Optimising Metabolic Health: Exploring The Synergy Between Micronutrient and Comprehensive Lifestyle Interventions

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Abstract—
Background: The global prevalence of metabolic syndrome (MetS) has reached epidemic proportions, and its impact on the Indian population cannot be underestimated. Currently, one in every four adult Indians has MetS. The current treatment strategy for MetS is mostly focused on medication and basic lifestyle changes; micronutrients are often overlooked.
Objectives: The objective of the research was to use a synergistic approach of micronutrient optimization and lifestyle treatments to enhance specific metabolic markers (HbA1c and one or more of the waist-hip ratio, blood pressure, HDL, and triglyceride levels) in an urban Indian subject group with MetS.
Material and Methods: A multidisciplinary healthcare team implemented a comprehensive treatment approach over a 3-month period for 20 individuals with MetS. The study included 20 patients with MetS seeking consultation at the Ultra Wellness Center-Truelife Functional Medicine Pvt. Ltd. Given the observational nature of the study, a quantitative technique was applied for analysis. Descriptive statistics were used to test the difference in the chosen biomarker parameters before and after the intervention.

Results: The intervention showed significant improvements in tested health parameters in both women and men. Mean HbA1c decreased from 6.9% (±1.462) to 6.0% (±0.823). Waist-to-hip ratio mean reduced for both women 0.79 (±0.074) to 0.75 (±0.059) and men 0.90 (±0.102) to 0.86 (±0.087). Blood pressure improved with mean systolic/diastolic readings dropping from 134 (±8.300) /86 (±4.807) mmHg to 126 (±5.887) /82 (±2.865) mmHg. HDL cholesterol increased in women 38.5 (±4.009) to 48.5 (±7.774) mg/dL and men 45.8 (±8.715) to 53.8 (±10.306) mg/dL. Mean triglyceride levels decreased from 194 (±144.211) mg/dL to 157 (±77.667) mg/dL. Participants reported a substantial increase in energy levels, with mean scores rising from 3.95 (±1.276) to 7.35 (±0.875) on a 10-point scale.

Conclusion: The intervention yielded a positive outcome, indicating the importance of addressing micronutrient deficiencies in conjunction with lifestyle changes to enhance metabolic health in MetS patients. However, long-term effects must be assessed by further research with demographically diverse groups.

***Keywords*—Metabolic Syndrome, Metabolic Parameters, Micronutrients, Lifestyle Interventions, Urban Indian Population**

I. INTRODUCTION

Currently, India is at the epicenter of diabetes with home to 77 million people [1]. Furthermore, people with Type 2 Diabetes Mellitus (T2DM) are more likely to develop insulin resistance, obesity, and prevalence of cardiovascular disorders later in their lives. Metabolic Syndrome (MetS), is a cluster of conditions that can lead to heart disease, diabetes, stroke, and other health problems. Metabolic syndrome is defined as having three or more of the following risk factors: high blood glucose, low HDL ("good") cholesterol levels in the blood, high triglyceride levels in the blood, a big waist circumference or "apple-shaped" physique, and high blood pressure [2]. Therefore, preventing the progression of MetS has lasting impact on the future of multiple co-morbidities.

In general, a balance of lifestyle, diet, and exercise has been increasingly accepted as crucial to addressing the metabolic syndrome and its co-morbidities, with nutrition being the most critical. The American Diabetes Association (ADA) and the American Dietetic Association both suggest that healthy adults who are not at high risk of nutritional deficiencies achieve their nutritional needs through natural dietary sources. These organisations typically oppose the use of micronutrient supplements for diabetics, and the supplements are the same as those advised for the general public. According to the ADA, people who are at a higher risk of micronutrient deficiencies, such as those on very low-calorie diets, the elderly, strict vegetarians, and other particular populations, may benefit from multivitamin supplements [3] Furthermore, there is no specific diet that is published that addresses MetS per se.

The normal functioning of human body requires both macro and micronutrients, especially micronutrients for the physiological processes. Further, these vitamins, minerals and trace elements are integral to a host of biochemical processes including stabilizing of enzymes and proteins and acting as co-factors for many enzymes [4]. Some studies have suggested that several trace elements have multiple roles in body metabolism, chronic hyperglycaemia, and cellular homeostasis [5]. In addition, early trace element imbalances in T2DM generate increased oxidative stress, which may contribute to the development of T2DM and raise the risk of diabetes complications [6]. Similarly, micronutrients like Vitamin D, Mg2+ and Calcium have helped to improve conditions like hyperlipidaemia and high blood pressure. Therefore, normal levels of these elements favour optimal functioning of key processes. Hence, it becomes vital that we have a well-balanced meal for proper functioning of our body.

