar *et al.,* (2022) in their research which states that the consumption of insufficient dietary fibre, vital fatty acids, and starchy foods may impact excessive body fat and controlling the intake of these food groups, can aid in healthy weight management. The intake of sugar did not change for Group 1 subjects but decreased by six grams for Group 2 and by nine grams for Group 3, thereby indicating the exclusive role of nutrition education on the two intervention groups' food choices regarding the sugar food group. It was also reported by Mathur and Pillai (2019) in their research that suggested that dietary modifications of sugar, salt and other acquired tastes can be modified solely through nutrition educations thereby, emphasising the role of nutritional education interventions to overcome issues of over consumption of the high energy and fat food groups and to minimise nutrition insecurity.

Therefore, it was statistically determined that increasing the awareness of mindful eating and good dietary practices through the nutrition education sessions (Group 2) as well as the combination intervention of the physical activity along with this nutrition education (Group 3) were the groups with the most improvements in the consumption of food groups such as cereals, pulses, leafy greens, fruits, and a reduction in the consumption of fats, oils, sugar and jaggery.

Table 4.33 displays the average nutrient consumption among all the subjects of the study. Overall, there is an increase in the protein, and nearly all of the micronutrients after the intervention period.

Table 4.33: Average final nutrient intake of subjects (N=632)

Nutrients (per day)	Standard (ICMR, 2020)[#]	Nutrient Intake (Mean±SD)	Excess / Deficit	t_{value}
Macronutrients				
Energy (kcals)[##]	1660	2314.16± 31.91	39.40	12.92*
Protein (g/kg body weight)	36.3	43.12±27.1	18.78	29.16*
Carbohydrate (g)	130	238.24± 23.5	83.26	46.16*
Fat (g)	20	43.27±19.2	2056.35	31.41*
Micronutrients				
Iron (mg)	15	16.21±2.14	8.06	25.3*
Calcium (mg)	800	763.0± 45.41	-4.62	31.7*
Vitamin A (mcg RAE)	840	832.51± 92.19	-0.89	61.53*
Vitamin B_1 (mg)	1.4	1.7±0.26	21.42	14.6*
Vitamin B_2 (mg)	2.0	1.65±0.21	-17.5	24.56*
Vitamin B_{12} (mg)	2.0	1.8±0.13	-10	31.19*
Total folate (mcg)	180	171.7±21.8	-4.61	20.17*
Vitamin D (400 IU or 10mcg)	400	18.12±3.13	-95.47	2.61*
Vitamin C (mg)	55	68.87± 23.54	25.21	9.45*

[#]Recommended Dietary Allowances (RDA), 2020

[##]EER – estimated energy requirement since energy has no RDA

*Significant at 95% level of confidence

The overall calorie intake and the final BMI of the subjects were positively correlated (r=0.272, p<0.001). However, the cause of increased variability in the consumption of nutrients can be fully comprehended on observing the results of the next table, that indicate the effects of the two different interventions imparted to the women subjects of the present study.

Table 4.34, in the following page, presents the impact of intervention on the nutrient intakes of the study subjects according to their intervention groups.

Table 4.34: Impact of interventions on nutrient intakes of subjects (N=632)

Nutrients	Group 0 (N=158)			Group 1 (N=158)			Group 2 (N=158)			Group 3 (N=158)		
	Pre	Post	t_{value}	Pre	Post	t_{value}	Pre	Post	t_{value}	Pre	Post	t_{value}
Energy (kcals)	2784.30± 71.14	2785.59± 70.87	1.97	2789.13± 73.36	2706.21± 94.11	1.27	2786.84± 83.54	2543.56± 63.53	543.79*	2803.01± 69.80	2409.11± 59.52	914.35*
Protein (g/kg body weight)	18.34± 13.16	22.61± 13.16	0.81	21.63± 14.17	25.14± 9.82	1.30	23.14± 12.16	41.14± 17.12	534.66*	32.14± 16.01	44.72± 7.14	841.02*
Carbohydrates (g)	241.37± 41.05	245.13± 37.11	1.79	255.13± 32.11	287.91± 21.17	2.17	261.12± 36.18	239.71± 20.13	618.19*	251.41± 48.12	238.12± 18.16	910.27*
Fat (g)	46.13± 30.1	51.5± 29.13	0.13	48.51± 13.6	50.15± 17.16	1.45	53.17± 16.31	33.41± 10.19	575.81*	43.51± 12.10	37.16± 9.01	873.86*
Iron (mg)	13.11± 3.81	15.4±2.17	0.56	14.92± 4.16	15.19± 6.43	1.85	15.5±3.17	18.31± 5.12	547.32*	14.8± 4.13	18.51± 6.13	870.17*
Calcium (mg)	712.36± 97.17	719.40± 93.18	1.03	710.81± 97.10	761.3± 36.41	0.33	717.16± 92.10	806.13± 23.11	618.19*	732.41± 83.17	810.12± 21.41	898.41*
Vitamin A (mcg RAE)	781.51± 81.20	784.61 ±73.12	0.21	751.11± 70.17	832.16± 9.12	0.26	736.12± 73.16	831.41± 28.17	670.13*	741.19± 70.23	827.14± 31.01	872.01*
Vitamin B_1 (mg)	1.27±0.96	1.26±0.29	2.16	1.21±0.81	1.31±0.28	0.19	1.25±0.97	1.52±0.23	535.21*	1.22±1.01	1.69±0.18	829.19*
Vitamin B_2 (mg)	1.40±0.50	1.41±0.20	2.01	1.40±0.61	1.63±0.19	0.23	1.41±0.62	1.65±0.19	562.39*	1.41±0.63	1.64±0.17	830.88*
Vitamin B_{12} (mg)	0.89±0.47	0.93±0.37	2.19	1.01±0.39	1.32±0.12	0.27	0.92±0.45	1.76±0.05	597.36*	0.91±0.44	1.80±0.09	819.15*
Total folate (mcg)	151.16± 36.51	150.61± 29.61	0.99	153.71± 28.7	165.13± 21.6	1.01	152.16± 32.7	170.51± 20.4	573.24*	151.41± 37.41	171.81± 19.13	827.71*
Vitamin D (400 IU or 10mcg)	18.01± 3.3	18.12± 2.94	1.71	17.73± 2.51	18.12± 3.79	1.41	18.91± 2.34	19.71± 2.81	694.29*	19.71± 3.03	21.18± 2.19	905.10*
Vitamin C (mg)	63.14± 31.03	64.19± 20.03	1.92	67.51± 32.16	68.02± 33.14	2.01	70.53± 20.81	72.43± 38.7	750.21*	68.53± 35.1	71.01± 19.15	892.32*

*Significant at 95% confidence level

On closer inspection of the results in the Table 4.34 that presents the impact of interventions on nutrient intakes of subjects, a similar outcome can be observed among the second and third experimental groups while there was little to no change in Group zero, and no significant changes in Group 1. As seen from the table, it can be observed that the post-intervention energy consumption had reduced in Group 1 by 83 kilocalories while it was reduced by 243 kilocalories in Group 2 and about 394 kilocalories in Group 3. These results may be explained due to the type of interventions that was administered to them. In fact, there is research that suggests that the most reduction in calorie consumption may happen from a combination of increasing an individual’s activity level and improving their dietary behaviour (Ryan & Braverman-Panza, 2014; Meshram *et al.,* 2016; Bolognese *et al.,* 2020).

