The suitability, acceptability, and feasibility of a culturally contextualized low-calorie diet among women at high risk for diabetes mellitus in Kerala: a mixed-methods study

Bhagiaswari Kodapally· Zinto Vilane· Jonathan Nsamba· Anjaly Joseph· Elezebeth Mathews· Kavumpurathu Raman Thankappan

Abstract

Background Nutritional therapy has been conventionally recommended for people with prediabetes as a method to delay or halt progression to type 2 diabetes mellitus (T2DM). The extensive diversity in food culture and habits in India pose a challenge in devising a uniform low-calorie diet plan. Though there are a number of studies related to different diet therapies, there exists limited evidence on culturally contextualized low-calorie diet plans and their process in India. The objective of the study is to test the suitability, acceptability, and feasibility of a culturally contextualized low-calorie diet among women with high risk for T2DM in Kerala.

Method We employed a four-stage equal-status sequential design for this study. Firstly, in-depth interviews (n = 10) were conducted to understand the modifiable and non-modifiable components of the usual diet for diabetes prevention. Secondly, we developed a low-calorie diet plan (1500 kcal per day) based on the local preferences and availability. Thirdly, we piloted the diet plan among 18 individuals in the community to know its acceptability. Fourthly, in-depth interviews were done (n = 4) among pilot participants to understand the feasibility of pursuing it through facilitators and barriers to implementing the diet plan.

Results Low-calorie diet plan was suitable for this setting as the burden of diabetes is very high and the diet plan had dietary components similar to the usual diet. Though participants had an intrinsic motivation to follow a healthy lifestyle, several systemic challenges such as the high cost of healthy foods options (fruits and vegetables), rice addiction, and food preferences driven by peer pressure act as hurdles.

Conclusion Apart from culturally contextualizing the low-calorie diet, it is important that complementary strategic measures such as reorientation of the public distribution system and subsidizing fruit and vegetable production and cost are required for the suitability, acceptability, and feasibility of implementation.

Keywords Prediabetes · Acceptability · Feasibility · Culturally appropriate dietary recommendation
Introduction

Diabetes mellitus is a global pandemic slowly becoming the leading cause of morbidity and disability worldwide [1]. International Diabetes Federation (IDF-2021) reported that 537 million adults (20–79 years) are living with diabetes [2]. As of 2021, the number of deaths that resulted from diabetes or its complications was estimated to be around 6.7 million [2].

Over the past years, type 2 diabetes mellitus (T2DM) has grown at an alarming rate, especially in developing countries like India. The majority of the 4.2 million deaths due to diabetes occurred in women (2.3 million) than men [3]. In India alone, over a million deaths were attributed to diabetes, making it the largest contributor to regional mortality. On that note, type 2 diabetes has become noticeable across all sections of society within India.

Globally, India has the second largest (74 million) number of people after China (140 million) living with diabetes among 20 to 79 years [4]. Within India, the state of Kerala is leading with at least 20% diabetes prevalence [5]. Even though studies that measure incidence could provide a more precise estimate, such studies are still very limited in the state [5].

Pre-diabetes has become increasingly important as it predisposes individuals to a higher risk of developing type 2 diabetes and cardiovascular diseases such as stroke [6]. The IDF estimated the global prevalence of pre-diabetes to be 7.5% and projected an increase of 8.0% by 2030[4]. The prevalence was higher in the American regions but lower in Europe and South-East Asia regions, respectively [6]. A recent nationwide study in India estimated the overall prevalence of prediabetics in all 15 states as 10.3% (10.0–10.6) [7]. The American Diabetes Association estimated that about 70% of people with pre-diabetes are likely to develop overt diabetes during their lifetime [8].

Clinical trials have demonstrated that reversing pre-diabetes is possible by implementing effective lifestyle modification programs that focus on physical activity and adopting the proper healthy dietary plan. Clinical trials among pre-diabetics, specifically among those with impaired glucose tolerance (IGT) on strategies including lifestyle modification, pharmacological intervention, and surgery have been demonstrated to be effective in preventing the progression to type 2 diabetes mellitus [9].

Diabetes prevention programs conducted in India and Kerala [10] targeted pre-diabetic individuals, predominantly those with IGT. The trials showed that a moderate goal of weight loss of 5% among individuals with isolated impaired fasting glucose was not sufficient to prevent type 2 diabetes mellitus [11]. A more intense and specific diet and weight loss plan were recommended to promote regression to normoglycemia among isolated impaired fasting glucose [11].

A diet rich in carbohydrates was a major driver of progression from normoglycemia to hyperglycemia as it induced hyperinsulinemia [12]. The Prospective Urban and Rural Epidemiology (PURE) study reported that those with IFG consumed more refined grains, fruit juices, lean meat, processed meat, and few nuts and seeds than normoglycemic individuals [13]. A 1-year-long trial with 1200 kcal per day was found to facilitate regression to normoglycemia among those with IFG [14]. These findings were similar to those that found among participants with IFG, a lower-fat diet/higher carbohydrate was significantly associated with lower fasting glucose [15]. Furthermore, a low carbohydrate diet had demonstrated to have facilitated weight loss, increased glucose control, and lowered glycated hemoglobin (HbA1C) levels [16].

The nutritional intervention for diabetes prevention, specifically for IFG, needs to focus on a low-calorie diet, up to 1500 cal per day [12] predominantly constituting food of low glycemic index. Adherence to the dietary recommendation is critical in achieving the targets and outcomes in clinical trials, and poor adherence often leads to less than predicted weight loss. Participant adherence was generally found to be good when food was prepared at the study site or provided in a clinical setting [17]. In a real-world scenario, adherence to a dietary recommendation in a sustainable manner could be enhanced by devising a calorie-restricted diet plan, taking into consideration the usual dietary preferences of a locality [18]. We found a gap in evidence of a culturally appropriate dietary plan that considers the population’s preferences in India. This was found to be a critical gap of evidence as India has the second-largest number of people living with diabetes as well as several others undiagnosed or pre-diabetic.

