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# Paper-based and mobile application-based self-monitoring tool for healthy dietary intake, development and applicability: a non-randomized trial

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## Abstract

**Background** Unhealthy diet is a key risk factor for Non-Communicable Diseases (NCDs) that contribute to increased morbidity and premature mortality. With increased computer literacy and mobile phone penetration, there is a high opportunity for mobile application-based interventions. The current study was conducted to develop a mobile application to monitor dietary intake and to assess its acceptability and effectiveness in diet control compared to a similar paper-based intervention.

A mobile application was developed based on research evidence and opinions of local experts. The mobile application was introduced to a selected group of office workers who were in preparation, action, and maintenance stages of the Trans Theoretical Model (TTM) and a paper-based intervention was used as the comparator. Socio-demographic data were collected through a self-administered questionnaire. Participants were followed up for three months for adherence. The effectiveness of interventions was assessed at the end of three months by comparing the progressive change in the stage of change and the change from unhealthy to healthy dietary intake between two groups as primary and secondary outcomes respectively.

**Results** Among 123 office workers who participated in the study, 19.5% preferred the mobile intervention over the paper-based intervention. Younger, unmarried office workers and those who do not have children, had a higher acceptance for the mobile intervention ($p < 0.05$). There was no difference in adherence (in all three months) or outcomes between the two groups of intervention.

**Conclusion and recommendations** Mobile application-based interventions are better accepted among the young age group and further studies are recommended to explore their applicability.

**Trial registration** The study was registered in the Sri Lankan Clinical Trial Registry (Registration No. SLCTR/2020/025; Date 15th December 2020).

**Keywords** Applicability, Development, Dietary intake, Mobile-based dietary interventions, Self-monitoring

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## Background

Non-communicable diseases (NCDs) have accounted for 73·4% (95% uncertainty interval [UI] 72·5–74·1) of the deaths around the world to become "the number one killer" in the year 2017 [1] and cardiovascular and cerebrovascular diseases accounted for 16.1% of the total Disability Adjusted Life Years (DALY) in 2016 [2]. Alarmingly, major contributions to deaths and DALY were from low- and middle-income countries [2]. Among four key risk factors (smoking, alcohol consumption, unhealthy diet, and physical inactivity) which have repeatedly shown associations with the development of NCDs, an unhealthy or suboptimal diet has a significant and well-established impact on the development of NCDs as well as its complications. It was highlighted that an unhealthy and suboptimal diet accounted for 11 million deaths and 225 million DALY in 2017 [3]. Similarly, both mortality and DALY burden are higher in the local context. Ischemic heart disease, stroke, and diabetes are the top three contributors to deaths and DALY due to NCDs among Sri Lankans [4]. Though alcohol and tobacco use were higher only among males (45.7% and 34.8% respectively), unhealthy diet and physical inactivity were prevalent in both males and females [5].

Even a small change in risk behaviours for developing NCD will result in a significant impact on the health of an individual or a community [6]. Hence, it is pivotal to work on behaviour changes to reduce the NCD burden. Human behaviour and its change do not occur at random. There are mechanisms of action that bring about a behaviour change. Behaviour change theories generally describe the mechanisms of action (mediators), moderators of behaviour change, and assumptions regarding behaviour change [7]. There has been a plethora of behaviour change theories that explain human behaviour and have been used in different types of interventions [7].

TTM is well-known to be effective in interventions for smoking cessation and its effectiveness in interventions for other behaviour changes has been evident in recent studies. It was shown to be effective in changing dietary behaviour, physical activity, and suicide prevention as well [8, 9]. With the recent increase of studies aiming at risk factors for chronic non-communicable diseases, TTM has been widely used in interventions aimed at changing dietary behaviour [9]. Recent reviews based on newer studies conclude that interventions based on TTM have been successful and effective in changing physical activity, dietary behaviour, smoking and opioid addiction prevention, and dental hygiene improvement [10]. Dietary interventions targeted at reducing dietary fat intake and improving fruit and vegetable consumption or general healthy dietary intake have been successful according to a very recent review of 14 studies based on TTM [11].

