Behavioural Changes Using mHealth: An Experimental Case Study

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Abstract. Mauritius has a very high prevalence of diabetes, hypertension and cardiovascular diseases, which are often linked to bad eating habits. The use of mHealth applications to bring about positive behavioural changes is practically non-existent in Mauritius since the local unique culinary scene makes it difficult to use such existing applications. The primary objective of this study is to create a customized mHealth application that caters for the peculiarities of the eclectic Mauritian cuisine. *MauLifeStyle*, a web-based application that caters for calorific content of different types of Mauritian foods and typical activities of the Mauritian population, has been developed and tested using recruited participants. The *MauLifeStyle* application has been evaluated based on different criteria of MoHTAM, which is a refined technology acceptance model for smart mobile phones. The clinical outcomes were not statistically significant following three months of monitoring. However, the participant feedback supports the demand for digitally mediated self-education for motivated individuals. The developed mHealth application comprises four main functionalities: *Blood Glucose Monitoring*, *Food Intake*, *Health and Fitness*, and *Calorie Monitor*. It is anticipated that over time, *MauLifeStyle* has the potential to reduce the prevalence of Diabetes in Mauritius and consequently alleviate the financial burden on the healthcare system through the application of preventive medicine.

Keywords: self-management · type 2 diabetes · mobile app · mHealth · self-monitoring

1 Introduction

Diabetes mellitus (DM) presents a significant global health challenge due to its high incidence, its serious impact on health and the substantial burden it places on healthcare systems. The global prevalence of diabetes has reached hundreds of millions with a trend of continued increase. Besides, it is found to be among the top 10 causes of death [1]. In Mauritius the prevalence of DM is alarming, with the figures in 2021 showing around 20% of the population being affected according to the Mauritius Non Communicable Diseases Survey 2021.[1]

[1] https://www.afro.who.int/.

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DM leads to several complications, which results in a heavy financial burden on the Mauritian healthcare system. In 2019, 16.9% of the total health expenditure was allocated to the disease [1]. However, patients' self-management of DM, particularly Type 2, can lead to a significant reduction in the complications associated with the disease, thus alleviating the financial load on the healthcare system. Proper education about self-monitoring of food-intake in lower glycemic levels by pre-diabetes patients can prevent them from developing diabetes in the long run. Patients' self-management requires behavioural changes in terms of regular physical activities and dietary control leading to weight-loss and improvement in metabolism.

Lately, there has been a growing recognition of the substantial impact that digital technologies, particularly mobile applications, can make on the behavioural changes of patients dealing with various medical conditions. This awareness has led to the development of many self-management applications for behavioural changes, which may reduce dependence on medications. Self-management applications for lifestyle management can help patients record their daily food intake and level of physical activities, and provide feedback on the correlation between the variation of their glucose and cholesterol levels and other parameters.

Internet access (including mobile technologies) by households in Mauritius, for years 2016 and 2018, has increased from 63% to 70%.[2] Leveraging on this high penetration of mobile and internet technologies, we have developed an innovative mHealth application, adapted to the Mauritian context, that can help people monitor their food intake and physical activities, based on calorific content of different types of Mauritian foods and typical activities of the Mauritian population. The aim of this application is to assist individuals living with pre-diabetes revert to normal (non-diabetic) state, while also helping those without diabetes to prevent developing diabetic conditions. The rest of the paper is organized as follows: Sect. 2 offers pertinent background information. Section 3 describes the proposed mobile application. Section 4 describes the methodology adopted to evaluate *MauLifeStyle*. Section 5 discusses the results obtained and Sect. 6 concludes the paper.

2 Background

This section presents the related works, mHealth for behavioural changes and health monitoring methods.

2.1 Related Works

Mobile devices provide a gamut of facilities and services in our contemporary society including the healthcare domain. The number of mobile health (mHealth) applications has witnessed an unprecedented growth to approximately 325, 000 in 2017 [2]. Their utilization has great potential in healthcare support in terms of quick access to healthcare information, patient empowerment and inclusion of people who have very limited access

[2] http://statsmauritius.govmu.org/English/Publications/Documents/2019/EI1464/ICT_Yr18.pdf.

to healthcare services [3]. Thousands of such applications are used for disease prevention and healthy lifestyles [4]. According to Larson [5], researchers have characterized four general categories of mHealth applications: (I) information applications, which depict information to the public; (II) diagnostic applications, which take patient information as input and assist to guide the physician to a diagnosis; (III) control applications, which enable remote control of medical equipment such as glucose analysers; and (IV) adapter applications, which convert a smartphone into a mobile medical device.