In terms of the protein consumption among all the intervention groups, there was a four gram increase in Group 1 while there was an 18 gram increase in Group 2 and a 12 gram increase among Group 3. Even though research has suggested that protein deficient diets are common in India (Swaminathan *et al.,* 2012; Rao *et al.,* 2018), the improvement in the consumption of protein among the women in the present study which may be due to the nutrition education intervention indicates the need for adequate nutrition education awareness at the community level. Research also agrees that meeting the community health guidelines would be better possible with approaches meant for the community at the grass root levels (Sharma *et al.,* 2020).

In terms of carbohydrates, there was an increase of 32 grams in Group 1, a decrease of about 22 grams in Group 2 and a decrease of about 13 grams in Group 3. The amount of fat consumed by the women subjects of Group 1 increased by two grams while it decreased by 20 grams in Group 2 and by six grams in the third intervention group. Prior research has suggested that individuals tend to increase their consumption of food, including carbohydrates and fats in their diet or allow it to remain the same to compensate for the energy that is lost from exercises (Melzer *et al.,* 2005; Donnelly *et al.,* 2014; Archer *et al.,* 2018) which may explain the increase in consumption of carbohydrates and dietary fat in Group 1.

Likewise, the decrease in the intervention Group 2 may be justified considering the nutrition education intervention that was imparted to the women subjects of the group, where they were made aware of the importance of judiciously consuming carbohydrates as part of Modules 8 and 9. A combination of these factors was what probably caused the lesser decrease in Group 3, whereby some subjects may have increased their consumption following their exercises while at the same time, consuming carbohydrates and fats after careful consideration. These results are in concordance with the present situation considering that research advocating for selective consumption of carbohydrates, dietary fats and processed foods towards good health has garnered attention on a global scale (Mathur & Pillai, 2019; Venkidasamy *et al.,* 2019; Goss *et al.,* 2020; Johnson *et al.,* 2020).

Observing the changes in the micro-nutrients, it can be deduced that the dietary iron intake had gone up by 1 milligram in Group 1, while it had increased by 2.8 milligrams for Group 2 and by 3.7 milligrams in Group 3. Although there is less evidence that suggests that iron intake can be improved exclusively through diet without supplements (Swaminathan *et al.,* 2019; Stoffel *et al.,* 2020), the present study suggests that consumption of this nutrient may also improve from adequate awareness due to an imparted nutritional education.

Similarly, the dietary calcium intake had increased by 51 milligrams in Group 1, by 89 milligrams in Group 2 and by 78 milligrams in Group 3. The increase in this micronutrient can be justified with the increase in the food groups of milk and milk products and green leafy vegetables as indicated in the previous sections. Current research suggests that the proper absorption of calcium may depend on exercise and adequate consumption of the food sources of the nutrient (Charoenphandhu, 2007; Booth & Camacho, 2013; Cormick & Belizán, 2019).

Considering the dietary intake of vitamin A, it can be observed that Group 1 had an increase in their vitamin intake by 81 micrograms of retinol activity equivalents, while the intake was up by 89 micrograms of retinol activity equivalents in Group 2 and by 78 micrograms of retinol activity equivalents in Group 3. The higher intake by the second intervention group subjects could be due to the nutrition education intervention. Research suggests that more than an intervention of physical activity, there are associations between educational awareness and increased vitamin A intake (Vazir *et al.,* 2013; Reddy *et al.,* 2022).

Among the B group vitamins, i.e., thiamine (B_1), riboflavin (B_2) and cobalamin (B_{12}), an increase in consumption could be observed among all the three intervention groups. B_1 increased by 0.10 milligrams in Group 1 while in Group 2 and Group 3, it increased by 0.27 and 0.47 milligrams respectively. B_2 increased by 0.23 milligrams in Group 1, 0.24 milligrams in Group 2 and 0.23 milligrams in Group 3. For B_{12}, the intake increased by 0.31 milligrams in Group 1, 0.84 milligrams in Group 2 and 0.89 milligrams in Group 3. There has been research that suggests that improving levels of physical activity and diet quality may results in the increase in consumption of the B group vitamins (Hardman *et al.,* 2020; Cunnane *et al.,* 2022), which supports the findings of the present study as well.

The intake of total dietary folate had also increased among the women subjects of the intervention group. It can be observed that in Group 1, the nutrient increased by 12 micrograms, while it increased by 18 micrograms in Group 2 and by 20 micrograms in Group 3. Corresponding to the improvements in the consumption of leafy vegetables, pulses and fruits, the increase in total dietary folate can be justified as per current research (Kumaran *et al.,* 2017; Elsayed *et al.,* 2022). Although limited, evidence also exists which proves that exercise improved folate uptake by the body in adults who are physically active (Baart *et al.,* 2021). It can also be said that the combined interventions of exercise and nutrition education contributed to the increased uptake of the cobalamin vitamin, the results of which are observed in the present study.

There was an observed 0.4 microgram increase in intake of vitamin D in Group 1, which was a 0.8 increase in Group 2 and a 1.4 increase in Group 3. Improved physical activity and knowledge about self-care practices have previously been reported to increase the consumption and uptake of vitamin D (Gupta & Gupta, 2014; Harinarayan, 2018; Balachandar *et al.,* 2021) due to which the outcomes of the present study regarding the dietary intake of vitamin D may be justified.

As for the vitamin C, there was an increase of 1.5 milligram in Group 1, an increase of 1.9 milligram in Group 2 and an increase of 2.5 milligram in Group 3. Research has suggested that vitamin C containing food sources are to be consumed in tandem with exercise and good dietary behaviour to be of the maximum benefit to individuals (Shankar *et al.,* 2017; Nunn *et al.,* 2019; Rowe & Carr, 2020), which was also observed in the present study. Therefore, it can be noted that increasing awareness about nutrients and their importance in the health of an individual or a combination of exercise and dietary awareness can improve the intake of macro and micro-nutrients among obese women.

4.5.2 Impact of intervention on lifestyle pattern of subjects

The impact of the interventions on three aspects of the subjects' lifestyle pattern namely the physical activity, sleep pattern and the knowledge, awareness and practices related to the management of obesity is discussed in this section.

4.5.2.1 Physical activity pattern of subjects

Table 4.35 below displays the scores of the global physical activity questionnaires filled out by the subjects after the intervention period.