Behaviour Change Techniques (BCT) are the smallest active ingredient of an intervention, and they are designed based on behaviour change theories [12]. Several systematic reviews and meta-analyses have been conducted to assess the effectiveness of BCT and concluded that goal setting, self-monitoring and providing information through credible sources (subject specialists) were more effective BCTs among various BCTs used in behaviour change interventions [12–14].

With the advancement and increased usage of mobile phones and devices, health interventions through such devices have come into the picture. Several studies and reviews have claimed the effectiveness of mobile health interventions over conventional health interventions [15–17]. Usage of BCT within the mobile application and adopting behaviour change theories or models are associated with the overall application quality and functionality of the application [17]. Further, BCTs such as providing instructions, feedback on behaviour, contingency rewards and the ability for self-monitoring were commonly used in mobile apps for health interventions [18]. Among BCTs, self-monitoring was more effective through mobile apps than other methods [19, 20].

Workforce participation of the population above 15 years of age in Sri Lanka was 52.3% in 2019 which consists of nearly three-fourths of males (73%) and one-third of females (34.1%) [21]. Around 25% of the workforce is employed in the public sector (government and semi-government) and it is around 1.1 million excluding tri-forces [22]. When considering the International Classification of Occupations, 57.6% of the Sri Lankan working population is comprised of professionals, technical and associate workers, and clerks [22]. Most of them perform office-based duties except in the Departments of Health and Education [22]. Because of the nature of their work, they are less physically active during working hours and are at a higher risk for developing NCDs. At the same time, a study conducted in public sector offices in the Colombo district showed a higher prevalence of NCD risk factors among office workers such as physical inactivity, excessive carbohydrate and sugar intake, high Body Mass Index (BMI) and high waist to hip ratio [23]. As a group of individuals with similar risk factors gathered in one place and considering the feasibility of implementation, the office setting is an ideal setting for health promotion interventions and it was found to be effective for such interventions [24].

While Sri Lanka is claiming high mobile phone penetration [25] with nearly 47% of smartphone usage among the public [26], more than 70% of office workers have computer literacy and 56% of them are accessing the internet [22]. Therefore, there is a higher potential for mobile application-based health interventions in

office settings and a higher need for intervention for this population considering their high risk of developing NCDs. Before implementing mobile application-based interventions, their acceptance and effectiveness need to be assessed.

Thus, the current study aimed to develop a mobile application for self-monitoring of dietary intake and assess its acceptability and effectiveness in diet control compared to a paper-based diet monitoring tool. It was hypothesized that mobile application-based interventions are more acceptable and effective than paper-based interventions.

## Methods

The study was conducted in two phases: design and implementation. During the design phase, an extensive literature survey was conducted to identify appropriate theory/ theories for behaviour change and BCTs to incorporate into diet monitoring tools (mobile application and paper-based tool). It was done through search applications including Google Scholar, Medline, PubMed and Mendeley for studies available online and the Post-Graduate Institute of Medicine (PGIM) library repository for theses and dissertations using keywords diet, dietary intake, behaviour change theory, behaviour change interventions and mobile application-based interventions. Following the literate review, experts in behavioural science, nutrition and mobile health interventions were consulted for their opinion on the layout of diet monitoring tools and operationalisation of dietary portions and servings. Combining findings from the literature review and experts' opinions the layout for diet monitoring tools was formed and the mobile application was discussed with the software development team. Then the mobile application was developed, and further discussions were conducted with experts on the operationalisation of the application. Upon reaching a consensus, the mobile application was pre-tested at a public sector office (Chief Secretariat – Southern province) which was not included in the proper study and piloted at an office in Matara district (Divisional Secretariat – Welipitiya).

### Study design

The implementation phase was conducted as a non-randomized pre-and post-intervention study. Two methods of delivering the intervention (mobile application versus paper-based) were compared for acceptance and effectiveness allowing participants to choose the preferred method as an open-label trial.

### Study setting

The study was conducted in 10 selected government offices in Galle districts which were the intervention clusters.

### Study population

Development officers (DO), Management assistants (MA) and administrative and management officers were selected for the study. Workers who were involved with any physical exertion during their duty and those who were on special dietary plans were excluded from the study.