2.2 mHealth for Behavioural Changes

mHealth applications have been widely used for weight management. They can be useful to monitor behaviour and user self-management, leading to lifestyle changes in the long run [6]. The risk of obesity and chronic diseases like diabetes, hypertension and cardiovascular diseases is therefore mitigated. Features, which are usually favoured in mHealth applications are self-monitoring, goal setting, physical activity, professional feedback and calorie counting. Essential requirements for such applications include security and privacy concerns, clinical guidance, usability issues and proper laboratory testing [6]. In their study on user acceptance for mHealth applications, Smahel et al. [4] reported that the most adopted features by users were those related to weight monitoring including BMI monitoring, calorie usage and calorie intake.

Direito et al. [7] conducted an mHealth programme to compare the effectiveness of mHealth interventions to foster physical activity (PA) and curb sedentary behaviour (SB) in free-living adolescents and adults with a comparator exposed to usual care/minimal intervention. SB decreased more following mHealth interventions than after usual care. As a result, the mHealth interventions have small effects on the physical activities and sedentary behaviour. Likewise, a study was set up to determine the presence/absence of behaviour change techniques (BCTs) in the top 20 free and top 20 paid physical activity and dietary applications from App Store [8]. It was found that the presence of BCTs varied by application type and price; nevertheless, BCTs related to increased intervention effectiveness were generally in paid applications.

Vandelanotte et al. [9] provide an overview of the state of evidence for the use of eHealth and mHealth in improving physical activity and nutrition behaviours among a group of people due to the prevalence of inadequate physical activity and poor diets. Investigations revealed that health and fitness applications accessible on iTunes and Google Play barely or did not use BCTs and rarely integrated evidence-based recommendations. Moreover, it is unclear how the BCTs are implemented, and hence it cannot be concluded whether they are as effective as face-to-face interventions. It was also found that most commercially available applications are not designed with the partnership of behavioural experts, thus leading to a scarcity of engagement techniques.

Various mHealth applications for behavioural changes have been analysed and a summary of their features is shown in Table 1. Most of the analysed applications keep track of food intake and physical activities. They all adopt different BCTs namely social media support, personalized feedback and notifications, gamifications, tailored messages and visualizations among others to provide a healthier lifestyle to users. However, evidence of achieving weight loss is missing for applications like Noom, HAPPY ME and Bant II. MyFitnessPal reported minimal weight change after a period of 6 months while

Weight Management Mentor reported substantial weight loss over a period of 8 weeks. Visual presentations of patient progress are available in a few applications. More efficient strategies to improve the logging mechanism and increase patient engagement such as personalized recommendations based on users' eating habits and physical activities are required.

2.3 Health Monitoring Methods

Several tools, such as pedometers, glucometers, blood pressure monitors and electrocardiograms (ECG/EKG) [21], are embedded in mobile phones, smartwatches and fitness devices, to monitor the health of individuals. The Apple Watch, for example, has helped to save lives in numerous occasions [22]. It has an ECG/EKG feature which can detect atrial fibrillation within 30 s [23] and a fall detection technology which can detect if the user is unconscious and 911 is called automatically [24].

Body Mass Index (BMI) is a measure which can be used for calculation of calories and facilitate weight management. The BMI is calculated as per the Europe World Health Organization [25] formula and the nutritional status as per BMI range is listed in Table 2.

