

INTEGRATING HEALTH BEHAVIOURAL CHANGE THEORIES IN THE DESIGN OF PREDIABETES SELF-CARE APPLICATIONS: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Type 2 diabetes is a lifelong metabolic disorder caused by high levels of glucose in the blood which can result in serious health conditions such as neuro-, nephro-, retino- and cardio-pathy. Enormous on-going research efforts and interventions are focussed on diabetes management but less on prediabetes which is associated with the prevention of or progression to Type 2 diabetes. Health behavioural change theories are important contributors to the effectiveness of interventions. However, they are rarely integrated systematically in the design of self-care applications for empowerment. In this paper, a Systematic Literature Review (SLR) is presented to evaluate the effectiveness of existing health behavioural change theories in managing prediabetes and to determine the effectiveness of self-care applications that incorporates these theories in their design. A total of four hundred and thirty-six papers were found in this regard. After careful study and the removal of duplicate papers and studies exclusion, 14 papers which met the inclusion criteria were selected for the review. On the whole, the review shows favorable impact of the integration of health behavioural change theories on prediabetics to better manage their prediabetes in changing behaviours, reducing blood glucose level, promoting healthier lifestyle habits, better body weight management and adoption of self-care behaviours. The commonly used theories were then identified to be incorporated into novel web and mobile self-care applications. This review will help application developers to integrate health behavioural change theories in designing impactful prediabetes self-care interventions. The results of this SLR show two clear gaps in this research field: 1) a lack of studies focussing on the integration of health behavioural change theories in prediabetes management and 2) a lack of studies contributing to the design of self-care applications for prediabetes. On a broader perspective, the review reveals that prediabetes self-care applications designed using health behavioural change theories have great potential in enabling prediabetics to take control of their health in preventing Type 2 diabetes.

Keywords: *Prediabetes, Health Behavioural Change Theories, Effectiveness, Self-care Applications, Self-care, Diabetes Prevention*

1. INTRODUCTION

Diabetes is a chronic metabolic condition that can lead to heart disease, stroke, kidney failure, high blood pressure and blindness. It is a lifelong disease caused by high levels of glucose (sugar) in the blood. There are two types of diabetes-Type 1 and Type 2 diabetes. Type 1 diabetes (previously known as insulin-dependent) is characterised by deficient insulin production in children and it

cannot be prevented. Type 2 diabetes (formerly known as non-insulin-dependent diabetes) is the most common form of diabetes (approximately 90% of cases). If left untreated, Type 2 diabetes can cause numerous serious health problems. Large amounts of glucose in the blood, if left unchecked, can result in the damage of blood vessels, nerves and organs.



The prevalence of diabetes in Malaysia has increased at an alarming rate [1]. Recent statistics reveal that 2.6 million adults in the country (15.2% of the adult population) already have diabetes [2]. The present figures are quite alarming as they have well surpassed the projection made by the World Health Organisation which projected that Malaysia would have about 2.48 million people with diabetes in the year 2030 [3, 4]. The problem is further compounded by the fact that the direct cost involved in the management of patients with diabetes in Malaysia is already overwhelming, costing close to RM 1.4 billion in 2012 [5].

As such, the ultimate goal lies in the prevention of diabetes from occurring in the first place. At a global level, enormous research efforts and interventions targeted towards diabetes management have been mounted. However, it has to be admitted that prediabetes has been inadequately addressed in the areas of health promotion and disease management.

Prediabetes is a condition whereby the blood glucose levels are higher than the normal acceptable limits, but not quite sufficiently high enough to be classified as diabetes. It often progresses to Type 2 diabetes which is a potentially irreversible state. Appropriate and adequate early intervention in the prediabetic stage can delay or prevent the development of Type 2 diabetes. Almost 20% of the adult population in Malaysia are estimated to have prediabetes [6].

Prediabetes can be prevented or delayed with proper lifestyle modification and behaviour changes [7]. Managing diet and doing regular exercise are known to be primary interventions of self-care that can lead one to manage prediabetes successfully [8]. Self-care means the way healthcare consumers self-manage their health by making informed health-related decisions and making the necessary changes to their lifestyles in meeting their personal health goals. Self-care behaviour is a major determinant in enabling one to take control of their health primarily by altering lifestyles and behaviour [9].

In the early 21st century, Information and Communication Technology (ICT) has been leveraged in the development of health support applications that were apparent in the form of health information websites and automated e-mailing [10, 11, 12]. Advancement to this digital era is the development of self-care applications that enable people to better manage their care independently. Recent applications have come in the form of web

or mobile apps, enabling users to deploy them conveniently to fit into their daily lifestyle patterns. To date, there are many mobile apps available (virtually free) to support healthcare consumers in managing their health conditions, which include diabetes management apps that allow diabetics patients to self-monitor their glucose levels [13]. There is evidence that mobile health apps can save up to US\$6 billion in yearly medical cost worldwide [14].