### Sample size and sampling

The study included participants who were in the preparation, action and maintenance stages of TTM. Therefore, a 100% improvement in the proportion of people consuming the recommended number of fruit and vegetable servings (reported by Steps Survey 2016) [5] was anticipated in the mobile application-based intervention group. An alpha error of 5% and a beta error of 20% were allowed in sample size calculation. As cluster sampling was done, a design effect 1.58 was also incorporated for the sample size. A 10% dropout rate was also incorporated into the study. Assuming 30% and 60% of participants will have recommended fruits and vegetable intake in the paper- and mobile application-based intervention groups respectively, the minimal sample size for one arm was 42. For both arms, it was 84. After correction for design effect and 10% drop-out rate, the ultimate sample size was 147.

Multistage cluster sampling was used to recruit the participants. A cluster was defined as an office with at least 30 clerical-type workers. Clusters were selected purposefully depending on the number of workers and the nature of work in the office. The participants within the clusters were selected randomly, using a series of random numbers. Participants in preparation, action and maintenance stages of TTM from the intervention clusters were selected using their responses to staging questions (Table 1).

### Data collection tools and data collection

Two-point data collection was conducted at the baseline and after the intervention. Data collection tools were comprised of three parts which included a self-administered (survey) questionnaire, a staging algorithm and 24-h dietary recall. Self-administered (survey) questionnaire was used to assess basic socio-demographic data, general health status, and dietary behaviours (Supplementary file 1). The weight and height of participants were measured according to standard procedures described in the European Health Examination Survey (EHES) [27]. A four-branching question staging algorithm was used to ascertain the stage of change for healthy behaviour change

**Table 1** Staging algorithm to determine the Stage of change

**a. Do you follow healthy dietary guidelines such as minimizing refined carbohydrate and sugar and salt consumption and higher fruit and vegetable consumption?**

**(Instructions to interviewer: Answer for this question should be matched with the dietary recall. If there is a mismatched dietary recall, explain the finding to the participant and proceed with the rest)**

i. If **yes**, for how long?
More than 6 months **(maintenance stage)**
Less than 6 months **(Action stage)**

ii. If **no**, are you seriously thinking of changing into healthy diet in next 6 months?
1. If yes, are you going to change your dietary habits in next month?
a. If yes **(preparation)**
b. If no **(contemplation)**
2. If no **(pre-contemplation)**

(Table 1). 24-h dietary recall by a trained data collector was used for the assessment of dietary intake. It was assisted with a picture guide (Supplementary file 2) to determine the unit of measurement and amount of food that a measuring unit will contain, and it was further assisted with computer software (Supplementary file 3) to calculate the number of servings taken from each food group. Basic socio-demographic data and general health status data were collected only at the baseline and the assessment of dietary intake and stage of change were done at the baseline and post-intervention as well.

## Intervention

A daily serving counter was introduced to participants who are planning to start or already started a dietary behaviour change (preparation, action and maintenance stage as described in TTM).

### *Mobile application-based intervention (intervention group)*

A simple mobile application was developed to mark daily intake of servings by adding the number of servings from each food group described in Food Based Dietary Guidelines (FBDG) for Sri Lankans [28]. In the main user interface, the serving counter was displayed for each food group (cereal and cereal-based foods, vegetables, fruits, fish meat and pulses, dairy products, nuts and seeds and unhealthy foods). Recommended numbers of servings were indicated in green colour. When exceeding or not meeting the recommended number, the indicator turns red colour indicating unhealthy eating. A serving guide customized to local foods was included as an additional interface and a link to the serving guide was included in the main interface.

### *Paper-based intervention (comparison group)*

A paper-based serving counter with a serving guide was also prepared with the same colour coding for the numbers of servings in each food group.

The principal investigator introduced a serving counter (both paper-based and mobile application-based) to the participants at the beginning of the intervention and they were allowed to choose the type of serving counter they wanted. The marking of the serving counter was assessed monthly to assess the adherence, by inspecting marked papers and observing the summary of marking of the mobile application-based serving counter. The application was configured to record a summary of markings for the last 30 days. If a participant had missed more than two days of marking per any week, it was considered as poor adherence to the serving counter.