Access to a well-balanced diet that considers the appropriate macros and micros is challenged increasingly by various factors including host of fad diets [7], agronomic, environmental factors, and industrial food processing, over the past 50 years [8]. The current diets prescribed for MetS conditions such as T2DM have approximately 50-60% complex carbohydrates, 10-15% fats, and 0.8g/kg of proteins [9]. Further, these diets are more likely deficient in micronutrients such as Mg2+, Calcium, Vitamin D, Vitamin B12 to name a few. A functional approach to nutrition where inadequacies in diet, lifestyle can be matched up by appropriate nutrition and support that can be personalised, yielding better outcomes would be appropriate is gaining more popularity [10].
As there are limited studies correlating MetS with lifestyle and nutrition, a detailed observational approach can provide certain cues and future direction addressing the synergy between micronutrients and lifestyle management to improve MetS in the urban Indian population.

II. OBJECTIVES

The objective of the study is to apply this approach to improve the following in the urban Indian subject group with MetS:
1. Improve HbA1c (glycated HbA1c) levels
2. Improve metabolic profile such as-
    a. Reduce waist to hip ratio (WHR)
    b. Improve blood pressure (BP) control
    c. Improve high Density lipoproteins (HDL) and Triglycerides levels (TG)

III. MATERIAL AND METHODS

Research Design and Data Source
A perspective observational study was done on subject group with MetS. The study data was obtained from the Ultra Wellness Center (Preventive Healthcare and Functional Medicine, working in association with Truelife Functional Medicine and Lifecare Hospital located at Ahemdabad, Gujarat.

Research Study Population
The study included 20 patients with MetS seeking consultation at the Ultra Wellness Center- Truelife Functional Medicine Pvt. Ltd. The patients were adults over 18 years; with 12 females and 8 males, aged between 34-59, with an average age of 48.
The inclusion criteria was patients with type 2 diabetes mellitus or pre-diabetes condition (HBA1c > 5.7), with or without hypertension (BP > 140/90 mmHg), low HDL, and high triglycerides count, with no other pre co-morbid conditions. All of them lived in urban Indian cities.
The exclusion criteria was gestational diabetes or lactating mothers, juvenile or Type 1 DM, chronic kidney disease, recent acute coronary syndrome (less than 6 months), stroke, less than 6 months of life expectancy, cancer, HIV and AIDS, recent surgery, recent COVID-19 infection.
The study area was urban India. The patients received treatment and support through in-person consultation or videoconferencing and online questionnaire.

Data Collections and Instruments
The data collection and measurements were conducted by trained healthcare professionals. Upon

enrollment each patient was asked to complete a series of online questionnaires to generate a detailed health profile of each individual. The information was collected and recorded using the standardized online questionnaires forms and software developed by Ultra Wellness Center, based on the recommendation of The Institute for Functional Medicine, USA, and the Indian Association of Functional Medicine, India.

The patient registration form included the basic demographic information, such as age, gender, living area, contact information to be used the treatment duration. The parameters mentioned below were collected twice, once at the beginning and then again at the end of 3 months period.

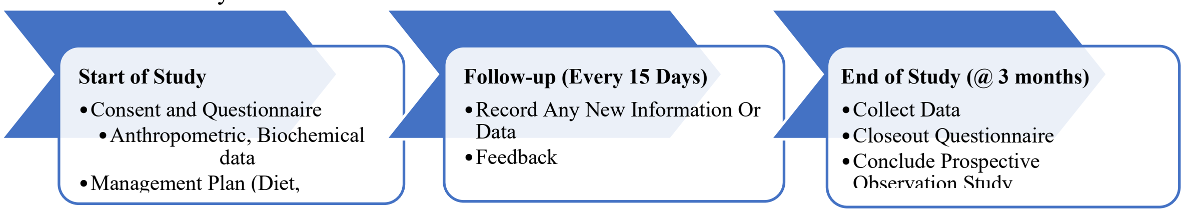
The anthropometry measurements included height, weight, waist circumferences and hip circumferences. Body Mass Index (BMI) was calculated by dividing the body weight (kg) by the square of the height (m). Waist hip ratio (WHR) was calculated by dividing waist circumference (cm) by hip circumference (cm).

The laboratory reports were collected from the patients and biochemical parameters gathered for the study purpose were: HbA1c, fasting blood sugar, fasting insulin, eAG, insulin C peptide, total cholesterol, HDL, LDL, triglycerides, SGOT, SGPT, homocysteine level, vitamin D, vitamin B 12, and magnesium.