According to several studies, there is a strong association between excess weight and an increased risk of Type 2 Diabetes [26]. When a person is trying to lose weight, s/he wants to know how much to fuel his/her body after a workout or how many calories s/he has burnt during any exercise. The following methods can be used to estimate the calorie expenditure by using a simple calculator/equation:

- **Calorie burned from pedometer.** Regular exercising plays an important role in maintaining an ideal weight. The easiest form of exercising is walking, with a minimum number of steps. The pedometer or step-counter can be used to count the number of steps a person has walked during a certain amount of time. Pedometers are being integrated more and more into mobile phones, smart watches and fitness device [27]. The calorie burned for a certain number of steps is computed using an unofficial formula from a physical fitness stack exchange [28]. Nonetheless, the equation is subsequently validated with weight, height and step count data from a partner of The Cleveland Clinic, *Verywell Fit*, to ensure that the equation accurately calculates calorie expenditure [29].
- **Calorie burned for specific exercises.** The calories burned for any exercise is calculated using the respective metabolic equivalent (MET) for each exercise [30] and the calorie expenditure formula by Roland [31].
- **Basal Metabolic Rate (BMR).** The Mifflin - St Jeor formulas by Hazell [32] are used to calculate the BMR for male and female respectively. BMR is the amount of energy required by the human body to function at rest.
- **Calorie to gram conversion**. The formula proposed by Haponiuk and Díez [33] is used for the calorie to gram conversion.

3 *MauLifeStyle* App

Mauritius features a diverse population characterized by Indo-Mauritians (of Indian origin), Creole (mixed African and European heritage), Sino-Mauritians (of Chinese origin) and others primarily of European descent. This plethora of cultures and religious

Table 1. Summary of mHealth Applications for Behavioural Changes.

Application	Open-Source/Paid	Target Audience	Features	Behaviour Change Techniques (BCT)	Areas of Improvement
Noom [10]	Paid	Adults	Individual food logging, Recommend daily calorie intake, Deliver relevant articles on health and nutrition	Social support - groups similar users so that they can interact together	Social support encouraged logging behaviour, but still needs to accomplish weight loss
MyBehavior [11]	Paid	Adults	Track physical activity, user location and food, Analyse activity and food logs	Personalized suggestions based on user's environment and previous behaviour	Addition of more human control over the suggestions, Provide easier logging mechanisms for food and exercise
Accupedo-Pro Pedometer [12]	Open-Source	Adults	Measure daily step counts, Feedback on distance, time, speed and calories burned	Automatic feedback, Visually appealing graphic display, Goal-setting, Goal-achievement feedback	Include objective measures of fitness like heart rate
NutriWalking [13]	Open-Source	Adults	Help users build healthy eating habits, Encourage users to adopt exercise habits	Personalized goals, Peer support	Adaptive features for personalizing daily nutrition goals based on behavioural adherence
DietApp [14]	N/A	Adults	Feedback on total energy balance based on food intake, Indication on calorie intake and burnt	Personalized suggestions according to illness, Attractively designed	Put nutritionists or endocrinologists in contact with patients for more personalized care

(continued)

Table 1. (*continued*)

Application	Open-Source/Paid	Target Audience	Features	Behaviour Change Techniques (BCT)	Areas of Improvement
Bant II [15]	Open-Source	Adults	Recording of food intake photos and weight, Body-worn activity monitors to count steps	Real-time feedback, Report trends in lifestyle against glycaemic control	Social support to facilitate connections among patients across geographical areas
Application	**Open-Source / Paid**	**Target Audience**	**Features**	**Behaviour Change Techniques (BCT)**	**Areas of Improvement**
Few Touch Application (FTA) [16]	Open-Source	Adults	Register eating habits, Automatic Step Counter	Feedback, Goal setting, Ease of use, Monitoring of lifestyle and progress by healthcare providers	Use sensors elements for other use cases apart from motivated healthy patients
Weight Management Mentor [17]	N/A	Adults	Collect food intake and weight data	Visualizations, Virtual rewards such as ribbons and trophies, Motivating feedback, Tailored textual messages of praise and support	Perform live user studies
HAPPY ME [18]	N/A	Children	Self-monitoring tool for preventing obesity, Collect data regarding dietary habits and physical performance, Step count used to measure activity	Tailored messages, Use of gamification and self-monitoring strategies	Perform randomized controlled trials, Develop gender-specific programs for preventing obesity
MyFitnessPal [19]	Open-Source	Adults	Track nutritional values of diets, Include exercise functions	Automatic notifications, Goal-setting, Social Support- Share progress with friends on social media, Visualizations	Develop a streamlined interface for entering food details, Sensitize users about the importance of self-monitoring prior to using the application
CarpeDiem [20]	N/A	All	Self-monitoring tool for preventing obesity, Collect data regarding food group intake, Gamification and rewards, Recommender system	Feedback, Goal setting, Ease of use, Use of gamification and self-monitoring strategies	Some information like physical exercise is collected using questionnaires and not through the app