The intervention was conducted for three months, and post-intervention assessments of dietary intake and stage of change were conducted at the end of the third month. Progressive (forward) change in stage of change (defined as 'a change from a lower stage to a higher stage in one or more stages') was considered as the primary outcome, whereas a change from an unhealthy diet to a healthy diet was considered as the secondary outcome. A healthy diet was defined as 'adherence to the number of servings recommended in FBDG for Sri Lankans for more than three food groups including cereal and cereal-based foods, fruits, and vegetables, with the consumption of one or no unhealthy food per day'. The participants, whose diet did not meet the definition of a healthy diet were considered as having an unhealthy diet. If such participant changed to have a healthy diet following the intervention, it was considered as a change from an unhealthy to a healthy diet.

## Statistical analysis

Sample characteristics were described in relation to socio-demographic, health and work-related factors. Acceptance rate and adherence to the intervention were described using percentages.

All participants were included in the post-intervention analysis considering the initial group irrespective of their adherence, to perform intention-to-treat analysis. However, it was not possible for the monthly adherence assessment for lost to follow-up participants. Therefore, those who had not turned up for the assessment of adherence were categorized as non-adherent participants.

Pre and post-comparison of the stage of change and dietary intake were done within and between the mobile application and paper-based groups using the Mcnemar test and Wilcoxon Signed Rank test to check the statistical significance. Paired t-test and Mann Whitney U test were used to check differences of means and medians respectively, while

a probability level of 0.05 was considered as the cut-off for statistical significance. Intention-to-treat analysis was performed and all participants initially selected for either mobile application or paper-based serving counter were included in the post-intervention assessment.

### Ethical and administrative clearance

Ethical approval for the study was obtained from the Ethical Review Committee, Faculty of Medicine, University of Ruhuna (Registration No. 2020/P/105) and the trial was registered in the Sri Lanka Clinical Trial Registry (Registration No. SLCTR/2020/025). Administrative approval was obtained from all relevant authorities (District Secretariat-Galle District, Provincial Ministry of Local Government, Regional Director of Health Services-Galle District). Informed written consent was obtained from all office workers prior to data collection. Workers identified with problems were referred to Teaching Hospital Karapitiya, Base Hospital Udugama, Elpitiya or Balapitiya.

The study was conducted while adhering to the World Medical Association Declaration of Helsinki on ethical principles for medical research involving human subjects.

## Results

### Phase I

The following themes were highlighted from the literature review. 1. Need for a behavioural theory as the basis for the intervention, 2. A correct mix of BCT is the key to the success of an intervention, 3. Need for an objective way of assessing the stage of change as the primary outcome, 4. Goal setting, self-monitoring and provision of information through credible sources (subject specialists) were more effective BCT, 5. BCTs such as providing instructions, feedback on behaviour, contingency rewards and the ability for self-monitoring were commonly used in mobile apps for health interventions.

Experts pointed out the following opinions after considering the findings from the literature review. 1. TTM is a good theoretical platform for dietary behaviour change interventions, 2. Goal setting, self-monitoring, and feedback on behaviour (through the mobile app) can be incorporated into the intervention. 3. FBDG Sri Lanka is the best available source to define the recommended levels of food intake as servings. 4. A serving guide can be included in the mobile app.

During the pre-testing and piloting, it was suggested to add a minus option for the serving counter and to add common foods (bread, yams etc.) for the serving guide.

### Phase II

One hundred and twenty-three participants in preparation, action and maintenance stages of TTM were invited to have either the mobile application or paper-based intervention and the response rate at baseline was 100%. However, 26 (21.1%) participants were lost to follow-up.

The mean age of the sample was 40 years (SD 8.04 years). A vast majority were educated up to General Certificate of Education (GCE) Advanced Level or higher, the majority were married and most of them were clerical and supportive workers where the category of DOs and MAs belong. Table 2 summarises the socio-demographic characteristics of the study sample.