The clinical parameters included blood pressure (BP) readings, medical symptoms, energy levels (scale of 1 to 10), duration of T2DM, duration of HTN in DM2 patients, any pre co-morbid conditions, stress levels, life events and family history, individuals health goals and readiness assessment.

The lifestyle parameters included individual's activity level (sedentary, active, heavy worker, athlete, etc), diet preferences (non- vegetarian, vegetarian, vegan, etc), diet patterns, alcohol consumption and smoking.

Timeline of the Study



Ethical Considerations

The data collected by the Ultra Wellness Center was used to improve the practices of the functional medicine approach in the treatment of the patients. While enrolling for the treatment at the Ultra Wellness Center, each patient had to agree to the New Patient Terms, which details the process, risks, disclaimers, support, and the research consent agreement, before submitting the forms. For the current study, all forms and documents provided by the Ultra Wellness Center, human subjects were identified only by a randomly selected patient number. No personal identifying information were used in the study; only the data obtained as a result of the study was utilized.

Statistical Analysis

Given the observational nature of the study, a quantitative statistical approach was chosen for the analysis. Descriptive statistics were used to test the difference in the biomarker parameters before and after the study's implementation. Continuous variables were expressed as the mean ± standard deviation. Categorical variables were expressed as medians. Where applicable, separate analyses for males and females were done due to gender-based standard reference range differences. Inferential statistics were not performed because of the small subject size (n = 20 patients).

IV. RESULTS AND DISCUSSION

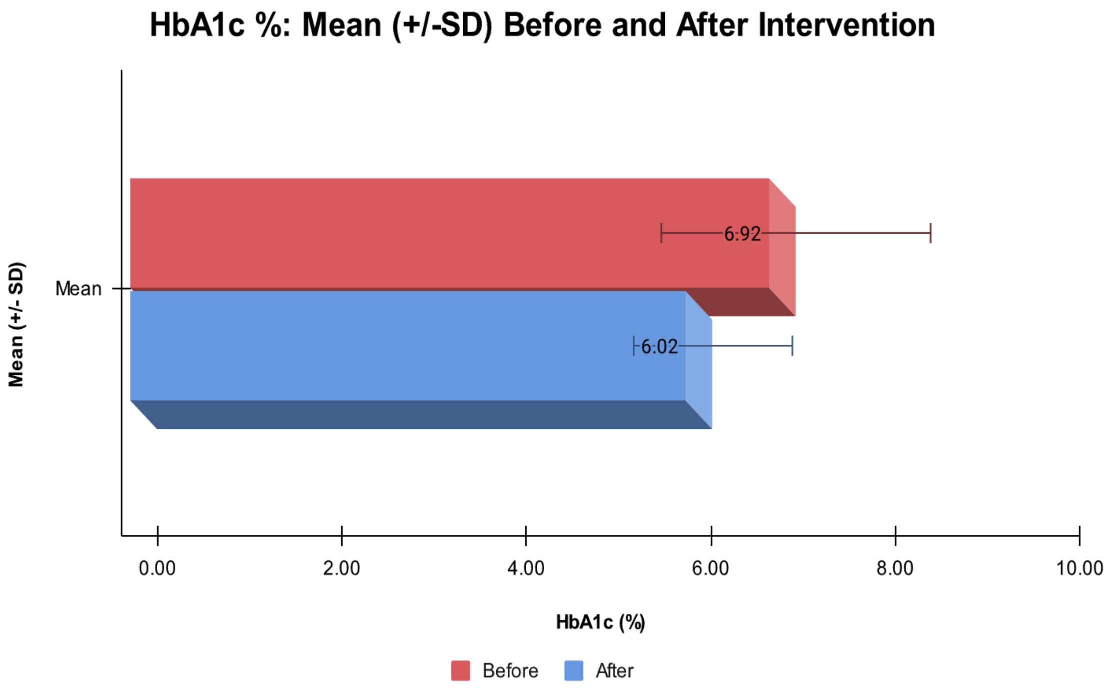
The study included 20 adult patients with MetS, with or without hypertension. Out of 20 patients, 12 females and 8 males, aged between 34-59, with an average age of 48. They participated in 3 month interventional program to improve their metabolic health. There were several differences between male and females with regards to anthropometric factors: Women had more visceral fat compare to men, while men reported to smoke, drink, and also exercise more compare to women. 85% of the total study population (n=20) had above normal range of BMI as per south asian standards at the beginning of the program. At the end of study 90% of total study population exhibited reduction in BMI.