Table 4.35: Final GPAQ scores of subjects across intervention groups (N=632)

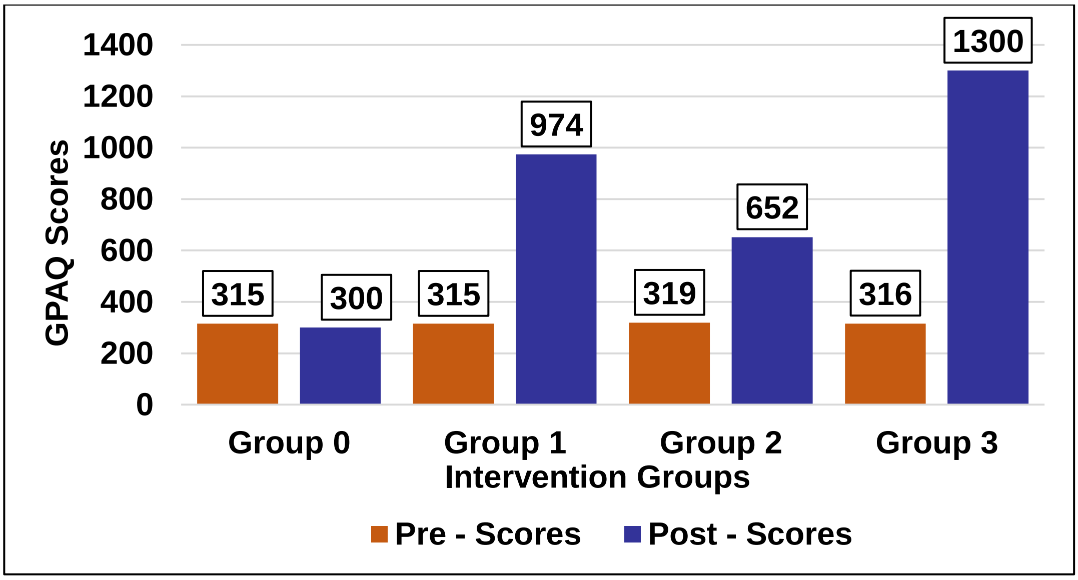
Group	Standard[#]	Mean±SD	Excess / Deficit	F_{value}
Group 0	> 600	314.58 ± 7.93	- 47.57	1465.35[S] (p<0.001*)
Group 1		974.67 ± 20.01	62.44	
Group 2		651.71 ± 30.20	8.61	
Group 3		1300.13 ± 31.08	116.68	
All Groups		**810.27 ± 392.31**	**35.04**	

[#]WHO (2002), *Significance at 96% confidence level, [S]Significant

It can be observed from the table that except for the Group zero, all the other groups' average scores are higher than the standard cutoff of the WHO. It was interesting to note that while Group 1 and Group 3 have considerable increases in their post-intervention GPAQ scores, Group 2 also had an increase just above the cutoff level. This may be attributed to the awareness about physical activity they had received as part of their nutrition education intervention. Final levels of physical activity and BMI were found to be negatively correlated (r=-0.743, p<0.001).

On observing Graph 4.12, the final GPAQ scores of the subjects as per the intervention groups before and after intervention can be understood.

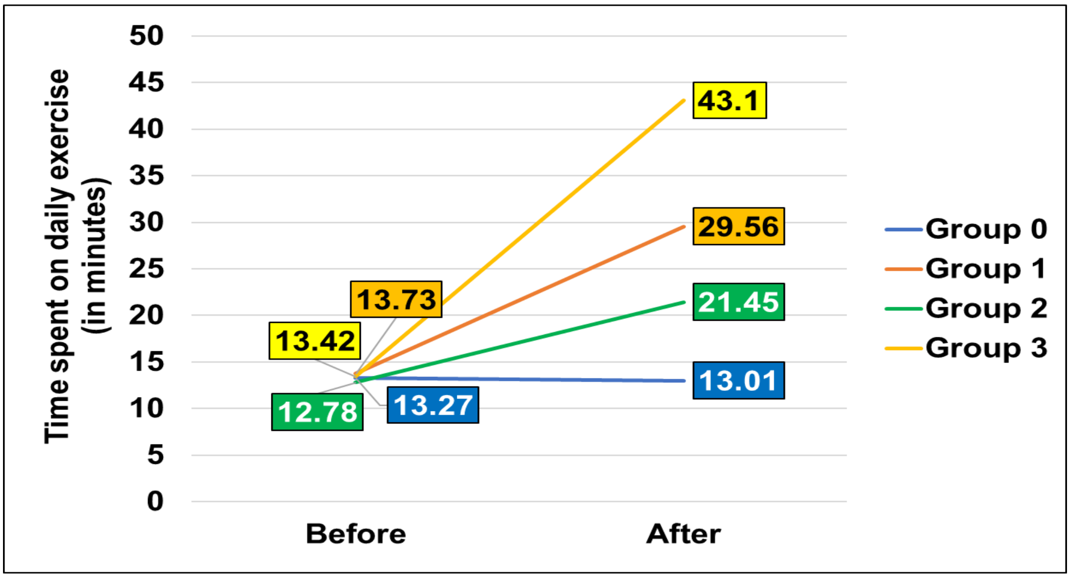
Graph 4.12: Final GPAQ scores of study subjects across intervention groups (N=632)



There were notable distinctions between the experimental and control groups when analysed with analysis of variances (F=31.63, p<0.001), with the highest difference being observed in experimental group, Group 3. This may mean that the physical activity in combination with nutrition education is more capable of increasing and improving an individual's daily physical activity when compared to the separate impacts of physical activity and nutrition education. Research has suggested that GPAQ scores are capable of indicating increases in the physical activity of an individual (Cleland *et al.,* 2014; Mumu *et al.,* 2014; Mahmoodabad *et al.,* 2017), which is in concordance with the results of this study.

After the intervention period, when the average time spent by subjects for exercise daily was observed and compared with the time recorded before the intervention a significant and positive change was seen in all the experimental groups (F=361.14, p<0.001*). The changes are recorded in the form of Graph 4.13.

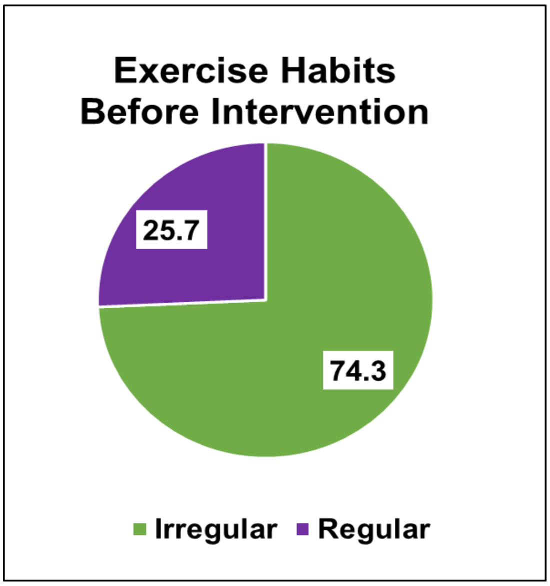
Graph 4.13: Average time (in minutes) spent exercising before and after intervention by study subjects (N=632)

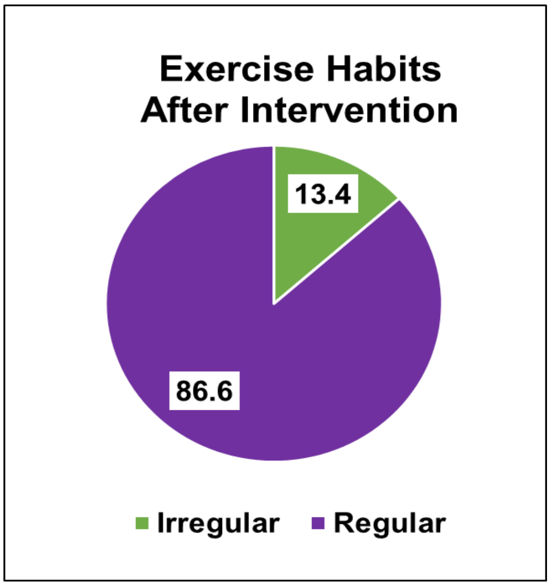


The maximum increase was seen in Group 3 that had both the physical activity and nutrition education interventions, followed by Group 1 that had only the physical activity intervention, then Group 2 that had the nutrition education intervention and lastly Group zero, the control group with no interventions.