### Acceptance of the intervention

Most of the sample (80.5%) preferred the paper-based intervention, while 19.5% preferred the mobile application. Figure 1 illustrates the flow of participants at

**Table 2** Socio-demographic characteristics of the study sample ($N = 123$)

| Characteristic | Number | Percentage |
|---|---|---|
| **Sex** | | |
| Male | 25 | 24.4 |
| Female | 98 | 75.6 |
| **Education** | | |
| Grade 6–11 | 2 | 1.6 |
| Passed GCE (Ordinary Level) | 6 | 4.9 |
| Passed GCE (Advanced Level) | 42 | 34.2 |
| Tertiary education | 73 | 59.3 |
| **Marital status** | | |
| Unmarried | 24 | 19.5 |
| Living together | 1 | 0.8 |
| Married | 96 | 78.0 |
| Divorced | 2 | 1.6 |
| **Current post** | | |
| Managerial | 17 | 13.8 |
| Professionals | 2 | 1.6 |
| Technical and associate officers | 12 | 9.8 |
| Clerical and supportive worker | 92 | 74.8 |
| **Number of children** | | |
| No children | 37 | 30.1 |
| 1 | 26 | 21.1 |
| 2 | 39 | 31.7 |
| 3 | 17 | 13.8 |
| 4 | 4 | 3.3 |
| **Travel time** | | |
| Less than 30 min | 57 | 46.3 |
| 30 min – 1 h | 50 | 40.7 |
| More than 1 h | 16 | 13.0 |
| **Travel method** | | |
| Walking | 3 | 2.4 |
| Public transport | 65 | 52.8 |
| Private vehicle (own/shared) | 55 | 44.7 |

*GCE* General Certificate of Education

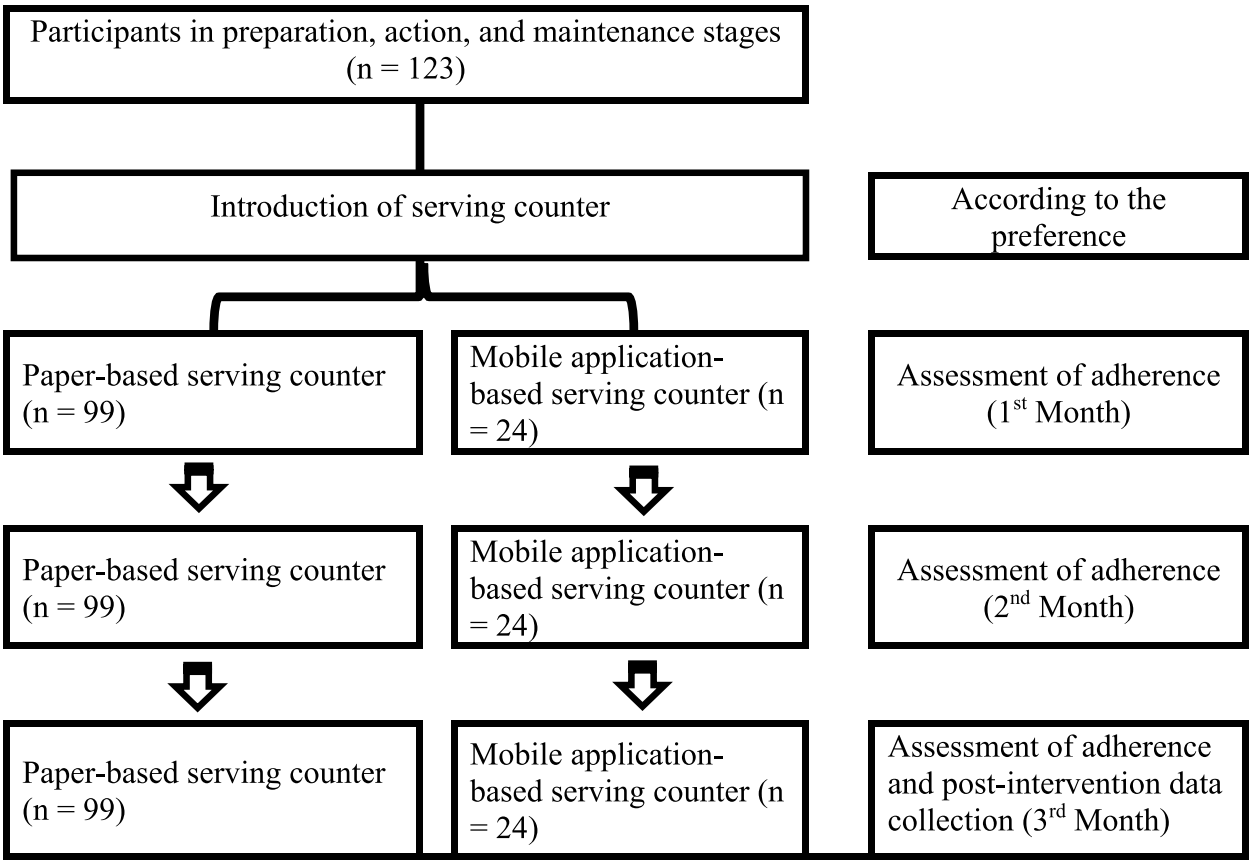


**Fig. 1** Flow chart of the distribution of participants between paper-based and mobile application-based intervention groups