Note: N/A means information not available

Table 2. Nutritional Status based on BMI range

BMI	Nutritional Status
Below 18.5	Underweight
18.5–24.5	Normal weight
25.0–29.9	Pre-obesity
30.0–34.9	Obesity class I
35.0–39.9	Obesity class II
Above 40	Obesity class III

beliefs is reflected in Mauritian cuisine, which is usually a combination of the ethnic favorites. The local foods include the dholl-puri (roti), curried rolls, noodles, gateau piment (a fried snack), Biryani and Boulettes (meatballs) amongst many others. This unique culinary scene makes it difficult to use existing applications to monitor the food intake of the participants. It is therefore vital for any application to take into consideration the peculiarities of the eclectic Mauritian cuisine.

MauLifeStyle is a responsive web-based application designed to be compatible with both desktop and mobile web browsers irrespective of operating systems and thus offers the inherent advantage of reaching out to a larger number of users. Figures 1 and 2 both show the main menu of *MauLifeStyle* with Fig. 1 representing the mobile view and Fig. 2 representing the desktop view. The mHealth application comprises the following four main functionalities: Blood Glucose Monitoring, Food Intake, Health and Fitness, and Calorie Monitor, are further described in the following subsections. The application incorporates the health monitoring formula discussed in Sect. 4.

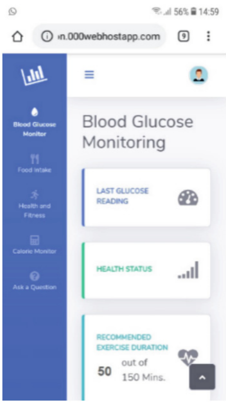


Fig. 1. Main Menu - Mobile View

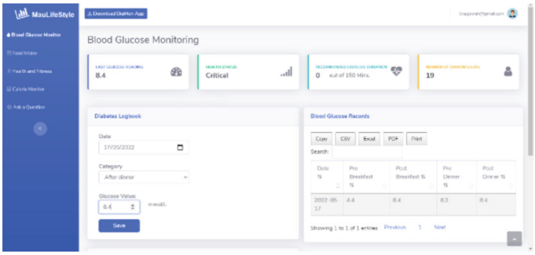


Fig. 2. Main Menu - Desktop View

3.1 Self-Blood Glucose Monitoring

Blood sugar readings are important parameters used by doctors for effective diabetes management. These can also be used by individuals to self-monitor their blood sugar levels pre and post meals. *MauLifeStyle* allows for the recording of these readings before and after breakfast, lunch, afternoon snack and dinner. It also provides an option for downloading these readings in CSV, Excel or PDF formats which may then be shared with treating doctors for monitoring purposes. Additionally, a print option is provided.

3.2 Food Intake

MauLifeStyle may become a useful tool for making healthy lifestyle changes. It is therefore vital that the users of the application record the food items that they are taking during each meal. The food intake functionality has also been carefully designed to suit the Mauritian context. There is a cultural habit in the country to eat locally prepared delicacies commonly known as 'Gâteaux De L'huile' (translated as *oily snacks*) during either breakfast or teatime. These local foodstuffs, currently unavailable in similar existing applications, have been included in the *MauLifeStyle* as shown in Fig. 3. Like the blood glucose monitoring, the food intake details may be downloaded or printed.

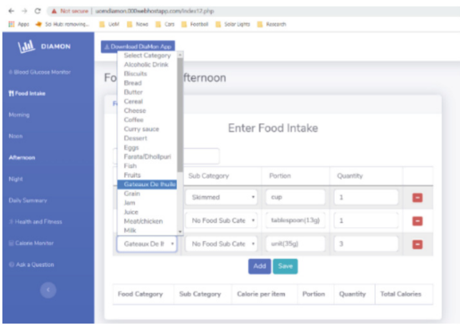
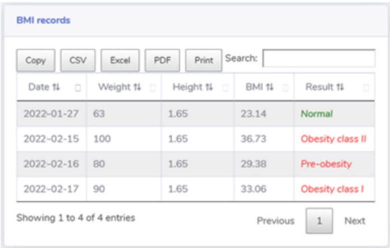


Fig. 3. Food Intake including local foodstuffs

3.3 Health and Fitness

MauLifeStyle application encompasses a multitude of fitness and health monitoring features among which, we can find a BMI calculator where users input their weight and height to obtain their BMI with customized comments such as underweight, normal, pre-obesity, obesity class I and obesity class II as illustrated in Fig. 4. The saved input and calculated values are visually presented on a line graph and bar chart as shown in Fig. 5.