The objective was to observe before and after difference in metabolic health parameters of the patients; with an aim to improve HbA1c, blood pressure, HDL and TG, and reduce WHR by the end of the intervention. Each parameter was analysed separately and reported below:

HbA1c % Analysis

According to the standard units for HbA1c%, a normal range is ≤ 5.7%, between 5.7% and 6.4% is pre-diabetes, and ≥6.5% is diabetes. It was observed that before the intervention, the mean ± SD HbA1c was 6.9 (± 1.462)% (Refer Figure 4A). The range of values observed were minimum of 5.8 % to a maximum of 10.7 %., with 6.2% median. After the intervention, the mean ± SD HbA1c % decreased to 6.0 (± 0.823) (Refer Figure 1). The range of values observed for this group ranged from 5.1 % to 7.9 %, with 5.8% median.

Figure 1: HbA1c%: Before & After Intervention Comparison

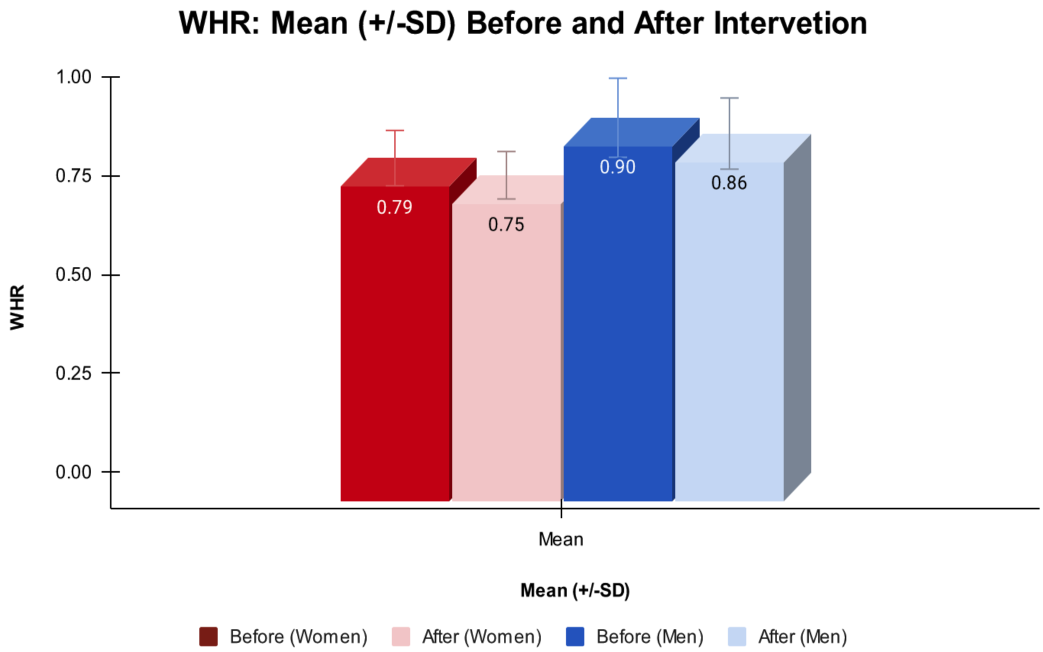


These results indicate that the intervention led to a reduction in HbA1c % levels, as the mean and median values decreased after the intervention. The narrower standard deviation suggests less variability in the data points after the intervention, indicating a positive impact of the intervention on HbA1c % levels, moving participants closer to the normal range and potentially mitigating the risk of diabetes.

WHR Analysis

The mean(±SD) WHR before the intervention for women was 0.79 (± 0.074). The minimum WHR observed was 0.63, while the maximum was 0.90. The median WHR was 0.81. After the intervention, the mean (± SD) WHR for women decreased to 0.75, (± 0.059). The minimum and maximum WHR values after the intervention were 0.63 and 0.86, respectively. The median WHR after the intervention was 0.76 (Refer Table 4B). Similarly, the mean (±SD) WHR before the intervention for men was 0.90 (± 0.102). The minimum WHR observed was 0.77, while the maximum was 1.03. The median WHR before the intervention for men was 0.90. After the intervention, the mean (±SD) WHR for men decreased to 0.86 (± 0.087). The minimum and maximum WHR values after the intervention were 0.75 and 0.98, respectively. The median WHR after the intervention was 0.85. The mean WHR for women decreased from 0.79 to 0.75 after the intervention (Refer Figure 2). The mean WHR for men decreased from 0.90 to 0.86 after the intervention.