To understand whether there was any improvement in the development of daily exercise as a habit after the period of intervention, a comparison was made as shown in Graph 4.14.

Graph 4.14: Exercise habits of subjects before and after intervention (N=632)





From the graphs, it can be noted that the lifestyle interventions may be the reason that caused a spike in the number of subjects having the regular habit of exercise i.e., from 25.7 percent at the initiation of the study period to 86.6 percent by the end of the study period. Similar research studies suggest that increasing physical activity through long term exercises, can cause a beneficial change in individuals, causing them to dedicate time exclusively for physical activity in their regular schedules (Skogstad *et al.,* 2018; Barett *et al.,* 2020).

4.5.2.2 Sleep quality of subjects

The sleep quality of the subjects assessed after the intervention period yielded the results as presented in Table 4.36.

Table 4.36: Final PSQI scores of subjects across intervention groups (N=632)

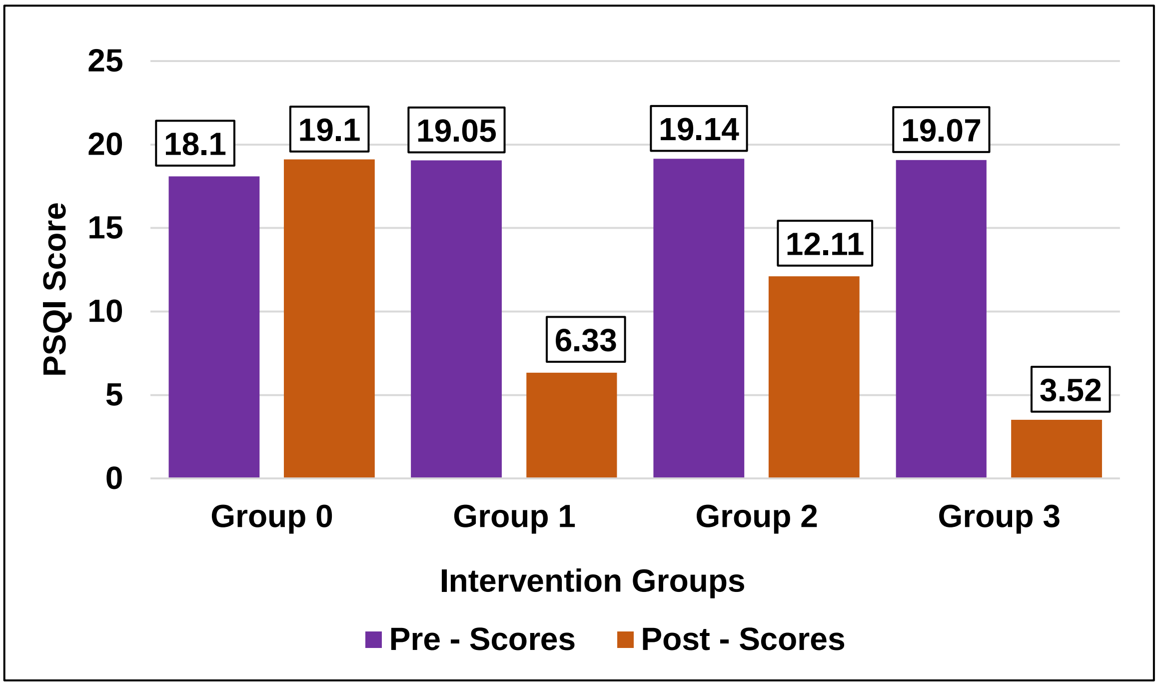
Group	Standard[#]	Mean±SD	F_{value}
Group 0	1 - 5: Good 6 - 15: Average 21 - 25: Poor	19.14±1.38	4612.59[S] (p<0.001*)
Group 1		6.33±1.04	
Group 2		12.11±1.55	
Group 3		3.52±1.06	
All Groups		10.27±6.12	

[#]WHO (2002), *Significance at 96% confidence level, [S]Significant

It may be noted that in the scoring system of the Pittsburgh Sleep Quality Index (PSQI) questionnaire, the lesser the score is, the better is the sleep quality (Buysse, 1989; Zhong *et al.,* 2015). Hence, as seen in the table below, it can be understood that the overall sleep quality of the study subjects was average, and Group 3 was the only group that had a sleep quality that was as recommended. Final sleep quality and BMI of the subjects were positively correlated (r=0.771, p<0.001).

Graph 4.15 shows the impact of the two interventions on the subjects' sleep quality across the three intervention groups.

Graph 4.15: Final PSQI scores of subjects across intervention groups (N=632)



It can be seen that this is a significant improvement (F=35.85, p<0.001) as compared to the initial sleep pattern of the subjects across intervention Groups 1 and 3. The unequal scores of the Group 1 and Group 3 indicates that although physical activity alone may have a beneficial effect on the sleep quality of an individual, the combination effect of both physical activity and educational awareness is yet to be studied, as confirmed by similar research studies which only state that exercise of moderate intensity may or may not significantly improves a variety of crucial objective sleep parameters (Kredlow *et al.,* 2015; Wang & Boros, 2021; Narayana *et al.,* 2023). At this point, it is necessary to mention that although evidential literature relating to PSQI and its effects on other lifestyle factors in the Indian context is available from different states, evidence towards national sleep quality is still inadequate and needs further research considering present times where sleep quality has reported be influenced by a variety of lifestyle factors including diet (Godos *et al.,* 2021; Hall, 2022).

4.5.2.3 Knowledge, attitudes and practices of subjects

To understand the effect of the nutrition educational awareness interventions among the study subjects, their Knowledge, Attitudes and Practices (KAP) was assessed at the end of the intervention period (Table 4.37).

Table 4.37: Final KAP scores of subjects across intervention groups (N=632)

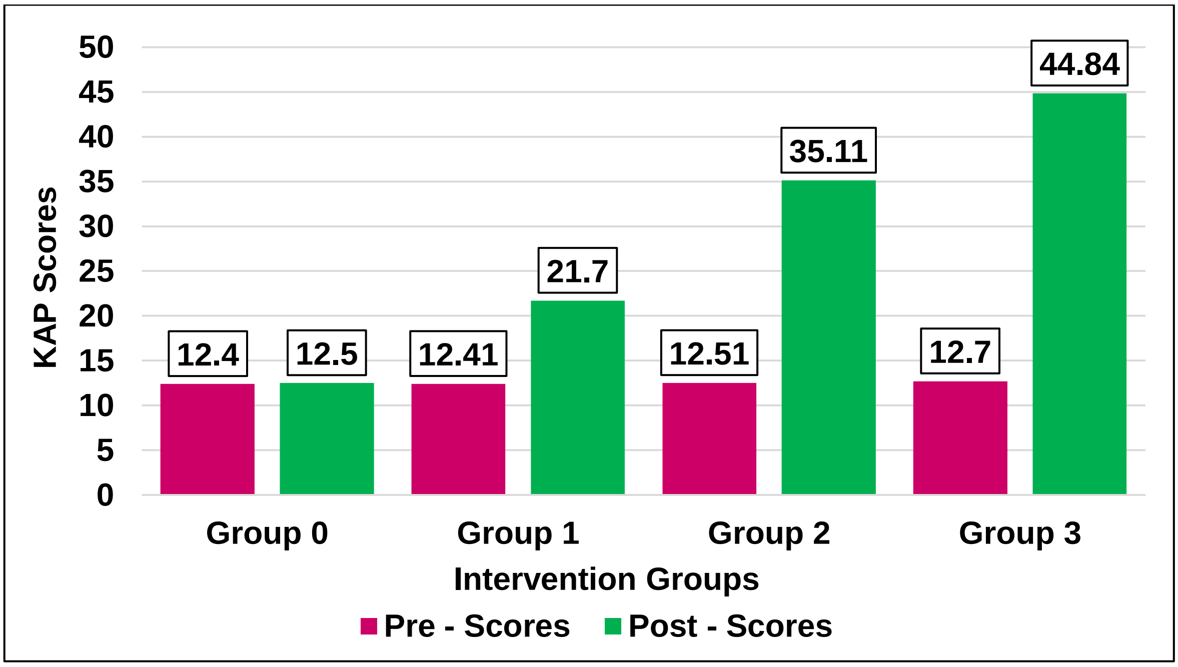
Group	Standard#	Mean±SD	Excess / Deficit	F_{value}
Group 0	45	12.58±2.08	-72.04	308.41S (p=0.002*)
Group 1		21.70±1.91	-51.78	
Group 2		35.11±2.35	-10.98	
Group 3		44.84±6.24	21.87	
All Groups		31.06±11.05	-30.98	