In India, women are centrally linked to cooking and diet management in households. Hence, we identified women as major stakeholders to assist in the development and testing of the calorie-restricted diet plan. The objective of this study was to test the suitability, feasibility, and acceptability of adopting a culturally appropriate low-calorie diet in Kerala, India, among those with a high risk for T2DM.

Materials and methods

Study approach and design

The study was primarily exploratory in nature and utilized multiple methodological approaches. The quantitative phase examined the nutrient analysis of the low-calorie
diet consumed using a 7-day 24-h recall, and the qualitative phase explored the suitability, acceptability, and feasibility of the participants using an in-depth interview technique. We adopted both STROBE and COREQ guidelines for reporting the study (Fig. 1).

Sample size

This study aimed to assess the feasibility, acceptability, and suitability of the recommended diet plan through a series of exploratory techniques. The study was piloted in a representative sample of high-risk women identified from an ongoing cross-sectional study using the Indian Diabetes Risk Score [19]. The Planning Pilot Studies in Clinical and Translational Research [20] recommends a minimum of 12 participants. We have altogether recruited 28 participants through multiple stages for this exploratory study, among which 18 women participated in the testing of the feasibility, acceptability, and suitability of the low-calorie diet plan.

Framework

The study was guided by the Suitability, Acceptability, and Feasibility (SAF model) [21] to understand the suitability, acceptability, and feasibility of adopting a low-calorie diet among “high-risk” women for the prevention of type 2 diabetes mellitus.

Suitability refers to the quality of the diet plan being right or appropriate for a particular person, taking into consideration the contexts of culture, socioeconomic standards, and individual preferences. Acceptability refers to the characteristic of being subject to the acceptance of the diet plan for diabetes prevention. Feasibility refers to the reasonable possibility of following the diet plan.

Data collection

Stage 1: understanding the usual diet, the dietary preferences, and the modifiable and non-modifiable components of the diet for diabetes prevention in the locality (AJ)

With an intention to develop a low-calorie diet plan for diabetes prevention that is culturally and contextually appropriate and sustainable, we ascertained the existing dietary habits based on the socio-cultural experience of the women through in-depth interviews (n = 10) (Table 1).

The primary aim of conducting the in-depth interview was to explore the participants’ knowledge of the importance of nutrition in preventing type 2 diabetes mellitus, their current dietary practices, attitudes towards changing dietary patterns, and barriers they encounter in changing dietary practices. Knowledge, current dietary practices, their preferred meals, types of oil used, meat, fruit, vegetable consumption patterns, attitudes towards adopting new dietary plans, and anticipated barriers and challenges were included in the interview. Purposive sampling was done.
among women screened for “high risk for type 2 diabetes mellitus” based on the Indian Diabetes Risk Score [19]. We approached 25 participants, among which 10 of them were willing to participate and consented to the study. A total of 10 in-depth interviews were conducted by one of the authors (AJ), a research scholar who specialized in qualitative and quantitative techniques, with 5 years of experience in the research field. The author played the role of an outsider as the participants did not have any association with the researcher and this helped to eliminate any bias in the study.

In-depth (ID) interviews were employed using an ID interview guide which included (i) knowledge of the nutritional requirements for the prevention of type 2 diabetes mellitus; (ii) current dietary practices; and (iii) attitude towards changing to a healthy diet. The data were collected through telephonic interviews in March 2020. Before the data collection, participants were contacted and explained about the study, the consent process, and the need for recording the telephonic interview. Following this, verbal consent was taken. The interview was conducted at the participant’s preferred time, which lasted for about 45 min to 60 min. The entire interview was audio recorded, and interview notes were also taken by AJ. Ethical aspects were considered, and the participant’s identity was masked with participant ID throughout the study.

**Stage 2: development of the low-calorie diet plan (JN)**

An extensive literature review was done to understand the recommendation for the diet to prevent progression to type 2 diabetes mellitus among high-risk/pre-diabetic individuals [22, 23]. The main goal of the new diet plan was to enable participants to lose weight, preferably about 5–7% of their baseline weight.

There is strong evidence on the recommendation of a low-calorie diet (~1000–1200 Cal) for the prevention of type 2 diabetes among high-risk individuals [24]. We agreed that a daily intake of 1500 cal [25] would be ideal in this population with an average calorie intake of 2200 to 2500 calories [26], to achieve the weight reduction goal in about 4–6 months.

At first, a generalized meal plan was developed by the study team, which was refined to a culturally specific diet based on the participants’ feedback. Calories of the food items were calculated using the National Institute of Nutrition food composition database for India and three Indian food composition tables [25–27] by the study dietician (JN) through a rigorous process.