Figure 2: WHR Mean (± SD) of the study population pre and post intervention



The results indicate that both women and men showed a reduction in their WHR after the intervention. For women, the mean WHR decreased from 0.79 to 0.75, which suggests a positive change in body composition. The standard deviation values for both groups were relatively small, indicating that the data points were clustered closely around the mean. However, it is worth noting that even though the mean WHR for women after the intervention was lower than the cutoff value for high risk (0.80), it is still in close proximity, suggesting that further improvements may be desirable. In the case of men, the mean WHR decreased from 0.90 to 0.86 after the intervention. This reduction indicates a positive change in body composition, although the mean value before and after the intervention remains above the high-risk threshold of 0.95. The standard deviation for men was also relatively small, indicating less variability in the data.

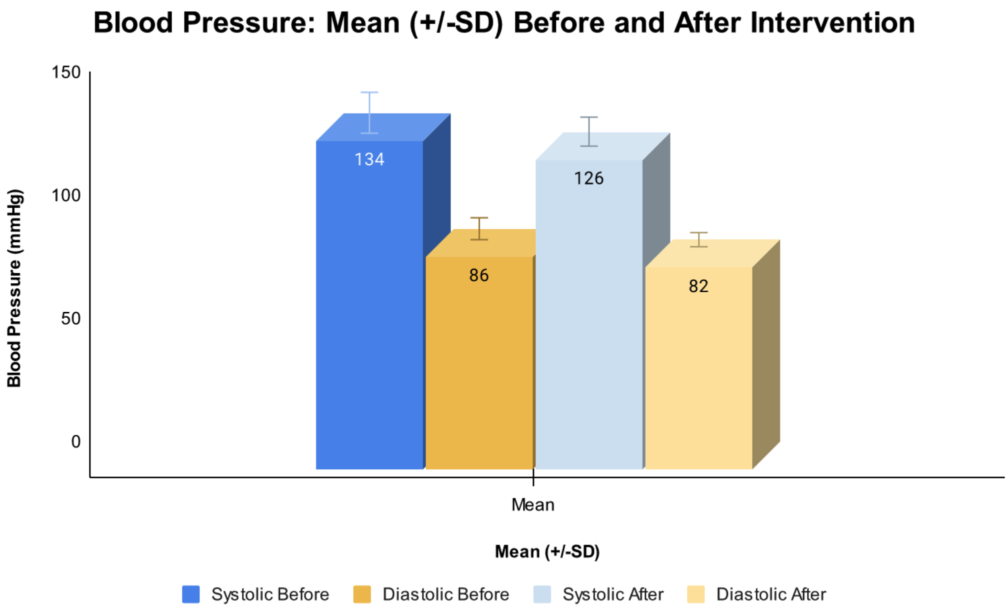
Overall, the findings suggest that the intervention had a favourable impact on reducing WHR for both women and men. However, it is important to consider individual variations and the established standards for high-risk WHR values.

Blood Pressure Analysis

Before the intervention, the mean (±SD) systolic blood pressure of the study participants was 134 (± 8.300.) mmHg, The lowest systolic blood pressure measured was 120 mmHg, while the highest was 150 mmHg, and the median systolic blood pressure was 135 mmHg. Before the intervention, the mean (±SD) diastolic blood pressure was 86 (± 4.807) mmHg,. The lowest diastolic blood pressure measured was 81 mmHg, while the highest was 100 mmHg, the median diastolic blood pressure was 85 mmHg. (Refer Table 3C).

After the intervention the mean (±SD) systolic blood pressure dropped to 126 (± 5.887.) mmHg after the intervention. Following the intervention, the lowest and maximum systolic blood pressure levels were 118 mmHg and 140 mmHg, respectively, and the median systolic blood pressure was 125 mmHg. After the intervention, the mean (±SD) diastolic blood pressure was 82 (± 2.865) mmHg Following the intervention, the lowest and maximum diastolic blood pressure readings were 78 mm Hg and 90 mm Hg, respectively, and the median diastolic blood pressure was 82 mm Hg. (Refer Table 3). The reduction in the mean(± SD) BP after the intervention variables were noted.

Figure 3: Blood Pressure Mean (± SD) of the study population



The results reveal a notable decrease in both systolic and diastolic blood pressure after the intervention. The mean systolic blood pressure decreased from 134 mmHg to 126 mmHg, indicating a positive change in blood pressure levels. Similarly, the mean diastolic blood pressure decreased from 86mm Hg to 82 mmHg, indicating a favorable outcome in terms of blood pressure regulation. It is important to note that the mean blood pressure values before the intervention were in the range of prehypertension, according to the provided blood pressure unit standard. Systolic blood pressure >120 mmHg and diastolic blood pressure >80 mmHg are considered prehypertension. After the intervention, the mean systolic and diastolic blood pressure values remained in the prehypertension range but showed a noticeable reduction.