Health behavioural change theories play an important role in changing behaviour to achieve better health outcomes. These theories are essential aspects of effective intervention as they can help in understanding how people behave and change. These theories can be applied in the design of novel applications by incorporating behaviour change techniques (BCTs). They provide promising guidelines for designing, implementing and evaluating health promotion programs which could be integrated in the design of self-care interventions addressing health-related behaviour [15]. BCT-based interventions can be utilised to promote health behaviour change among users [16]. Incorporating more BCTs in any health support interventions are seen to be more effective in bringing about the desired behaviour change.

A number of studies have investigated the incorporation of health behavioural change theories in the design of health support applications. However, limited studies emphasise such inclusion in prediabetes self-care applications [17, 18, 19, 20]. The results from the prediabetes studies show that prevention of diabetes and management of prediabetes is possible, if and only if prediabetics are motivated to take charge of their health by changing their attitudes via self-care behaviour. In this study, we evaluate the effectiveness of existing health behavioural change theories when applied in prediabetes interventions globally, and determine the effectiveness of self-care applications that incorporate such theories.

This paper adopts the Systematic Literature Review (SLR) approach and is organised as follows. The first section describes the method we used in conducting the review. The subsequent section reports the results obtained based on the synthesis of existing evidence. The next section discusses key findings and implications of the review. The conclusion section is inclusive of both summary and future work.

2. METHODS

The SLR approach has been used in this paper to perform the research systematically and to reduce uncertainties and biases. SLR helps to conduct comprehensive strategy to search for relevant studies [21]. The following are the details on how the SLR was conducted.

For this study, published papers were searched from ScienceDirect, Taylor & Francis Online,

PubMed, IEEE and SAGE Publications using the combination of terms as follows: [(behaviour change theories OR behaviour change models OR behaviour alteration OR persuasive technology OR health education) AND (prediabetes OR pre-diabetes OR diabetes prevention) AND (self-care OR self-care applications OR preventive self-care)]. The search was carried out between April 2015 and May 2015.