**Stage 3: piloting the low-calorie diet plan in the community to know its feasibility and acceptance for adoption (BK)**

The piloted intervention for this study is the dietary modification and not pharmacological intervention. Dietary interventions are proven effective by large clinical trials in the USA [28], Europe [29], and India [30]. Moreover, long-term effects of lifestyle modification for diabetes prevention were found among high-risk individuals compared to pharmacotherapy [31]. The low-calorie diet plan piloted was 1500 calories per day, which is slightly higher than the 1000 calorie recommendation [24] to enhance adoption and considering the population characteristics (predominantly carbohydrate diet). We identified 20 high-risk and/or pre-diabetic women, who had not participated in stage 1 of the study to pilot the diet plan for its acceptability and feasibility. Participants were briefed on the study, and the consenting process and verbal consent were taken. Participants were given the printed diet plan by a local health worker (Accredited Social Health Activist) 3 days prior, for preparation. They were asked to implement the plan for at least seven consecutive days. A 24-h dietary recall on all days was recorded by the local health worker for 7 days, including weekends. At the end of the intervention, only 18 participants completed the 24-h dietary recall for 7 days. In order to ensure data quality, we cross-checked the dietary data by random telephonic calls to five out of the 18 participants (25%) daily.

| Table 1 In-depth interview guide for the participants in stage 1 |
|-------------------|---------------------------------|
| 1. What is the role of diet in diabetes prevention? |
| 2. What are healthy dietary components? |
| 3. Which is your preferred meal of the day? |
| 4. Which oil do you mostly use for cooking? |
| 5. On an average how many days in a week do you consume meat? |
| 6. Have you been on any weight loss diet previously? |
| 7. What do you think about your existing diet intake? |
| 8. Is there anything in your current food pattern that you cannot change? |
| 9. How acceptable for you is the change from coconut oil to sunflower oil? |
| 10. Are you willing to cut down the amount of rice intake and consume more vegetables and fruits? |
| 11. Do you feel that the head of the family has any role in determining the things you purchase for cooking? |
Stage 4: understanding the acceptability and feasibility of implementing and pursuing the low-calorie diet plan (BK)

We followed up with 18 participants to know their acceptability of the low-calorie diet plan. Out of the 18 participants who took part in the dietary intervention, 15 participants consumed calories within the range of 1000–1500 Cal/day, two participants consumed less than 1000 Cal/day, and only one consumed more than 1500 cal per day. Based on this, we classified them into three categories: participants who adhered to the recommended calories of 1500 approx., participants who consumed less than the recommended calories, i.e., 1000 calories approximately, and the participant who consumed more than recommended, i.e., 1750 calories. We identified one each from each of these categories based on the researcher’s opportunity to intensely engage with them over a period of 2 weeks post-diet implementation. We were able to reach data saturation based on informational redundancy, as the data collected were rich, thick, and in-depth in quality due to selected participants being critical cases for the in-depth interviews. The sample was chosen based on the best opportunity for the researcher to reach data saturation[32]. In-depth interviews were conducted using an ID guide to understand the facilitators and barriers in the adoption and sustainability of the recommended diet plan among individuals with variations in calorie intake. We tried to explore the influence of the family on food choices, support from the spouse, availability, affordability, and sustainability in following the dietary recommendations. The in-depth interviews were conducted by one of the authors (BK), a post-graduate in public health, and trained in quantitative and qualitative research techniques, with 3 years of experience; the author acted here in a dual role as an insider, who followed the participants closely, which helped in identifying key informants, and also as an outsider as the researcher had no personal association with the participants, thereby eliminating any bias (Table 2).

The participants were contacted a day before the interview to brief on the purpose of the interview, the consenting process, and the role of the participants in the study by one of the authors (BK). Participants were given a day to contact the interviewer prior to the interview, for queries related to the participation. Before the interview session, verbal informed consent was audio-recorded for participation. The interview on an average lasted for 45 to 60 min on more than

Table 2  In-depth interview guide for the participants in stage 4

|   |   |
|---|---|
| 1 | How did you feel about following the prescribed diet plan? Were you able to follow it? How was your experience? |
| 2 | Did you make any major changes in your diet from your usual one? If yes, what major changes were made? [Reducing portion size? Fruits? Vegetables? Nuts? Three meals a day with no snacks?] |
| 3 | What were the challenges you faced in following this diet plan? |
| 4 | What were the factors that helped you follow this diet plan?* [In terms of food availability, family support, spouse support, children support (and how each one contributed to the adherence/non-adherence, cost of food items)] |
| 5 | Did you feel any difficulty while switching on to this diet plan?* [In terms of food availability, family support, spouse support, children support (ask specifically how each one contributed to the adherence/non-adherence, cost of food items)] |
| 6 | What do you think about adding fruits and nuts to your daily diet? How well were you able to follow it? |
| 7 | Was all the food given in the diet chart, easy to prepare? Where are all the ingredients used in the food easily available in the market? How easy was it implementable in terms of availability and cost?* |
| 8 | Did you modify the recommended portion size of any food given in the diet chart?* If yes, how? |
| 9 | Did you substitute any food portions in the diet chart? |
| 10 | Did the diet plan in any way influence your daily activities?* |
| 11 | What all efforts did you take to stick on to this diet plan?* |
| 12 | Was the adherence to the diet stressful for you?* |
| 13 | Were you hungry in between the prescribed diet and if so, how did you manage the hunger?* |
| 14 | Was there any point in time where you felt you can’t go any further with this diet plan? |
| 15 | Do you think in the long run you would accept this diet plan for your family? |
| 16 | Did you talk about this to your family? How receptive and supportive were they of this change? |
| 17 | What was your husband’s response to you taking up this challenge? |
| 18 | Was he interested to be a part of the revised diet plan? |
| 19 | How supportive were your other family members? |
| 20 | Did your family adhere to this diet plan? |
| 21 | What type of rice do you consume? Do you have household cereals purchased from the ration provision from Public Distribution System? |
| 22 | According to your view, what are the changes required to the existing diet plan? |
one occasion, not exceeding three, over a period of 2 weeks. This was done as we wanted to understand the perceptions on the acceptability and feasibility of the diet plan post-implementation through rigorous engagements at multiple convenient times. The questions were asked in the regional language (Malayalam) and were audio-recorded. The audio records were translated and transcribed into the English language. The verbatim was transcribed in the participant's own words. To ensure quality and accuracy, back-to-back translation was reviewed and approved by a language expert).