BMI records

Copy CSV Excel PDF Print Search:

Date	Weight	Height	BMI	Result
2022-01-27	63	1.65	23.14	Normal
2022-02-15	100	1.65	36.73	Obesity class II
2022-02-16	80	1.65	29.38	Pre-obesity
2022-02-17	90	1.65	33.06	Obesity class I

Showing 1 to 4 of 4 entries Previous 1 Next

Fig. 4. BMI Recordings

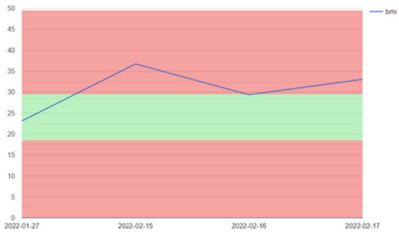


Fig. 5. Graph of BMI over time

Additionally, the mobile version of *MauLifeStyle* comprises a pedometer that works with the accelerometer sensor of the mobile phone and automatically records the number of steps that a user takes daily. However, users of the web version must manually enter the number of steps on the *MauLifeStyle* platform. *MauLifeStyle* also entails an exercise section where the user enters one or multiple physical activities undertaken during the day or week and their respective durations. *MauLifeStyle* automatically calculates the approximate number of calories burned during those respective activities.

3.4 Calorie Monitor

MauLifeStyle has a diet-tracking feature that estimates the number of calories per food item. The calorie of each food item has been referenced from the world's largest verified nutrition database[3] and MyFitnessPal.com. To assess whether an individual has gained or lost calories during a specific day, *MauLifeStyle* performs the following computations:

(i) **Calorie Intake Calculation**: Calorie intake is the aggregation of calorie values from meals consumed at various times of the day. Depending on gender (with a daily recommended intake of 2000 cal for women and 2500 cal for men[4]), if the daily calorie intake exceeds the recommended limit, the total is displayed in red; otherwise it appears in green.

(ii) **Calorie Expense Calculation**: The calorie expense relies on two key factors: (a) physical activities (the variation in calories burned is influenced by the MET values associated with different activities) and (b) the BMR.

[3] https://www.nutritionix.com/.

[4] https://health.gov/our-work/food-nutrition/2015-2020-dietary-guidelines/guidelines/.

The calorie gain or loss at the end of a person's journey is approximated into grams. *MauLifeStyle* also saves the calorie intake and expenditure over time and these may also be downloaded or printed. The calorie gain/loss is converted to grams through the formula proposed by Haponiuk and Díez [32].

4 Methods

A study was designed to assess the receptiveness of an mHealth application, investigate the behavioural changes resulting from its use, measure the change in selected biomarkers following a 3 months intervention and determine the change in clinical outcomes before and after the intervention among individuals at risk of developing diabetes mellitus. The pilot study was conducted over 12 weeks. Ethical clearance was received by the University of Mauritius Research Ethics Committee prior to the recruitment of participants for the study. All procedures were in line with the Helsinki declaration.[5] All participants signed an informed consent prior to enrolment. Participants were recruited from the University of Mauritius and neighbouring institutions. All interested participants were screened for the inclusion and exclusion criteria. The inclusion and exclusion criteria for the selection of participants are as follows:

Inclusion Criteria

- Participants aged 18 years and above
- Participants with a predisposition for developing DM by meeting at least one of the following criteria: (1) One or more member of the family being diagnosed with Type 2 Diabetes Mellitus (2) Participants who have a BMI of 25 kg/m^2 and above
- Participants with known pre-diabetes conditions diagnosed by repeated fasting blood sugar, HbA1c or oral glucose tolerance test
- Participants with previous history of gestational diabetes

Exclusion Criteria

- Any pregnant or lactating women
- Participants with diabetes mellitus or current gestational diabetes
- Participants on anti-lipid agents
- Participants on specific diets

All baseline and demographic information were retrieved through face-to-face sessions, which consisted of an interview to capture all information concerning their medical history, past medical history, family history, medications, smoking and drinking habits and lifestyle practices such as eating and exercise. A standard template was used to facilitate this process. An informative session on how to use the application was conducted, during which participants were introduced to the use of *MauLifeStyle*.