#WHO (2002), *Significant at 95% level of confidence, SSignificant

The final KAP scores were negatively correlated with BMI levels (r=-0.098, p<0.001) which suggest that better awareness can lead to lesser degrees of overnutrition.

Graph 4.16 discusses the final KAP scores of the subjects across the intervention groups.

Graph 4.16: Final KAP Scores of subjects across intervention groups (N=632)



It can be observed that due to the nutrition education intervention provided to the experimental groups, Group 2 and Group 3, their KAP scores have significantly improved when compared with the other control and experimental groups ($F=35.31$, $p<0.001$). The significant difference between the Group 2 and Group 3 KAP responses, may be due to the additive effect of awareness bought about by the physical activity interventions and their related questions in the KAP questionnaire, leading to a 20 percent excess as compared to the other groups.

Research from similar studies do suggest an association between an educational awareness intervention and the KAP of the subjects regarding nutrition in the studies carried out by Ostarahimi *et al.,* (2010), Yetnayet *et al.,* (2017), and Anand & Anuradha (2018) however, they do not scrutinize the probable effect of an exercise intervention on the KAP levels of the subjects, as presented in the present study.

Considering the above results, since there are significant associations between the degree of overnutrition and being less physically active, having poor dietary intake, poor sleep quality and poor KAP, the $H_0 2$ is rejected.

PHASE VI

4.6 Assessing effectiveness of intervention on subjects

Once the associations between both the interventions were made with the nutritional status and lifestyle pattern of the subjects, it became essential to understand the extent of these associations and whether a pattern could be predicted which may help the present study's results to be extrapolated in the general population. In this regard, multiple regression analyses were carried out keeping the interventions as the independent variables and the measured parameters of the subjects as the dependent variables. A multiple regression is defined to be used "for predicting a quantitative response on the basis of multiple predictor variables" and it indicates the degree to which an independent variable exerts sole influence over dependent variables and the percentage to which it can be a pattern when applied under similar circumstances i.e., from the analysis, the model fit (R^2 or the coefficient of determination), the percent by which a variable is likely to increase or decrease with every unit of change of the independent variable (unstandardised regression coefficient) and the more effective intervention method (standardised coefficient of beta) can be determined (James *et al.,* 2023).

4.6.1 Effect of intervention on anthropometric factors of study subjects

The effect of intervention on anthropometric factors of the 164 sub-samples of the present study was analysed and its results are presented in Table 4.38.

Table 4.38: Effect of intervention on anthropometric parameters of sub-samples (N=164)

Interventions/ Independent Variables	Anthropometric factors/ Dependent Variables	R^2	Unstd. Coeff.	Std. Coeff. of Beta	F_{value}	t_{value}
Nutrition Education	Weight (kg)	0.60	-1.97	-1.12	40.76**	-3.87**
	BMI (kg/m^2)		-1.86	-1.64		-5.83**
	WHR		-2.05	-0.66		-9.19**
	SMM (kg)		1.92	0.34		3.99**
	PBF (%)		-2.41	-0.68		-2.83*
	BMR (kcals)		0.57	0.37		2.06*
Exercise	Weight (kg)	0.77	-2.84	-21.2	91.76**	-2.97*
	BMI (kg/m^2)		-2.78	-0.61		-2.89*
	WHR		-2.42	-0.34		-6.38**
	SMM (kg)		2.71	2.01		8.46**
	PBF (%)		-1.37	-1.02		-4.33**
	BMR (kcals)		0.56	0.94		2.61*
Both	Weight (kg)	0.42	-1.71	-0.97	19.56**	-2.78**
	BMI (kg/m^2)		-1.26	-0.80		-2.11**
	WHR		-2.10	-0.15		-1.73*
	SMM (kg)		0.87	0.36		3.31**
	PBF (%)		-2.35	-1.48		-3.89**
	BMR (kcals)		0.40	0.58		2.63*

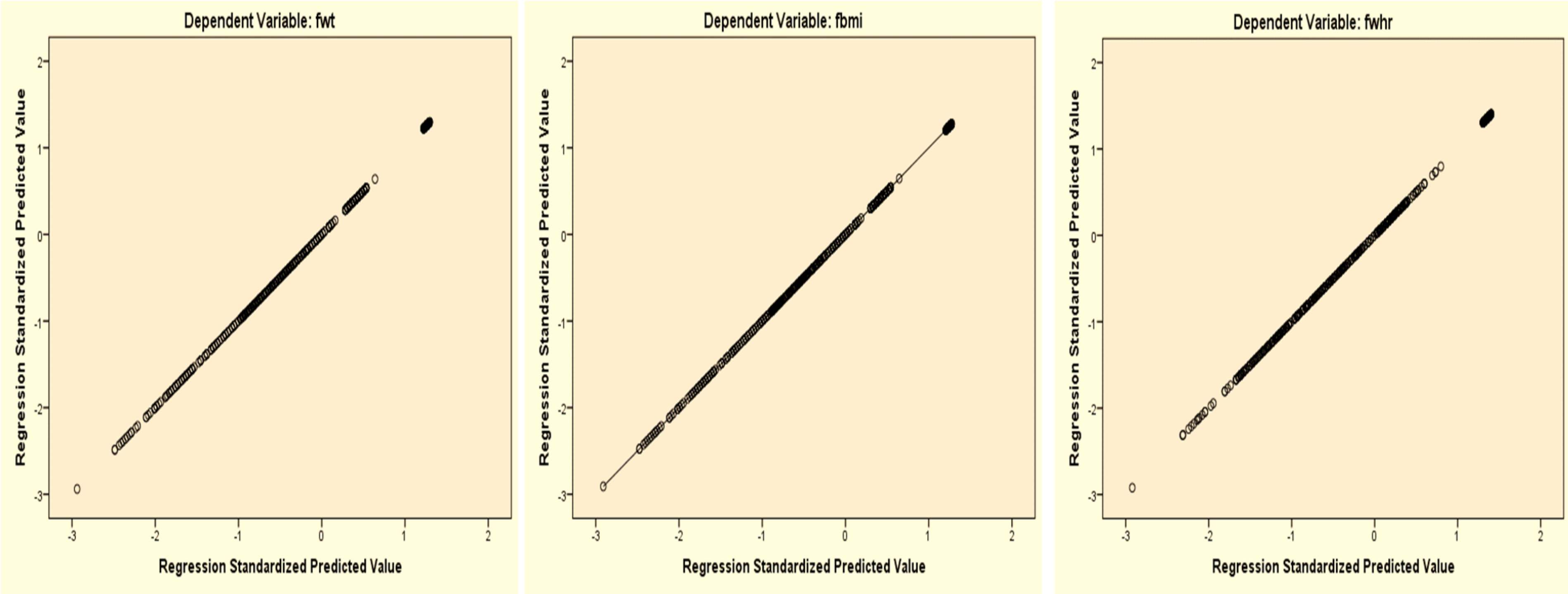
*Significant at 95% confidence level, **Significant at 99% confidence level