different levels of the intervention. Younger age, being unmarried and not having children were associated with acceptance of the mobile application over the paper-based intervention. Table 3 summarizes factors associated with the acceptance of mobile applications as the method of intervention.

#### Dietary intake among participants at pre- and post-intervention

The median number of cereal-based food servings consumed was 5.5 at pre-intervention. It was slightly below the recommended range of servings (6 to 7 servings per day). It remained the same even after the intervention. However, there was a significant change in the variance of cereal-based food intake in pre-and post-intervention. There was a statistically significant improvement in the intake of fruits and vegetables from pre- to post-intervention. Fruit and vegetable intake was below the recommended level (5 servings a day), and it has increased to the recommended level following the intervention in both groups. Unhealthy food (defined as food containing only sugar and starch, deep-fried snacks and processed foods) intake was reduced post-intervention compared to pre-intervention state. Table 4 summarises the median number of servings consumed by all participants and participants in mobile and paper-based intervention groups separately at pre- and post-intervention states.

There were only seven (5.6%) participants had a healthy diet at the baseline (pre-intervention), whereas there were 51 (52.6%) participants having a healthy diet at the post-intervention assessment.

#### Adherence and outcome of the intervention

Adherence to the intervention was higher in all three months (75.6%, 77.2% and 81.3% respectively). Method of intervention (mobile application or paper-based) was not associated significantly with adherence in any month. More than half of the participants (57.9%) have achieved a progressive change in their stage of change and 46.4% of participants have changed towards a healthy diet. However, neither the adherence nor the outcomes showed a significant association with the mode of intervention. Table 5 summarises

**Table 3** Factors associated with the acceptance of mobile application among the office workers

| Characteristic | Mobile application accepted Number (%) *n* = 24 | Mobile application not accepted Number (%) *n* = 99 | Chi square value | *p* value |
|---|---|---|---|---|
| **Age** | | | | |
| Mean (SD) | 34.3 (7.3) | 41 (7.6) | - | < 0.001* |
| **Sex** | | | | |
| Male | 4 (16.0) | 21 (84.0) | 0.25 | 0.62 |
| Female | 20 (20.4) | 78 (79.6) | | |
| **Completed tertiary education** | | | | |
| Yes | 18 (24.7) | 55 (75.3) | 3.03 | 0.08 |
| No | 6 (12.0) | 44 (88.0) | | |
| **Married** | | | | |
| Yes | 14 (14.6) | 82 (85.4) | 6.77 | 0.01 |
| No | 10 (37.0) | 17 (63.0) | | |
| **Post held** | | | | |
| DO/ MA | 19 (20.7) | 73 (79.3) | 0.30 | 0.58 |
| Other categories | 5 (16.1) | 26 (83.9) | | |
| **Having children** | | | | |
| Yes | 11 (12.8) | 75 (87.2) | 8.22 | 0.04 |
| No | 13 (35.1) | 24 (35.1) | | |
| **Travel time** | | | | |
| Less than 30 min | 11 (19.3) | 46 (80.7) | 0.70 | 0.71 |
| 30 min – 1 h | 11 (22.0) | 39 (88.0) | | |
| More than 1 h | 2 (12.5) | 14 (87.5) | | |
| **Travel method** | | | | |
| Walking | 0 (0.0) | 3 (100.0) | 4.17 | 0.13 |
| Public transport | 9 (13.8) | 56 (86.2) | | |
| Private vehicle (own/shared) | 15 (27.3) | 40 (72.7) | | |

* Independent sample t-test

associations of adherence and outcomes with the mode of intervention.

## Discussion

Most of the sample characteristics were compatible with data from the labour force data except in the gender distribution. The labour force data report has also highlighted that the composition of the workforce will change from sector to sector as well as office to office [22]. Further, the gender distribution of the current study is compatible with a previous study conducted in an office setup in Sri Lanka [23].