Setting

The study was conducted in the Indian State of Kerala, the diabetes capital of India. The dietary plan was developed in particular for Kasaragod district, the northernmost district in Kerala. Considering the low rural–urban divide and minimal variations in major nutritional components within the State, this plan could apply to a larger population within the State of Kerala.

Study population

The study participants included women aged between 30 and 60 years. Participants’ high risk for diabetes was identified using an Indian Diabetes Risk Score (IDRS) [33] from an ongoing cross-sectional survey [34]. IDRS was developed using four parameters namely age, abdominal obesity, family history of diabetes, and physical activity. A maximum score of 100 is given for these categories combined. Subjects with an IDRS of < 30 were categorized as low risk, 30–50 as medium risk, and those with > 60 as high risk for diabetes [33].

Inclusion criteria

- Women aged 30–60 years
- Those with an Indian Diabetes Risk Score of > 30

Exclusion criteria

- Pregnant women
- History of gestational diabetes mellitus
- Women with type 2 diabetes mellitus

Ethical clearance

The study was approved by the Institutional Human Ethics Committee of the Central University of Kerala (CUK/IHEC/2019/034_A, 21st November 2019). Privacy of the participants and the confidentiality of the information were strictly maintained.

Data analysis

Data analysis for qualitative phase (stages 1 and 4)

In the first and fourth stages of the qualitative phase, a member check was done to ensure the validity of the transcribed data. During the interview, the participants were asked to confirm if the interpretation affirms their feelings and views. Minor changes were made to align with their feedback. Conventional Braun and Clark’s thematic analysis was adopted to analyze the qualitative data. In the first and fourth stages, analysis was conducted by two coders (AJ&BK) and (ZV&BK), respectively. The transcript was thoroughly read for familiarization with the data and coding was done using NVivo (version 2020).

In the qualitative phases, both deductive and inductive coding was done. Similar codes were identified and classified to form categories that were reviewed, collapsed, and classified into themes.

In the first stage, four categories were derived in the coding tree, which were (i) knowledge of the role of diet in T2DM prevention, (ii) current dietary practices, (iii) attitude toward changing dietary patterns, and (iv) support from home. Similarly in stage 4, we derived three major themes: (1) experience with adopting the recommended low calorie-diet plan which describes the experiences the participants had upon adopting the diet plan; (2) the challenges of low-calorie diet plan, which involved the challenges in adopting the diet plan and; and (3) the acceptance of low-calorie diet plan, which describes the acceptance in adopting the diet plan. The researcher employed the peer-debriefing strategy to determine the trustworthiness of the data analyzed. The peer debriefing involved an expert in social and preventive medicine, who is not involved in any part of the study. Critical opinions were considered, and the data was reanalyzed to form the major themes and findings that are presented in the “Results” section.

Data synthesis and condensation process

Samples for condensation process of the transcripts for stages 1 and 4 are shown in Tables 3 and 4.

Nutrient data analysis (stage 3)

Dietary data were obtained from 7 days 24-h recalls of 18 participants covering breakfast, lunch, and dinner meals. Portion sizes, as consumed by each participant, were entered into Nutrisurvey® software. Nutrient intake per meal and per day were computed using Nutrisurvey® software, by multiplying the intake in grams by the nutrient content of the specified portion size, based on the country-specific food composition database for India.
The total calories and total macro nutrient intake (carbohydrates, fats, and proteins) were summed up, and its average consumption for week was calculated by finding individual averages for each macro nutrients and calorie consumption. Local Indian foods missing in the database were manually included using values from three Indian food composition tables [25–27].

Nutrisurvey® is the English translation of professional German nutrition software (EBISpro) Version 2010. It contains all useful functions such as nutrient analysis and calculation of energy requirements, planning of diets, diet history, food frequency, and nutrient calculation of foods for all cultural contexts, including India [35].

The primary nutrients of interest in our study were total energy (Kcal), fat (saturated, trans fatty acids, polyunsaturated fatty acids, monounsaturated fatty acids, and cholesterol), proteins, carbohydrates, sugars, dietary fiber, sodium, and potassium. Each participant’s total daily calorie intake (covering breakfast, lunch, and dinner) was summarized and compared to the recommended calorie intake (1500 cal approx.).

Results

Stage 1: understanding the usual diet, the dietary preferences, and the modifiable and non-modifiable components of the diet for diabetes prevention in the locality

All the 10 female study participants were between the ages of 30 and 60 years, and most of them were unemployed with high school education coming from lower or middle-income households.

The findings from the qualitative research were categorized into four themes and described briefly.
| Participant ID | Paragraph statement                                                                 | Condensed to statements                                                                 | codes                          | Themes                                                      |
|---------------|---------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------------------------|-------------------------------------------------------------|
| PS4-1         | No, I haven't made any particular changes because everything in the food items was similar to what I make at home, but I have reduced portion size. The items were all available in the market, so it was not a problem | I haven't made any particular changes because everything in the food items was similar to what I make at home | Ease of cooking             | Experience with adopting the recommended dietary plan       |
|               |                                                                                                                                 | I have reduced the portion size                                                        | Controlling portion size      |                                                             |
|               |                                                                                                                                 | The items were all available in the market, so it was not a problem                   | Easily accessible             |                                                             |
| PS4-2         | My husband is working outside. I don’t go to the market usually, so the neighborhood boy gets me the vegetables. My husband becomes late also so sometimes shops will be closed | My husband comes late, sometimes shops will be closed                                   | lack of accessibility        | Experience with adopting the recommended dietary plan       |
| PS4-3         | Without having rice I felt excessive hunger and tiredness. I didn’t feel full and I was drinking water to get that full feeling. I felt exhausted, felt like I can’t do work, nothing else in my thoughts | * Without having rice, I felt excessive hunger                                         | Rice addiction                | Challenges with adopting the dietary plan                   |
|               |                                                                                                                                 | * I felt exhausted, felt like I can’t do work                                          | Exhausted                     |                                                             |
| PS4-3         | It’s good to add fruits and nuts to the diet, fruits we have when the husband brings them | It’s good to add fruits and nuts to the diet                                           | instigating fruit-eating habit | Acceptance of the diet plan                                |
| PS4-2         | My husband was supportive; he said to control my food and eat as recommended          | My husband was supportive                                                             | Spouse support                |                                                             |
Theme 1: knowledge of the role of diet in T2DM prevention