[5] https://www.wma.net/what-we-do/medical-ethics/declaration-of-helsinki/doh-sept1989/

Twenty-five(25) participants attended the screening session. All participants had their clinical indicators such as height, weight and blood pressure measured at baseline following the debriefing session and 3 months after the intervention to determine any changes following the use of the application. Measurement of blood sugar levels: fasting blood glucose and fasting lipid levels were undertaken using clinical biochemistry testing, at baseline and after 3 months of using *MauLifeStyle.*

During the debriefing session, the *MauLifeStyle* app was installed on the participants smartphones. Participants were further advised to record their daily food intake and daily duration of exercise on the application. During the 3 months of the study, the participants were contacted regularly for follow up and to offer any technical support needed. By the end of the 3 months, a survey was undertaken to assess the acceptability of the application using a validated MARS (Medication Adherence Report Scale) questionnaire. The MARS scale is used to assess the quality of mobile apps that are used in health promotion. It is an objective tool that measures acceptability of the application.

A participant survey was conducted to capture the participants' experience while using *MauLifeStyle* during the study period. The details of the user evaluation were categorized according to different criteria of the refined technology acceptance model for smart mobile phones (MoHTAM) [34]. All data were analyzed using Microsoft Excel. All categorical data were presented in percentages, while continuous data were presented in means, standard deviations and confidence intervals. Confidence intervals were set at 95% and a P-value of less than 0.05 was considered as significant.

5 Results and Discussions

Of the participants who attended the screening workshop, 28% were excluded as they did not satisfy the eligibility criteria. There were 36% male and 36% female participants and the mean age of participants was 38.68 ± 8.41 (CI 34.2–43.2). Table 3 shows the participants profile information.

5.1 Primary Outcomes

The primary outcomes of the participant survey are presented here.

A. Perceived Ease of Use

Given the target audience, it was imperative to consider HCI issues in the design of the application. Participants were therefore requested to give feedback on the user interface. Concerning usability features, participants stated that the application was good in terms of performance (78%), ease of use (78%), navigation (56%), gestural design (67%) and interactive features (78%). 78% of the participants found that the layout was well-designed and that the graphics were of high quality and resolution. 44% of the participants found the overall visual appeal as pleasant and beautiful while the remaining found it average.

B. Perceived Usefulness of mHealth

The findings indicate that the application has had a positive impact on participants.

Table 3. Participants Profile

Participants (Total, N)	18
Gender (n: male, n: Female)	9,9
Mean age (SD, CI)	38.68 ± 8.41 (CI 34.2 - 43.2)
Mean BMI (Baseline)/Kg/m^2	27.06
Medical History • **Healthy** • **Major comorbidity** • **Minor comorbidity**	6 participants had minor problems (Low platelets white blood cells, Asthma, Blood Pressure, Hypertension, Knee pain)
Medications	Amlodipine, Zyloric, Atorvastatin, Ventolin, Astrix
Smoking	2 participants: 6–10 cigarettes / day
Alcohol	None
Baseline Fasting blood glucose (mmol/L)	4.84 ± 0.35 (CI 4.64 - 5.04)
Baseline total cholesterol (mmol/L)	4.48 ± 0.91 (CI 3.95- 5.00)
Baseline HDL (mmol/L)	1.18 ± 0.25 (CI 1.04 -1.33)
Baseline Triglycerides (mmol/L)	1.19 ± 0.84 (CI 0.71 - 1.68)
Baseline LDL (mmol/L)	2.75 ± 0.72 (CI 2.33 - 3.17)

Notably, 78% of the participants reported an increase in awareness while 89% noted an improvement in their knowledge regarding the importance of their health behaviour. 78% of the participants confirmed that their attitudes and motivation towards their health behaviour have improved and that the application motivates them to seek further help regarding their health. 67% of participants agreed that usage of the application indeed helped them in achieving positive behavioural changes.