Acceptance of the mobile application was low (19.5%) among office workers, despite their higher computer literacy (70%) and internet usage (56%). This might be due to the lack of trust in the mobile application and concerns regarding data safety which have been identified as barriers for acceptance of mobile application-based interventions [29]. Acceptance of mobile applications was associated with younger age, not having children and unmarried status (Table 3). This clearly shows that mobile application was more accepted among young workers who have had experience in mobile applications. Studies have highlighted the higher acceptance of mobile apps among the younger population. Research conducted among American adults has shown higher acceptance of nutrition apps at younger ages [29, 30]. A systematic review examining seven studies with different age stratifications and age and acceptability correlations has pointed out the association between the acceptability of mobile application-based intervention and younger ages [29]. Though similar studies were lacking in the local context, digital literacy was higher among the young population and reduced among the older population [31]. The adherence was not associated with the mode of intervention (paper-based serving counter or mobile application). This can be due to the selection bias as participants were allowed to

**Table 4** Number of servings consumed by different groups at pre- and post-intervention stages

| Food group (Recommended range of servings/day) | Participant group | Servings consumed Median (IQR) | |
|---|---|---|---|
| | | Pre-intervention | Post-intervention |
| Cereal-based food (6–7) | Mobile intervention group | 5.3 (2.6) | 5.3 (2.1) |
| | Paper intervention group | 5.6 (3.2) | 5.6 (1.6)* |
| | Total | 5.5 (3.1) | 5.5 (1.6)* |
| Vegetables (3–5) | Mobile intervention group | 3.0 (2.0) | 3.7 (2.0) |
| | Paper intervention group | 2.7 (1.8) | 3.3 (1.0)* |
| | Total | 2.8 (1.9) | 3.3 (1.0)* |
| Fruits (2–3) | Mobile intervention group | 1.0 (2.0) | 2.0 (2.0)* |
| | Paper intervention group | 0.0 (1.0) | 1.5 (2.0)** |
| | Total | 0.0 (1.1) | 1.5 (2.0)** |
| Fish, meat and pulses (1–2) | Mobile intervention group | 3.3 (3.0) | 2.7 (2.1) |
| | Paper intervention group | 2.7 (2.2) | 2.8 (1.9) |
| | Total | 2.7 (2.3) | 2.7 (1.9) |
| Dairy products (3–4) | Mobile intervention group | 0.5 (1.5) | 1.0 (1.5) |
| | Paper intervention group | 0.0 (1.0) | 0.0 (1.0) |
| | Total | 0.0 (1.0) | 0.0 (1.0) |
| Nut and seeds (2–4) | Mobile intervention group | 0.0 (0.0) | 0.0 (0.0) |
| | Paper intervention group | 0.0 (0.0) | 0.0 (0.0) |
| | Total | 0.0 (1.0) | 0.0 (0.0) |
| Unhealthy foods (Have sparingly) | Mobile intervention group | 2.0 (1.0) | 1.0 (1.0)* |
| | Paper intervention group | 2.0 (2.0) | 1.0 (1.0)** |
| | Total | 2.0 (2.0) | 1.0 (1.0)** |

* $p$-value < 0.05

** $p$-value < 0.001

**Table 5** Associations of adherence and outcomes with the mode of intervention

| Adherence/ Outcome | Mobile application Number (%) | Paper-based intervention Number (%) | Chi square value | $p$ value |
|---|---|---|---|---|
| Adherence (1st month) | | | | |
| Yes | 16 (66.7) | 77 (77.8) | 1.30 | 0.26 |
| No | 8 (33.3) | 22 (22.2) | | |
| Adherence (2nd month) | | | | |
| Yes | 16 (66.7) | 79 (79.8) | 1.90 | 0.17 |
| No | 8 (33.3) | 20 (20.2) | | |
| Adherence (3rd month) | | | | |
| Yes | 20 (83.3) | 80 (80.8) | 0.80 | 0.78 |
| No | 4 (16.7) | 19 (19.2) | | |
| Progressive change in the stage of change[a] | | | | |
| Yes | 8 (42.1) | 32 (42.1) | 0.0 | 1.00 |
| No | 11 (57.9) | 44 (57.9) | | |
| Change to a healthier diet[b] | | | | |
| Yes | 10 (52.6) | 42 (53.8) | 0.0 | 1.00 |
| No | 9 (47.4) | 36 (46.2) | | |

[a] missing 28

[b] missing 26

use the method of intervention they preferred. As they have chosen the mode of intervention that is more comfortable for them, adherence would have been good.