The interviews demonstrated that the participants had good knowledge of the role of diet in preventing diabetes. The majority perceived foods rich in carbohydrate, sugar, and fat as the main causes of diabetes; hence, their reduction or avoidance can help to prevent T2DM.

“Yes. I think diet can prevent diabetes. It is by reducing sugar intake and fatty foods.” (Participant 8).

Most of the participants pointed out the importance of sugar reduction, four participants said it is important to reduce rice intake, and a few participants emphasized avoiding oily/fried foods. Besides, some participants suggested other important beneficial practices including exercising and eating home-cooked meals.

“Food can prevent diabetes. Reduced sugar consumption and exercise can prevent diabetes.” (Participant 4).

The participants demonstrated good knowledge of various foods that should be taken more as prevention which include home-cooked meals, milk, grains, fruits, and vegetables. The majority of the participants emphasized the importance of taking fruits and vegetables. Only one participant demonstrated poor knowledge as she repeatedly responded not to know anything about the role of diet in T2DM prevention.

Theme 2: current diet practices

Breakfast: All the study participants verbalized to start their day with tea of which half of them often go for unsweetened black tea. Most participants took their tea with dosa or appam or idly (rice based) which was served with curry. Curry taken by most participants was the Bengal gram curry. Other participants said they also take sambar—a lentil-based vegetable stew/porridge/soup, cooked tamarind broth, and/or coconut chutney—finely ground fresh white coconut with either green chilies or dry red chilies and salt. However, some of the participants did not add curry to their breakfast.

Lunch: All the participants reported taking at least 1–3 serving spoons or cups of rice together with pulses or grams and vegetables. The majority of participants stated that they took about two serving spoons or cups of rice, three participants said they only take 1.5 serving spoons of rice and only one reported taking just one serving spoon of rice. Few participants said they took rice with either Bengal/green gram, sambar, or pulses. Meat or chicken consumption was minimal as most of the participants reported only take it once a month or 2 weeks. However, most of the participants reported also taking fish curry daily.

Evening/supper: In the evening, most participants consumed tea with a mixture (tea time fried snack). Others pointed out that they sometimes took evening tea with other bakery products such as biscuits and a few other snacks in the evening. For most of the participants, supper was usually the same as lunch (leftovers from lunch meal); otherwise, others take chapatti or fruits (one participant).

Most of the participants reported having bananas available in their homes, and others bought bananas at least once a week. Other fruits and cashew nuts were reported to be taken rarely. Most of the participants preferred home-cooked meals, half of them reported only buying Biriyani once in 2 months, and three out of ten said they never buy fast foods at all.

“We don’t eat fast food. Only once in two months, we buy Biriyani.” (Participant 4).

Preferred meal of the day: all the participants usually had about three meals a day. Most of them cannot skip their breakfast and some cannot skip their lunch. Few said they can’t avoid any of the three meals.

“I can’t avoid any meals.” (Participant 6).

The oil used: for cooking, the majority of the participants used coconut oil, only a few reported using sunflower oil, and this is used together alternately with the coconut oil, and the rest of the participants said they used palm oil for dosa only; otherwise, they used coconut oil.

Preference in preparing meals: participants said they consider their family’s preferences whenever they prepared food but some said they prepared as they wished.

Theme 3: attitude towards changing the diet patterns

When asked about any previous weight loss diet plan, the majority of participants reported not having adopted any, but some had tried before and cut down the amount of rice taken. Most participants were unable to avoid breakfast and lunch but had no problem with supper or changing their nighttime food. However, others verbalized challenges, and participants said they were unable to avoid rice or tea.

“I tried dieting. But I can’t avoid rice.” (Participant 2).

Interestingly, all the participants were very eager and open to an increase in intake of fruits and vegetables. With the current dietary intake, most of the participants were unaware of any unhealthy foods that they were taking regardless of having earlier on reporting to know that rice, sugar, and oil are the main causes of diabetes. Most participants were unwilling to change from using coconut oil to sunflower oil, and the main challenge was the cost of sunflower oil since most of them verbalized that coconut oil is free from the ration shop and easily accessible. Others said they disliked sunflower oil due to its smell, and one said it makes her sick.

The participants were willing to cut down on rice intake and...
increase that of fruits and vegetables. Others pointed out that they have already been doing it.

**Theme 4: support from family**

Most of their diet preferences were based on their child’s preferences:

“My child wants only oily snacks like banana fritters for an evening snack, and since they are coming from school all tired. He loves it and I tend to make banana fritters most often for him, we also tend to eat as an evening snack.” (Participant 5).

“My daughter doesn’t eat anything made of rice, she wants *puri* every day so most of the days our breakfast is *puri* itself.” (Participant 7).

“My children don’t have lunch without fish fry and the only relief is that we make coconut oil at home which is pure.” (Participant 9).

Most of the women’s dietary habits were based on their spouse’s decisions as it was they who brought the grocery items.

“I ask my husband to get any vegetables that are available in the market that he likes, he gets what he wants.” (Participant 9).