C. Intention to Use mHealth

The responses were quite positive and it was encouraging to learn that all participants were willing to continue using the application even after the study. Most of them also stated that they would recommend the application to other people. All the participants (100%) found that the quality of information presented as well as visuals used in the application were correct, comprehensive, concise and relevant to the topic. They also agreed that the information provided in the application comes from credible sources. 75% of the participants stated that they would surely recommend the application to others while 25% stated that they would probably recommend it to users who might need it. 62.5% mentioned that they intended to use the application 2–3 times a week while 37.5% mentioned that they would use the application daily. However, only 12.5% of participants were agreeable to pay for the application. The participants were quite satisfied with the application as 37.5% rated it as average and 62.5% rated it as above average.

D. Technological Factors (Technology Design & mHealth)
A significant portion of the participants, 67%, found the application to be engaging and capable of holding their interest for an extended time. While some participants believed that the application was not really customisable to their individual preferences, 78% of them agreed that it provided interactivity through the user input functions and the personalised feedback. Furthermore, all participants unanimously agreed that the application content (visuals, language, design) was well-suited for the intended target audience.

E. Socio-Cultural Factors
Socio-cultural factors have been taken in consideration while designing the application. The inclusion of food items relevant to the country's culture has contributed to the perceived ease of use (78%) by the participants, since they found that the selection of food items for each of their meals was straightforward, thus facilitating data entry. Approximately 55.5% of the participants affirmed that the application offers customisation options and all participants concurred that *MauLifeStyle* has been well-designed for the intended users. The information session at the start of the study reassured participants that their data would be kept confidential and anonymised, thus building trust in the application.

5.2 Secondary Outcomes

Of the 18 participants who were registered in the study, 50% regularly used the *MauLifeStyle* application. Among those who used the application regularly, the mean calorie intake was 2119 ± 253.83 (CI 2047.7–2190.5). Additionally, the average carbohydrate intake was 274.6 ± 32.9 (CI 265.4- 283.9) daily. The mean exercise duration was 34 ± 7.90 (CI 32.08–36.67, which notably increased from 27.5 ± 3.78 (CI 37.34–30.66) minutes to 34.2 ± 7.32 (CI 27.5–41.1) minutes daily by week 6. The exercises consisted of essentially walking and cycling. It was found that there is no major difference in these outcomes between the start of the use of the intervention and towards the end of the intervention. The calorie and carbohydrate intake was the same throughout the use of the intervention for up to 60 days.

Secondary outcomes included change in weight, BMI, waist circumference and lipid levels after a minimum of three months of using *MauLifeStyle*. As per our findings, there were no significant differences in secondary outcomes in the baseline and post intervention groups. There were also no remarkable baseline differences between the group of participants who used the *MauLifeStyle* application and the group of participants who did not use the application.

5.3 Limitations of the Study

This pilot study has tested the feasibility of implementing mHealth for positive behavioural changes in Mauritius. A small sample of working adults were enrolled in this study. The enrolment was driven essentially by the participant's motivation to adopt a change in behaviour that might delay a diagnosis of diabetes mellitus. Participants who have at least one risk factor of diabetes mellitus, such as being overweight, having a family history of diabetes or experiencing pre-diabetic conditions, were invited to participate in the study. Following the Covid-19 pandemic, staff at the university are working in a hybrid mode. Hence, not all staff were on campus during the study and this may have impacted on the recruitment of participants.

Minimal differences in the biomarker and the anthropological measurements were noted but none were statistically significant. This observation can be justified by a small group sample. We had only 18 participants and out of them, only 9 used the mobile application regularly. Due to the small sample, it might be difficult to draw conclusions as to the efficacy of the mobile application as a tool that can be used to delay the development of diabetes mellitus or adopt healthy lifestyle behaviours. Further, rigorous longitudinal studies might be required to determine the efficacy of *MauLifeStyle*.