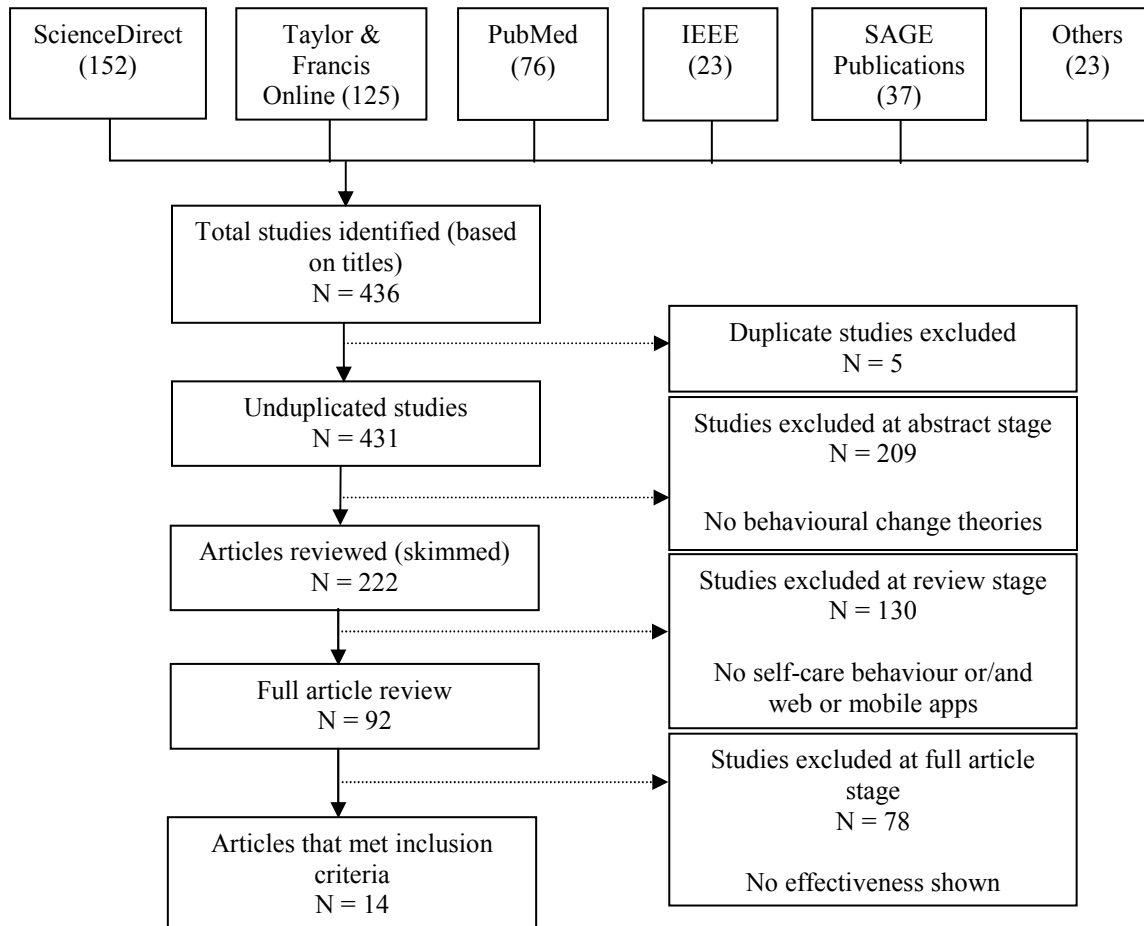


Figure 1: SLR Flow Diagram

The inclusion criteria for this search were: (1) any behavioural change models or theories which are related to health, and (2) any study which can show the effectiveness of the theories and self-care behaviour or application. The exclusion criteria were: (1) papers focussing on primary-care, (2) review papers, and (3) papers not written in English.

In total, 436 papers were selected by looking at the titles: 152 papers were derived from ScienceDirect, 125 papers were derived from Taylor & Francis Online, 76 papers were derived from PubMed, 23 papers were derived from IEEE, 37 papers were derived from SAGE Publications and a further 23 papers were derived from other resources. From these, five papers were found to be duplicates and they were removed accordingly.



Reading the abstract helped to effectively remove 209 papers as they did not contain any behavioural change theories. Examining the remaining 222 papers by looking first at the introduction, subsequently the headings and finally the conclusion for self-care behaviour or/and web or mobile apps, resulted in 92 papers being left after the elimination process.

From that list, papers which did not discuss effectiveness of the applied theories and review papers were eliminated too. After exhaustive elimination, 14 papers were selected for the review. Figure-1 shows the SLR flow diagram.

3. RESULTS

Relevant information that was extracted from the reviewed papers (i.e. the theory used, type of application, result and effectiveness of the intervention) are summarised in Table-1. From the table, it is noted that there were five studies on prediabetes and nine studies on other health areas. Of the fourteen studies, two studies were found to be hypothetical, i.e. they were without any empirical evaluation. Thirteen studies were found to be related to the use of health behavioural change theories and one study focussed on identifying the effective BCTs. Eleven studies involved the use of web and/or mobile apps and three of the studies were not based on any application but solely focussed on self-care behaviour.

The first objective of the review was to evaluate the effectiveness of existing health behavioural change theories when applied in prediabetes interventions. Based on the findings, the application of the existing health behavioural change theories are found to be effective in managing prediabetes. It shows favourable changes in reducing blood glucose levels, changing behaviour, improvement on body mass index, better weight management, healthier lifestyle habits and adoption of health-promoting self-care behaviour.

The second objective of the review was to determine the effectiveness of self-care applications incorporating health behavioural change theories. It is apparent that self-care applications designed using health behavioural change theories are effective in managing diseases (i.e. diabetes, cancer, depression, alcohol addiction, and many other chronic diseases) and general health. These applications are able to motivate patients to improve adherence to medication regimens, promote self-care behaviour, improve health and lower depression. There were a few studies

conducted to evaluate usability of applications and it was concluded that these self-care applications are primarily easy to understand and use as the patients were confident in using the applications and carrying out the required tasks.

Common theories used in the design of self-care applications and self-care behaviour were also found. These theories include: Social Cognitive Theory, Transtheoretical Model/Stages of Change Model, the Theory of Planned Behaviour, Health Belief Model, Cognitive Behaviour Therapy, Self-care behaviour, Motivational Interviewing and BCTs (e.g. goal setting, action planning, and feedback). Table-2 shows the summarised description of these theories.

It would be interesting to determine the most commonly used health behavioural change theory in previous studies. Based on findings, all the theories (except for Bandura Social Learning Theory) have been used repeatedly in the studies either exclusively or in combination with other theories.

4. DISCUSSION

Evolution of technology has enabled application developers to leverage on different technologies in designing health support solutions for people to achieve their health goals. For example, early attempts to encourage people in taking good care of their health were done via email reminders [10]. Today, individualized websites, interactive emails, mobile health support apps and social media are being leveraged upon to reach healthcare consumers in meeting their health needs [17].