### Table 5  Baseline characteristics of participants who piloted the diet plan (stage 3, n = 18)

| Variable                                      | Sub-variable          | N (%) |
|-----------------------------------------------|-----------------------|-------|
| Age group                                     | 30–39 years           | 1 (5.5) |
|                                                | 40–49 years           | 13 (72.2) |
|                                                | 50–60 years           | 4 (22.3) |
| Religion                                      | Hindu                 | 18 (100) |
| Marital status                                | Married               | 16 (88.9) |
|                                                | Separated             | 2 (11.1) |
| Average monthly income of the household       | INR 11,837–17,755     | 1 (5.6) |
|                                                | INR 7102–11,836       | 7 (38.9) |
|                                                | INR 2391–7101         | 8 (44.4) |
|                                                | INR < 2390            | 2 (11.1) |
| Educational status                            | Graduate              | 2 (11.1) |
|                                                | Intermediate/diploma  | 5 (27.8) |
|                                                | High school           | 9 (50.0) |
|                                                | Middle school         | 1 (5.6) |
|                                                | Primary school        | 1 (5.6) |
| Occupational status                           | Professional          | 1 (5.6) |
|                                                | Clerical/shop/farm-   | 3 (16.7) |
|                                                | Skilled worker        | 3 (16.7) |
|                                                | Unskilled worker      | 3 (16.7) |
|                                                | Unemployed            | 8 (44.4) |
| Participant’s type of income                  | Regular               | 4 (22.2) |
|                                                | Non-regular           | 14 (77.8) |
| Number of members in participant’s household  | 2                     | 4 (22.2) |
| (including the respondent)                    | 3 or more             | 14 (77.8) |
| No of the members in the participant’s household who earns regularly | None | 2 (11.1) |
|                                                | 1                     | 8 (44.4) |
|                                                | 2 or more             | 8 (44.5) |
| Type of ration card (document issued by government indicating individuals economic status) | Yellow card (most economically backward section of society) | 1 (5.6) |
|                                                | Pink card (below poverty line) | 9 (50.0) |
|                                                | Blue card (above poverty line) | 3 (16.7) |
|                                                | White card (non-priority) | 5 (27.8) |
| Type of ownership of the house                | Own                   | 18 (100) |
| Physically activity status (self-reported)    | Sedentary             | 3 (16.7) |
|                                                | Active                | 15 (83.3) |
“I ask my husband to get vegetables only as fruits are costly, he gets it only sometimes.” (Participant 8).

**Stage 2: development of low-calorie diet plan**

The calorie-restricted or low-calorie diet plan was developed based on the key dietary recommendations identified through evidence-based research for the prevention of T2DM among the pre-diabetics and suitability based on the findings from stage 1.

The findings of the in-depth interview suggested the following:

- Rice-based dishes cannot be replaced but can be limited.
- Fried food items though integral to the existing diet can be cut down.
- Replacing the use of saturated oil (coconut oil) with unsaturated oils is challenging.
- Fruits and vegetable consumption can be increased based on availability.

The recommendations from evidence based research suggest the following:

- Consumption of 1500 cal mostly from starch (polysaccharides) (24)
- Reduce the consumption of polished rice, red meats, animal fat, and coconut oil (37)
- Limit consumption of salt, sugar, and starch powder (37)
- Stick to regular 3 meals per day (38)
- Daily consumption of fruits and vegetables with a low glycemic index (15)

The sample e diet plan adhering to the aforementioned conditions is given as (Online resource 1).

**Stage 3: findings of the pilot testing of low-calorie diet plan**

The mean age of the study participants was 48.9 years (range 30–60). The baseline characteristics of the study participants are described in (Table 5).

We also analyzed a 7-day meal plan on 18 participants and their calorie consumption and macronutrient consumption (Table 6). There were no reported side effects for the prescribed diet. A graphical representation of the calories consumed through fruits and vegetables, nuts and rice is presented in Fig. 2.

The average total calories were 1202.14 cal, comprising 266.20 cal from carbohydrates, 771.13 cal from fat, and 164.81 cal from protein. We found that a major portion of the calories came from carbohydrates, and the fruit, vegetable, and nut consumption was minimal.