From the table, it can be understood that the nutrition education intervention as well as the exercise intervention solely and significantly influence weight, BMI, WHR and the fitness score of the body composition analysis.

The multiple regression analysis showed that there was a 60 percent probability that educational awareness improved anthropometric parameters including a decrease in weight by nearly two kg, reduction in BMI by two kg/m^2 and reduction in WHR by nearly 3 points. There was a 77 percent likelihood that exercise improves SMM by 2.7 kg and BMR by 0.5 kcals. When evaluating the combined effect of both the interventions, it was observed that there was a 42 percent chance that weight, BMI, WHR, and PBF could decrease while SMM and BMR could increase. Therefore, it could be said that more than the combined effect of the two lifestyle interventions, exercise could be a better predictor of the changes in the anthropometric parameters.

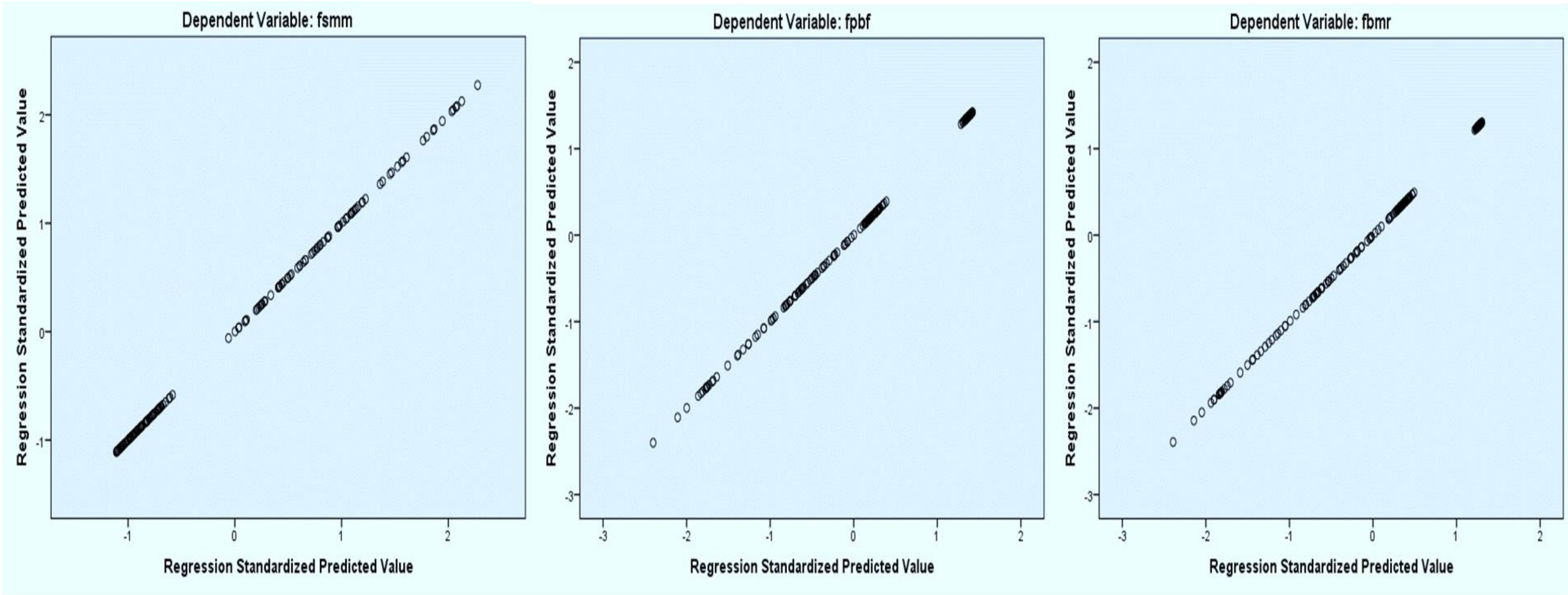
Scatter plots were employed to graphically represent the relationship between the combined effect of both interventions as the independent variable and the nutritional status and lifestyle pattern parameters as the dependent variables.

Both the Graphs 4.17 and 4.18 display the scattered plots that denote the combined effect of both the interventions on anthropometric parameters.



Graph 4.17: Scattered plots of the effect of intervention on anthropometric parameters of subjects (N=632)

Description: From left to right, the scattered plots show the effect of the combined intervention on the body weight (fwt), body mass index (fbmi) and the waist-to-hip ratio (fwhr) of the study subjects. It can be observed that the effect is negative, indicating that the degree of overnutrition, as measured by body weight, BMI and WHR can be decreased by improving physical activity and diet practices through educated awareness.



Graph 4.18: Scattered plots of the effect of intervention on body composition parameters of subjects (N=164)

Description: From left to right, the scattered plots show the effect of the combined intervention on the skeletal muscle mass (fsmm), percent of body fat (fpbf) and basal metabolic rate (fbmr). It can be observed that the effect of both the interventions is strongly negative in the case of SMM, and moderately positive in the case of PBF and BMR, indicating that the degree of overnutrition decreases as SMM increases while it increases as both PBF and BMR increases.

Research that was previously conducted to analyse the influence of exercise on the body composition parameters include the works of Kaur *et al.,* (2012), Zouhal *et al.,* (2020), and Srivastava *et al.,* (2021). However, the effect of an educational intervention on these body composition parameters has not been exhaustively studied in the existing literature, which indicates the novelty of the present study.

4.6.2 Effect of intervention on biochemical parameters of study subjects

Checking for the sole influence of the two interventions on the biochemical parameters of the sub-samples yielded the results as displayed in Table 4.39.