Dietary intake was suboptimal before the intervention with an adequate median intake of cereal-based foods, and a low median intake of vegetables and fruits and a high median intake of unhealthy foods. Following the intervention, the median consumption of vegetables and fruits had increased and consumption of unhealthy foods had reduced among all participants, particularly in the paper-based intervention group. However, favourable change in vegetable and unhealthy food intake was noted among the mobile application-based intervention group as well (Table 4).

There was no significant difference in achieving the primary and secondary outcomes between the paper-based and the mobile application-based intervention groups. This indicates that the intervention was effective in changing the stage of change and subsequent change in dietary behaviour. However, the mode of intervention did not affect the effectiveness of the intervention. Though there were hardly any studies assessing the effectiveness of mobile-based intervention purely in changing

the stage of change, several systematic reviews and interventional studies (including randomized controlled trials and non-randomized trials) have assessed the effectiveness of mobile application-based interventions in achieving positive dietary behaviour change. They have provided inconclusive evidence on the effectiveness, some claiming the effectiveness of mobile application-based interventions while others concluding that there is no significant improvement in dietary practices following interventions. A recent systematic review has explored the effectiveness of mobile application-based intervention in achieving dietary behaviour changes. It has shown that both randomized and non-randomized trials were effective in achieving dietary behaviour changes [32]. Another systematic review highlighted the inconclusive evidence [33] while three studies concluded no significant improvement in dietary intake following mobile application-based interventions [34–36]. Several randomised controlled trials have reported a reduction in saturated fat [37] and sugar-sweetened beverages [37, 38] intake following interventions. Increased vegetable and fruit consumption was also noted following mobile application-based interventions [38–40].

### Strengths and limitations

The study sample is representative of the entire district, hence generalization of the study findings would be more accurate. The non-randomized experimental trial design contains its inherent drawbacks as the inability to give a clear comparison between two groups.

## Conclusion and recommendations

Mobile application-based intervention was better accepted among the younger generation, and it can be used to achieve behaviour changes. However, the current study was unable to establish a difference between paper-based interventions and mobile application-based interventions in achieving intended outcomes. Further studies are recommended to explore the feasibility and effectiveness of mobile health interventions in dietary behaviour change in more diverse study settings and populations.

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s44247-024-00109-5.

Additional file 1. Survey questionnaire.

Additional file 2. Picture guide used to determine portion sizes using household measurements or food portions on a standard plate.

Additional file 3. Microsoft Excel software used to convert household measurements or portion sizes into numbers of servings.

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**Authors' contributions**

CJW and MSDW provided technical guidance and supervised the research project while JG did the planning the research project, data collection analysis and report writing.

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**Availability of data and materials**

The datasets used and/or analysed during the current study are available from the following link, https://drive.google.com/drive/folders/1LQZnbvlT7uoc0AcTsYi52bO-3FM2v2br?usp=sharing with permission from the corresponding author on request.

## Declarations

**Ethics approval and consent to participate**

Authors declare that Ethical approval for the study was obtained from the Ethical Review Committee, Faculty of Medicine, University of Ruhuna (Registration No. 2020/P/105) and the trial was registered in Sri Lanka Clinical Trial Registry (Registration No. SLCTR/2020/025). Administrative approval was obtained by all relevant authorities (District Secretariat Galle District, Provincial Ministry of Local Government, Regional Director of Health Services-Galle District). Informed written consent was obtained from all office workers prior to data collection. Workers identified with problems were referred to Teaching Hospital Karapitiya, Base Hospital Udugama, Elpitiya or Balapitiya Study was conducted while adhering to the World Medical Association Declaration of Helsinki on ethical principles for medical research involving human subjects.

**Consent for publication**

In the current study consent for publication is not applicable as no individual level data with identification was included in the manuscript.

**Competing interests**

The authors declare no competing interests.

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## Publisher's Note