### Table 6 Quality and composition of food consumed on average for 7 days (a week) by the pilot participants (stage 3)

| Participant No | Days | Average fruit-vegetable consumption for 7 days (grams) | Average nuts consumption for 7 days in (grams) | The average portion size of rice in grams (portion size = 80 g) | Total calorie intake | Fat (g) | Carbohydrate (g) | Protein (g) |
|----------------|------|------------------------------------------------------|-----------------------------------------------|-----------------------------------------------------------|---------------------|--------|-----------------|------------|
| 1              | 7    | 139.83                                               | 0                                             | 1060.48                                                   | 22.55               | 186.2  | 28.31           |
| 2              | 7    | 128.09                                               | 0                                             | 956.06                                                    | 19.57               | 158.55 | 30.17           |
| 3              | 7    | 173                                                  | 0                                             | 1308.91                                                   | 30.48               | 216.89 | 48.29           |
| 4              | 7    | 78.64                                                | 0                                             | 1124.17                                                   | 24.05               | 194.32 | 33.11           |
| 5              | 7    | 169.04                                               | 0                                             | 1277.02                                                   | 24.11               | 263.71 | 46.97           |
| 6              | 7    | 128.43                                               | 0                                             | 1311.47                                                   | 37.24               | 203.99 | 37.4            |
| 7              | 7    | 197.31                                               | 0                                             | 1248.52                                                   | 32.99               | 200.85 | 40.24           |
| 8              | 7    | 136.78                                               | 14.28                                         | 961.84                                                    | 31.39               | 138.5  | 30.95           |
| 9              | 7    | 101.22                                               | 4.28                                          | 1093.31                                                   | 29.16               | 183.54 | 39.17           |
| 10             | 7    | 181.27                                               | 0                                             | 1087.67                                                   | 19.27               | 192.85 | 36.45           |
| 11             | 7    | 85.17                                                | 0                                             | 1439.39                                                   | 43.93               | 188.07 | 59.41           |
| 12             | 7    | 228.01                                               | 0                                             | 1045.96                                                   | 39.38               | 207.7  | 34.01           |
| 13             | 7    | 97.68                                                | 0                                             | 1764.11                                                   | 48.73               | 278.98 | 56.67           |
| 14             | 7    | 87.49                                                | 0                                             | 1421.39                                                   | 44.95               | 194.14 | 66.51           |
| 15             | 7    | 100.86                                               | 0                                             | 1030.39                                                   | 34.25               | 146.79 | 36.56           |
| 16             | 7    | 84.53                                                | 0                                             | 1102.45                                                   | 34.2                | 164.75 | 36.23           |
| 17             | 7    | 151.49                                               | 0                                             | 1265.32                                                   | 36.92               | 202.74 | 38.68           |
| 18             | 7    | 87.94                                                | 0                                             | 1140.13                                                   | 34.3                | 147.45 | 42.56           |
Stage 4: understanding the acceptability and feasibility of implementing and pursuing the low-calorie diet plan

The major findings of the in-depth interviews among three critical cases, who piloted the diet plan for 7 days, are described below.

Theme 1: experience with adopting the low-calorie diet plan

The interviews demonstrated that women were strongly willing to undertake recommended dietary plans. The participants who adhered to the recommended calories had a good experience with the diet. However, one of them verbalized having felt very hungry in between the meals.

“I was starving and drinking water and small bananas to compensate for hunger.” (Participant 3)

In adopting the recommended dietary plan, the only change all the participants had to take was reducing their usual portion size. These were not much different from their everyday food items.

“No, I haven’t made any particular changes because everything in the food items was similar to what I make at home, but I have reduced portion size.” (Participant 1)

The participants had it very easy to follow the diet plan as it was easy to prepare. The various ingredients/items included were mainly those readily available either in their homes or from the ration or at a nearby market.

“It was easy to prepare as I told you, it had everyday food items except for fruits and nuts. The cost was equal to what we usually pay, and it’s easily available in the market” (Participant 1)

The food items were also not costly as they were similar to their usual, which meant that they did not have to go far from their usual budget for groceries. What made it even easier for the participants is that their families, especially their husbands, were very supportive and were supportive of the idea of adopting the diet plan.

“My husband was supportive; he said to control my food and eat as recommended” (Participant 3)

Theme 2: challenges with adopting the low-calorie diet plan

One of the significant challenges faced by the families in adopting the diet plan was that the husbands were working. Hence, it would be difficult for them to follow the plan at all times strictly. The husbands are the ones who bought the groceries; hence after work, they found shops closed. One
of the participants who followed the diet plan expressed the feeling of excessive hunger and tiredness to the extent that they could not wake up nor do any productive work, but this was mainly during the initial phase of adopting the plan.

“I felt exhausted, felt like I can’t do work, nothing else in my thoughts.” (Participant 3)

Theme 3: acceptance of the low-calorie diet plan

The participants were very eager to accept the diet plan, and some were already practicing it, mainly because their husbands were also interested and very cooperative. The only challenge they had was the availability of fruits and nuts. Since the husbands were the ones who purchased groceries, it was viewed as a burden to demand unusual food items such as nuts and fruits as they were very costly. The participants said they only took fruits if their husbands brought them; otherwise, they never asked for them.

“It’s good to add fruits and nuts in the diet, fruits we have when the husband brings them, I sometimes persuade him to buy seasonal fruits.” (Participant 3)

“I didn’t have dry fruits during my diet, just that I had groundnuts. I didn’t want to trouble my husband,” (Participant 2)

Based on these findings, we conceptualized a theoretical framework for suitability, acceptability, and feasibility for the adoption of calorie restricted diet for diabetes prevention (Fig. 3).

Discussion

The study aimed to assess the suitability, acceptability, and feasibility of implementing a dietary recommendation plan among women identified as high risk for type 2 diabetes mellitus. Adherence to the recommended diet of 1500 kcal/day was moderate as the average calorie intake per day among the study participants was 1203 cal per day (IQR: 956.1–1763). We observed those who followed the 1500 cal were mostly between the ages 40 to 50 years.

The major contributor to the calories in the diet for the study participants was rice (carbohydrate) as it is the predominant ingredient of the diet [23]. Restricting the carbohydrate intake, predominantly rice, is a major challenge for the South Indian population, rice being the staple food. Consumption of large quantities of rice is one of the major risks within the dietary risk factor for diabetes [36] as it has a high glycemic index and glycemic load. Replacement of rice with other cereals or food to reduce carbohydrate intake is challenging and is not culturally sustainable. Studies estimating the glycemic index of different varieties of rice [37] and laboratory development of high-fiber white rice are underway. However, it is vital to explore the existing rice landraces and estimate the glycemic index of these varieties. Furthermore, low glycemic index rice varieties can be developed from these rice landraces using innovative plant breeding and biotechnology techniques to ensure the availability of cost-effective and palatable replacements for high glycemic index rice.