5.4 Evaluation of *MauLifeStyle*

Several mHealth applications which aim at bringing about behavioural changes in individuals in terms of food intake and physical exercise have been analysed and summarised in Table 1. However, none of these is appropriate for use in the Mauritian context, given the peculiarities of the Mauritian cuisine. Entering data in the "Food Intake" functionality of *MauLifeStyle* is very quick and efficient due to the comprehensive list of food items which include all specific Mauritian meals. However, *MauLifeStyle* does not cater for scanning of store-bought foods and drinks using barcode as compared to *MyFitnessPal* and does not allow the capture of meal photos using the mobile phone's camera like *Bant II*.

Applications like *DietApp* also have a calorie counter, however, the counter may not be appropriate for the local context. For example, "Fried Rice" in the Mauritian context may be different from the general "Fried Rice" and may have different calorie values, therefore giving a wrong estimation of the calorie intake. The design of *MauLifeStyle* included a careful computation of calorie values of different meals, based on the cooking habits of Mauritian people. Apart from *DietApp*, applications like *Noom* and *Accupedo-Pro Pedometer*, only computed either the calorie intake or calorie expense. On the other hand, the Calorie Monitor of *MauLifeStyle* computes the total calorie gain or loss at the end of the day from the calorie intake and calorie expense. Based on the calorie computation, a personalized message is displayed to the user. This feature is not available in most applications.

The *Few Touch Application* has considered only three exercise activities namely walking, stairs and jogging motions as compared to *MauLifeStyle* which considers eighteen activities namely badminton, basketball, cycling, dancing, football, hiking, jogging, karate, swimming, muscle strengthening, rope skipping, stair climbing, running, stretching, tai chi, slow walking, moderate walking, brisk pace walking and yoga.

Weight Management Mentor provides virtual rewards such as ribbons and trophies for positive behaviour. This feature can be included in *MauLifeStyle* in the future to encourage users to improve their health behaviour. Additionally, a social-networking feature that enables users to find friends and share their progress can be included in *MauLifeStyle* like in *MyFitnessPal*. Furthermore, *MauLifeStyle* presently allows recording of blood glucose pre and post breakfast and pre and post dinner as compared to *Bant II*, which considers recording of blood glucose pre and post lunch in addition to breakfast and dinner. This feature can be considered in future to enhance the application. Additionally, like *MyFitnessPal*, *MauLifeStyle* can include automatic notifications or reminders when the application is left unused to motivate users.

6 Conclusion

This paper discusses the development and evaluation of the *MauLifeStyle* application which aims at promoting positive behavioural changes in the lifestyle among the people of Mauritius. The *MauLifeStyle* application comprises four main functionalities: blood glucose monitoring, food intake monitoring, fitness activity tracking, and calorie monitoring. It has been tailored specifically for the local context, providing information on the calorie content of Mauritian foods and the typical activities of the Mauritian population.

Individuals who have at least one risk factor of diabetes mellitus were invited to participate in the study. A screening session was conducted to outline the objectives of the study and attracted 44 potential participants. Unfortunately, given that the participants were recruited on University premises through investigators contacts and staff were still working from home in a hybrid format, we were not able to recruit a larger number of participants. Ultimately, 25 participants chose to participate in the 6-week study; however 28% of them were excluded as they did not satisfy the eligibility criteria. 50% of the participants were classified as regular users of the *MauLifeStyle* application while the others did not use the application regularly. Among the participants who used the applications regularly, the mean calorie intake was 2119 and the average carbohydrate intake was 274.6 daily. An increase in the mean daily duration of exercises, from 27.5 min to 34.2 min, was observed by the end of the study.

Post-study changes in the biomarker (lipid profiles and Fasting blood glucose) and the anthropological measurements did not reach statistical significance. This outcome could be attributed to the small number of participants who actively used the *MauLifeStyle* application. Therefore, it may currently be too early to draw any definitive conclusions on the effectiveness of the application within the local context.

In the future, more diverse participants can be recruited. With the situation returning to normality, we plan to embark on a new study with more number of people, both with pre-diabetic conditions and those who are not pre-diabetic but have the problem of obesity, and measure the impact of this application on their lifestyle. Additionally, it is known that gamification techniques can improve the experience of application users in m-health. Hence, we also plan to improve the application using gamification techniques. Eventually, we plan to propose this application to the Mauritian Ministry of Health to be used alongside other health campaigns in view of promoting a healthy lifestyle among Mauritians.

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