Table 4.39: Effect of intervention on biochemical parameters of sub-samples (N=164)

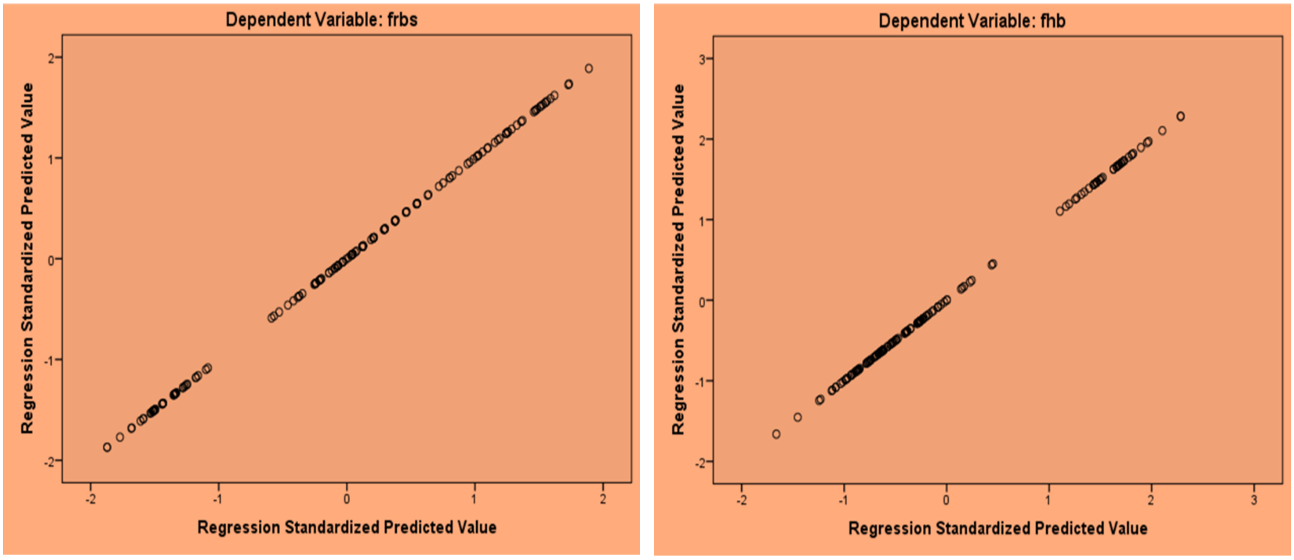
Interventions/ Independent Variables	Biochemical parameters/ Dependent Variables	R^2	Unstd. Coeff.	Std. Coeff. of Beta	F_{value}	t_{value}
Nutrition Education	RBG (mg/dl)	0.23	-0.10	-0.15	3.56**	-0.21*
	Hb (g)		2.70	0.42		2.06**
	T_3 (ng/dl)		-0.51	-0.12		-1.56*
	T_4 (mcg/dl)		-0.12	-0.57		-1.40*
	TSH (mc IU/ml)		-0.81	-0.28		-0.72*
Exercise	RBG (mg/dl)	0.31	-1.49	-0.15	3.54**	-0.71*
	Hb (g)		1.47	0.24		0.12
	T_3 (ng/dl)		-1.16	-0.37		-1.53*
	T_4 (mcg/dl)		-1.47	-0.51		-1.16*
	TSH (mc IU/ml)		-2.41	-0.29		0.16*
Both	RBG (mg/dl)	0.48	-0.30	-0.12	11.60**	-1.47*
	Hb (g)		0.53	0.24		3.15**
	T_3 (ng/dl)		-0.96	-0.51		-2.12*
	T_4 (mcg/dl)		-1.64	-0.70		-1.58*
	TSH (mc IU/ml)		-1.30	-0.23		-0.05*

*Significant at 95% confidence level, **Significant at 99% confidence level

It can be observed that there is a significant 23 percent probability that the nutrition education intervention improved the haemoglobin content (by 2.70 g) as well as lowered the serum TSH (by 0.81 mc IU/ml) levels of the study subjects.

Similarly, for the exercise intervention, it was found that at least a 31 percent of significant chance existed for 1.47 g of haemoglobin content to improve while the individual's TSH reduced by 2.41 mc IU/ml. Combing the effect of both interventions, it may be observed that there is a 48 percent likelihood that serum parameters including RBG, and thyroid function parameters would decrease while Hb would increase.

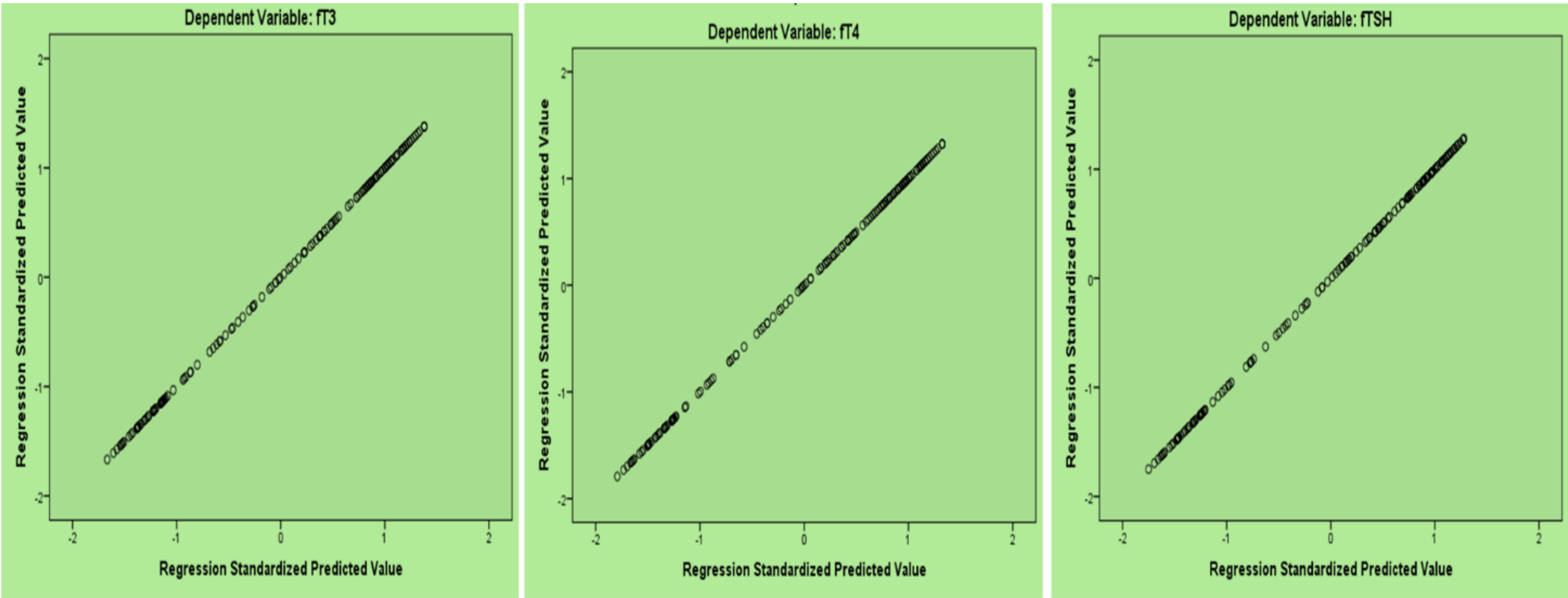
Corresponding to the above table's data, Graph 4.19 shows the scattered plot of the effect of intervention on random blood glucose (left) and haemoglobin (right) levels of sub-samples.



Graph 4.19: Scattered plots of the effect of intervention on RBG and haemoglobin of subjects (N=164)

Description: Corresponding to the multiple regression analyses, it can be observed from both the above scattered plots that there is an inverse relationship between the level of educated awareness, and the level of physical activity when plotted to the RBG and a proportional relationship when plotted to the Hb levels of the subjects.

Similarly, Graph 4.20 shows the scattered plot of the effect of intervention on serum thyroid parameters of sub-samples. Proceeding from left to right, the first is of T_3, the second is of T_4 and the third is of TSH.