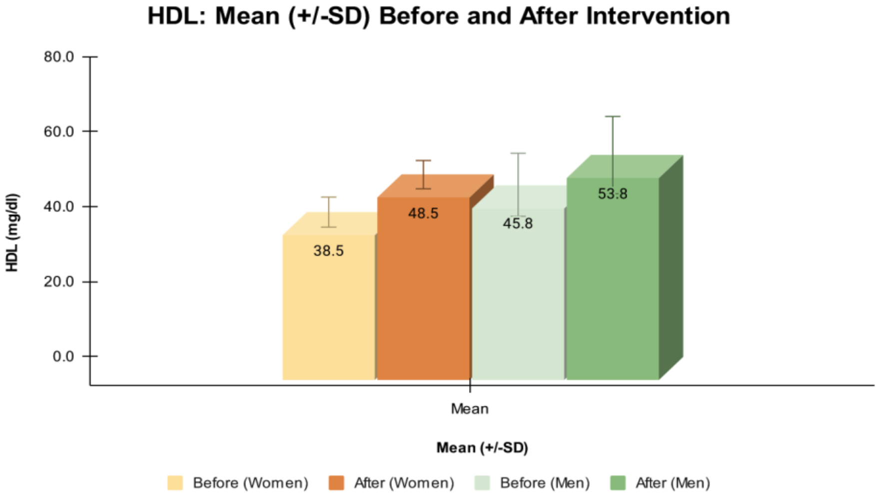
These findings suggest that the intervention had a positive impact on lowering blood pressure levels. However, it is crucial to interpret the results in the context of individual health and consider the provided blood pressure units as standard. Individuals with prehypertension are at an increased risk of developing hypertension, which is characterised by a systolic blood pressure of ≥140 mmHg and a diastolic blood pressure of ≥90 mmHg. While the mean blood pressure values after the intervention were lower than the pre-intervention values, they still indicate the need for continued monitoring and further interventions to achieve optimal blood pressure levels and reduce the risk of hypertension.

HDL Analysis

The mean (± SD) HDL level before the intervention for women in the study participants (N = 20) was 38.5 (± 4.009) mg/dl. The lowest recorded HDL level was 30.0 mg/dl, while the highest was 44.0 mg/dl, and the median HDL level in women was 38.7 mg/dl. The mean (± SD) HDL level in women increased to 48.5 (± 7.774) mg/dl after the intervention. After the intervention, the minimum and highest HDL values were 38.0 mg/dl and 62.0 mg/dl, respectively, and the median HDL level in women was 48.7 mg/dl.

Before the intervention, the mean (± SD) HDL level in males was 45.8 (± 8.715) mg/dl. The lowest HDL level measured was 34.6 mg/dl, while the highest was 56.0 mg/dl; and the median HDL level in males was 45.5 mg/dl. The mean (± SD) HDL level for males improved to 53.8 (± 10.306) mg/dl after the intervention. After the intervention, the minimum and highest HDL values were 40.0 mg/dl and 71.0 mg/dl, respectively; and median HDL level was 54.5 mg/dl in men. For a quick visual depiction of the HDL data analysis, review Figure 4.

Figure 4: HDL Mean (± SD) of the study population



The results indicate a significant improvement in HDL levels after the intervention for both women and men. HDL is often referred to as "good" cholesterol, and higher levels are associated with a reduced risk of cardiovascular diseases. The mean HDL levels increased from 38.5 mg/dl to 48.5 mg/dl in women and from 45.8 mg/dl to 53.8 mg/dl in men after the intervention, demonstrating a positive change in HDL profiles. It is worth noting that the mean HDL levels after the intervention for both women and men exceeded the optimal standards for South Asians (≥ 50 mg/dl for women and ≥ 40 mg/dl for men). This suggests that the intervention had a beneficial effect on HDL levels, potentially reducing the risk of cardiovascular disease in the study participants.