Fig. 3 Suitable, acceptability, and feasibility framework for the adoption of calorie-restricted diet for diabetes prevention
The consumption of fruits and vegetables was found to be substantially low in the studied population and followed an inverse relationship between rice consumed and calorie intake. Similar findings were observed in fruit and vegetable consumption in 28 low middle-income countries, with only 18% of individuals 15 years or older meeting the WHO recommendations of 400 gm per day [38]. Focus on both quantity reductions (total calories) as well as the quality of food consumed has to be stressed at the population level for NCD prevention. Inequity in access (physical and financial) to fruits, vegetables, and nuts was reported in low-income countries compared to middle and high-income countries, and the cost of income for five servings of fruits and vegetables per individual accounted for 51% of the household income in a low-income country, 18.1% in low middle-income countries, 15.8% in upper-middle-income countries, and 1.85% in high-income countries. An intervention study to improve a healthy diet in Kerala reported that it was difficult to increase fruit and vegetable consumption due to high cost, whereas it was possible to reduce sugar, salt, and oil [39]. A higher percentage of income was required among those who lived in rural areas compared to urban in all these regions, for attaining the recommended levels of fruit and vegetable consumption indicating the disparity in accessibility and affordability worldwide [40]. Innovative healthy food financing initiatives and redefining the farm bill are critical for the long-term supply and management of fruits and vegetables. India, despite having stringent laws for the use and sale of agricultural land, and subsidies including tax waivers for protection from market forces, only one-sixth of the GDP is accounted for by farming. Strong collaboration between the agricultural, finance, human resources, and technology sectors is pertinent to enhancing production at low cost and supply chain management. Substitution and social marketing of low-cost, regional food items are required to facilitate transition and uptake of diet for T2DM prevention.

Most of the study participants relied on the government-funded Public Distribution System (PDS) for cereals and consumed Parboiled white rice (Puzhukkalari) supplied by them. The Public Distribution System (PDS) is social welfare and anti-poverty program by the government, which controls the rationing and marketing of essential commodities such as cereals consisting of rice, wheat, pulses, sugar, oil, and kerosene. Those who relied on PDS were of the lower middle class, like many others in the rural settings. The PDS is a viable system with equitable distribution and a wider network across the country making it a platform for pro-healthy interventions. Reorientation of the items distributed in PDS needs to be a priority in the context of diabetes/NCD prevention.

Though the responsibility of cooking primarily rests with women, most households are managed financially by men, who regulate the purchase of food items and choices in the household. Gender differences in food choices and health behaviors are extensively reported [41]. Hence, the involvement of men in food choices and decision-making is crucial to making dietary changes in the household.

In this study, we found that majority had awareness of the importance of diet and exercise in diabetes prevention, were willing to make a change, and had support from spouses and family. However, the translation of knowledge into action was seen as an impediment due to the need for transition from a carbohydrate (predominantly rice)-based diet to a low-calorie vegetable-based diet; unaffordability and lack of free availability of fruits and nuts; and unsupportive food systems for disease prevention [42]. A psychological dependence/addiction to rice was observed in the population as in other rice-eating cultures [43] which need to be seriously addressed. We also observed no side effect among our participants who adopted low-calorie diet. There were a few who reported tiredness in the initial days which was reported to have accustomed subsequent days. There was no coercion to follow the diet plan from the study team. This research is an ongoing one, focusing on the life style modification directed for a period of 2 years that involves individualized training and monitoring to maintain a dietary intake of 1500 cal per day [35]. We will assess the sustainability of the low-calorie diet in the future.

This calls for efforts to translate existing evidence-based health programs [44] into National Diabetes Prevention Program, with consistent efforts to change the food culture to a healthy one over time. Unless an effort is made at the policy level regionally or nationally, support systems to facilitate and encourage early adopters through collaboration between government agencies, academic researchers, community-based healthcare providers, and other key stakeholders are not possible.

One of the limitations of the study could be that the diet plan was tested among those identified as high risk for diabetes based on the Indian Diabetes Risk Score. These women participants may have intrinsic motivation to adopt a calorie-restricted diet, and hence, the acceptability as reported in this study may not be generalizable to the general population.

Conclusions

The current study explored different facets in the development and the implementation of a diabetes prevention diet and tested the acceptability and feasibility of the same for the prevention of T2DM among high-risk individuals. Importance must be laid on devising a diet plan with dietary components similar to the usual diet for adherence, effective uptake, and sustainability, and strategies to increase fruit and vegetable consumption have to be directed at household, community, and policy levels as there exists inequity.
in access and affordability. Reorientation of food items included in the Public Distribution System is critical in the context of diabetes prevention. Decision on healthy food choices should involve men, women, and children of the household as power dynamics exists within the household, with women not primarily being the decision-makers on food and diet.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s13410-022-01134-8.

**Author contribution** Conceptualization; funding acquisition; investigation; methodology; project administration; resources; visualization; writing, original draft preparation; writing, review and editing; formal analysis; validation: E.M. Formal analysis, validation, and writing—review and editing: Z.V., B.K., J.N, and A.J. Conceptualization, validation, visualization, and writing—review and editing, K.R.T. All authors have read and agreed to the published version of the manuscript.

**Funding** Elezebeth Mathews is supported by a Clinical and Public Health Early Career Fellowship (grant number IA/CPHE/17/1/503345) from the DBT India Alliance/Wellcome Trust-Department of Biotechnology, India Alliance (2018–2023).

**Data availability** The data sets for the research presented in the publication are available from the corresponding author on reasonable request.

**Declarations**

**Ethics approval** An ethics committee approval was obtained from the Institutional Human Ethics Committee of Central University of Kerala (CUK/IHEC/2019/034_A, 21st November 2019).

**Consent to participate** A verbal recorded consent was obtained from the participants after sharing the participant information sheet and informed consent form through a mobile platform, due to the COVID-19 situation. Privacy and confidentiality were maintained throughout the study.

**Competing interests** The authors declare no competing interests.

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