Graph 4.20: Scattered plots of the effect of intervention on serum thyroid parameters of subjects (N=164)

Description: Proceeding from left to right, the first graph is of T_3, the second is of T_4 and the third is of TSH. Corresponding to the negative correlations between the degree of obesity and the thyroid parameters, it can be said that the combined effect of both the interventions reduced the overall levels of the serum thyroid parameters in the study subjects.

Considering that there is existing proof that suggests exercise can significantly alter random blood glucose, haemoglobin and thyroid levels (Nagarathna *et al.,* 2020; Kriswanto *et al.,* 2021; Klasson *et al.,* 2022), the results of the present study agree with the said findings while proceeding to suggest a beneficial association between an educational intervention and serum parameters of haemoglobin and the thyroid stimulating hormone.

4.6.3 Effectiveness of intervention on diet and sleep pattern of study subjects

Comparing the sole effect of the two interventions on the overall dietary intake (kcals) and the PSQI sleep scores yielded the results as presented in Table 4.40.

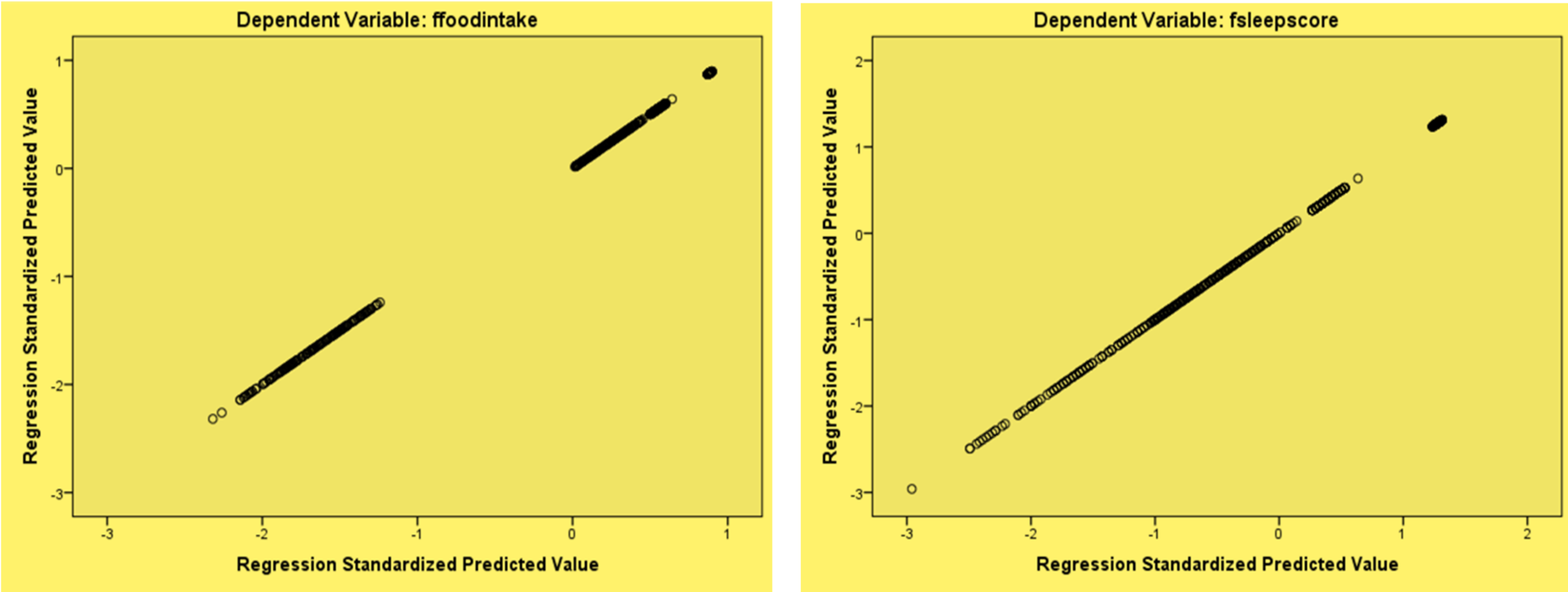
Table 4.40: Effect of intervention on diet intake and sleep pattern indicators of study samples (N=632)

Interventions/ Independent Variables	Dependent Variables	R^2	Unstd. Coeff.	Std. Coeff. of Beta	F_{value}	t_{value}
Nutrition Education	Dietary Intake (kcals)	0.12	-1.75	-0.08	51.76*	-7.74*
	Sleep Scores		-0.29	-0.25		-5.78*
Exercise	Dietary Intake (kcals)	0.81	-0.87	-0.88	1357.3**	-2.86*
	Sleep Scores		-5.48	-0.53		-47.7*
Both	Dietary Intake (kcals)	0.44	-0.34	-0.19	247.37**	-6.15**
	Sleep Scores		-0.21	-0.56		-17.89**

*Significant at 95% confidence level, **Significant at 99% confidence level

There is a 12 percent chance that nutrition education significantly explains the 1.75 reduction in dietary intake and a 0.29 reduction in the sleep score.

Graph 4.21 shows the scattered plots of the effect of intervention on diet intake and sleep pattern of subjects.



Graph 4.21: Scattered plots of the effect of intervention on diet intake and sleep pattern of subjects (N=632)

Description: These scatter plots assess the effect of the exercise and nutrition education interventions on the food intake (left) and on the sleep quality (right). It can be observed that the plot is discontinued for the food intake data. This is likely to be due to the high variance between among the four groups of the study, in terms of their food consumption. However, such a variance is less observable in the sleep quality of the subjects. Regardless, it indicates that the consumption of food is directly related to the degree of overnutrition while inversely related to the sleep quality of the subjects.

Similarly, exercise may explain both dietary intake and sleep scores to the extent of 81 percent, where there is a 0.87 reduction in the calorie consumption of food and a 5.48 reduction or improvement in the PSQI sleep scores. There was a 44 percent likelihood that both the interventions combined would significantly reduce dietary intake as well as improve the sleep quality of the study subjects.

Recent research has studied the effect of being more physically active and improved lifestyle factors such as sleep, diet, and mental health of individuals (Ghrouz *et al.,* 2019; Sankar *et al.,* 2020; Faulkner *et al.*, 2021; Wang & Boros, 2021). However, it is the present study's novelty that it finds a significant relationship between elevated physical activity levels and improved KAP on the lifestyle factors of individuals including dietary behaviour and sleep pattern of individuals.

Considering the above results, since there was significant improvements in the levels of physical activity, dietary intake, sleep quality and the KAP of the subjects following the aerobic exercise and nutrition education interventions, the $H_0$3 is rejected.

The comprehensive findings of the present study suggests that management of the global epidemic that is obesity may need to start at the individual level. From the results described above, it can be understood that after a duration of twenty-six weeks or six months of following a physical activity and nutrition education interventions to their lifestyles, there are significant reductions in the weight, BMI, and significant improvements in their knowledge, attitudes and practices, along with their sleep pattern and physical activity. At the same time, it is to be emphasised that the present study suggests that the goal of obesity management is not just about weight control, but improving one's awareness related to the advantages of regular physical activity, the changes to make to an individual's diet to make it 'mindful eating' and the observable and unobservable benefits of making such changes to one's lifestyle with assistance from a dedicated and regular schedule. Research aimed at sustainable lifestyle changes at the personal level will go a long way towards conquering this public health concern to ensure healthier future generations.