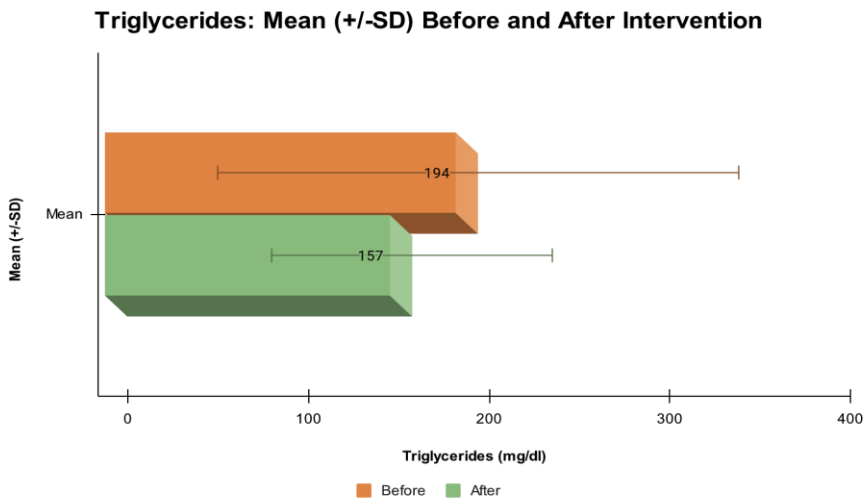
The standard deviations in both groups were relatively high, indicating a wide range of variability in HDL levels among individuals. This variability could be influenced by various factors, such as genetics, lifestyle, and individual response to the intervention. It is important to consider these factors when interpreting the results and implementing interventions to improve HDL levels.

Triglycerides Analysis

The mean triglyceride level before the intervention was 194 (± 144.211) mg/dL, in the examination of triglyceride levels for the study participants (N = 20). The lowest observed triglyceride level was 50 mg/dL, while the highest was 543 mg/dL; and the median triglyceride level was 144 mg/dL.

The mean triglyceride level after the intervention was 157(±77.667) mg/dL. After the intervention, the lowest and highest triglyceride levels were 74 mg/dL and 350 mg/dL, respectively; and the median triglyceride level was 143 mg/dL. For a quick visual depiction of the TG analysis, review Figure 5.

Figure 5: Graph of Triglycerides Mean (± SD)



The results demonstrate a decrease in triglyceride levels after the intervention, indicating a positive outcome for the study participants. The mean triglyceride level decreased from 194 mg/dL to 157 mg/dL, reflecting an improvement in triglyceride profiles. This reduction suggests a potential decrease in the risk of cardiovascular diseases associated with elevated triglyceride levels.

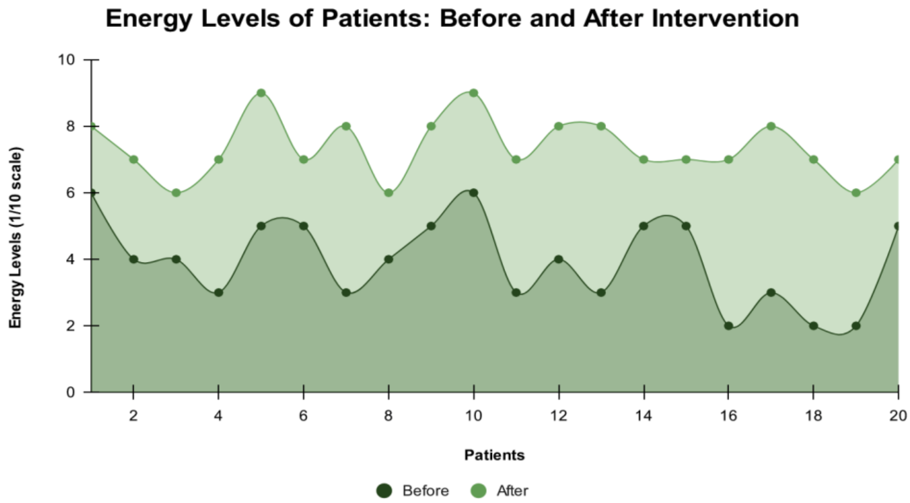
It is important to note that the mean triglyceride levels before the intervention exceeded the normal range (≤ 150 mg/dL). Triglyceride levels above 200 mg/dL are generally considered high and indicate an increased risk of cardiovascular problems. The mean triglyceride level after the intervention fell within the borderline high range (150–199 mg/dL), but it showed a noticeable decrease compared to the pre-intervention levels. The standard deviations for both before and after the intervention were relatively high, suggesting considerable variability in triglyceride levels among the study participants. This variability could be influenced by factors such as genetics, diet, and individual responses to the intervention.

Energy Levels Analysis

Before the intervention, the mean energy level for the study participants (N = 20) was 3.95 on a scale of 1 to 10, with a standard deviation of 1.276. The lowest observed energy level was 2, while the highest was 6. Before the intervention, the median energy level was 4. After the intervention, the mean energy level improved dramatically to 7.35, with a standard deviation of 0.875. After the intervention, the minimum and highest energy levels were 6 and 9, respectively. Following the intervention, the median energy level was 7.

Figure 6, reports that the energy levels of each individual patient (total n = 20), improved on the scale of 1to 10; 1 being the lowest and 10 being the highest. This could be the result of combination of many intervention parameters and overall counselling provided by health counsellors.

Figure 6: Graph of Energy Levels Experienced by Participant



The results reveal a notable improvement in energy levels after the intervention. The mean energy level increased from 3.95 to 7.35 on a scale of 1 to 10, indicating a substantial positive change. The standard deviation values for both before and after the intervention were relatively small, suggesting that the data points were clustered closely around the means.

The increase in energy levels after the intervention indicates that the intervention had a positive impact on participants' overall energy and vitality. This improvement may be attributed to various factors, such as changes in lifestyle, diet, exercise, or other aspects addressed during the intervention. Higher energy levels could contribute to improved productivity, motivation, overall well-being, and the ability to manage stress, supporting overall recovery. However, it is crucial to consider individual variations and the subjective nature of self-reported energy levels. Factors such as individual perception, psychological well-being, and personal experiences can influence reported energy levels. Additionally, the sample size of 20 participants may limit the generalizability of the results.

V. SUMMARY

The global incidence of MetS is increasing, with an estimated global prevalence of 30% of the adult population. According to 2020 research by Bhalwar R., India has consistently demonstrated a high prevalence, up to 25% of the adult population, with increasing age and female gender being at higher risk [15]. The therapeutic method involves intervention at both the macro and micro levels, as well as the management of many risk factors through the use of therapeutic lifestyle techniques for the control of obesity and visceral obesity, as well as a targeted approach to the control of specific risk factors [16].

Thus, MetS has become a capital concern for both public health practitioners and doctors in our country, and it requires coordinated, all-around efforts for prevention, early detection, treatment, management, and research [15]. Currently, the most typical treatment method is medicine as determined by the physician, with lifestyle recommendations focusing on macronutrients in food and basic exercise; micronutrients are rarely administered as part of MetS treatment.

In light of the above, this study asked, "Can we optimise the metabolic system by implementing a personalised functional approach of addressing micronutrient deficiency in synergy with lifestyle interventions in the urban Indian subject group with MetS?" The study was implemented accordingly, where patients received a personalised plan addressing their micronutrient deficiency (like Vitamin B12, Folate, Vitamin D3+K, Vitamin C, Iron, and Magnesium,), along with lifestyle changes (like diet, exercise, stress management, relaxation, meditation, smoking, and alcohol reduction or abstinence), and regular health counselling to keep them motivated and on track with the treatment plan.

The overall discussion provides a comprehensive overview of the study's findings across multiple parameters. The results indicate positive outcomes in various parameters of the study following the intervention.
Specifically, HbA1c% levels decreased, suggesting a potential reduction in the risk of diabetes. Both women and men showed improvements in their WHR, indicating positive changes in body composition. However, while mean WHR values decreased, the standard deviation range indicated individuals with high-risk thresholds, indicating room for further improvement. Blood pressure levels also decreased, although they still fell within the prehypertension range, emphasizing the need for continued monitoring and interventions. HDL cholesterol levels increased and TG levels decreased, reflecting a potential decrease in cardiovascular risk. Participants reported higher energy levels, suggesting an overall improvement in vitality. These findings demonstrate the beneficial effects of the intervention on various health parameters; however, further intervention would be needed to continue to maintain and/or improve the outcome for the patients.

VI. CONCLUSION

In conclusion, the results suggested that the intervention had a positive impact on improving the aimed metabolic parameters. Both women and men also reported an overall improved level of energy. In line with the short study timeline, the outcome was positive, yet the long-term impact needs further interventions. A healthy lifestyle is a lifelong commitment. Successfully controlling MetS takes long-term effort and teamwork between patients and health care providers.

Limitations and Future Research Directions
While the research findings suggested that the intervention positively influenced the measured parameters in the study participants, it is important to interpret the results cautiously and consider individual variations and long-term effects. The study timeline and intervention period were set for 3 months, with a study population of 20 patients. Further research with larger sample sizes and longer intervention periods is necessary to validate these results and determine the sustained effects of the intervention in achieving optimal metabolic health and reducing the risk associated with metabolic syndrome. Research is needed to unravel the underlying mechanisms, improve risk prediction, and develop personalized approaches for managing metabolic syndrome.

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