However, existing diabetes self-care applications show little adherence to health behavioural change models or clinical recommendations for self-care regimes/routines [22, 23]. These applications are not developed by health professionals or academics [15, 24] and hence they are designed based on superficial understanding of the metabolic disorders. Designing a self-care intervention without behavioural theory does not enable prudent assessment of its effectiveness in promoting behaviour change and adherence to diabetes control [25].

This paper shades light on the potential of health behavioural change theories in achieving effective self-care solutions, especially those that are targeted to prevent diabetes. This review examines the effectiveness of: (1) health behavioural change theories when applied in managing prediabetes and (2) self-care applications that are designed using



health behavioural change theories. The categorised based on the clinical results and effectiveness of the 14 reviewed studies were duly usability testing of the applications.

Table 1: Analyses of Studies Involving Health Behavioural Change Theories

Title	Type of Application	Intervention	Behavioural Change Theories	Results
A conceptual framework for targeting prediabetes with lifestyle, clinical, and behavioral management interventions [7]	Prediabetes: Self-care behaviour via health coaching approach (no application)	Hypothetical patient, 52 years old woman with a family history of diabetes, high cholesterol (257), mild hypertension (142/92) and with BMI = 35. She was given motivational interviewing (MI)-based health coaching over the telephone.	Motivational Interviewing, Self-care behaviour	Increased self-efficacy for weight management, healthier lifestyle habits, and improved blood glucose values. Empirical: No
A fully automated diabetes prevention program, Alive-PD: Program design and randomized controlled trial protocol [17]	Prediabetes: E-mail, Web, and Mobile application for support	340 patients with prediabetes, age 30-69 years old, BMI ≥ 27, who have access to e-mail and internet were randomised to the intervention group (n=164) or delayed-entry control group (n=176). Length of study is 12 months. The participants went through the Alive-PD, a fully automated program where the coaching was delivered via website and e-mails and supported by a mobile app.	Social Cognitive Theory, Theory of Planned Behaviour, Health Belief Model	Statistics showed Alive-PD program has significant treatment effect on reducing HbA1c, fasting glucose and body weight. Empirical: Yes
A feasibility study to develop a diabetes prevention program for young adults with prediabetes by using digital platforms and a handheld device [18]	Prediabetes: Web and mobile digital platforms and handheld device	13 participants aged 18-29 years with prediabetes were selected for this study, which was conducted over a period of 12 weeks. The participants were given in-person orientation and weekly intervention using digital platforms and a handheld device.	Social Cognitive Theory	Changes in behaviours were observed. Even when there was not much difference in the participants' fasting glucose, the mean body mass index and mean A1C decreased from 41.0 ± 7.3 kg/m ² and 6.0 ± 0.5% to 40.1 ± 7.0 kg/m ² and 5.6 ± 0.5% respectively. Empirical: Yes



<p>Predicting health-promoting self-care behaviors in people with pre-diabetes by applying Bandura social learning theory [19]</p>	<p>Prediabetes: Self-care behaviour (no application)</p>	<p>200 participants who were diagnosed with prediabetes. Questionnaire survey was performed to collect data regarding personal and environmental factors that may have connections with health-promoting self-care behaviours. Length of questionnaire survey time was 20-30 minutes.</p>	<p>Bandura Social Learning Theory, Self-care behaviour</p>	<p>Adoption of health-promoting self-care behaviours had a mean score of 64.57 (SD 6.43) for N=200. It was revealed that health-promoting self-care behaviours were much related with family history of diabetes, prediabetes knowledge, self-efficacy, social support and perception of the empowerment process. These personal and environmental factors support the Bandura social learning theories.</p> <p>Empirical: Yes</p>
<p>A mobile phone and web-based intervention for improving mental well-being in young people with Type 1 diabetes: Design of a randomized controlled trial [26]</p>	<p>Type 1 Diabetes: Web and mobile application</p>	<p>Design: 280 young participants (two-arm randomised controlled trial) with Type 1 diabetes and at least mild psychological distress will be recruited. The randomized intervention group will use the 'myCompass' application for 7 weeks and the control group will use an active placebo program.</p>	<p>Cognitive Behaviour Therapy</p>	<p>The study hypothesised that the scores on the measurement of the outcome will improve significantly for mobile and web-based intervention compared to the control group. The outcome measurement will be based on mental well-being, work and social functioning and diabetes self-care, biochemical measures and mental health self-efficacy.</p> <p>Empirical: No</p>
<p>Evaluation of a web portal for improving public access to evidence-based health information and health literacy skills: A pragmatic trial [27]</p>	<p>General Health: Web application</p>	<p>96 parents who had children aged < 4 randomised into intervention group (n=47) and control group (n=49). Length of study was 3 weeks. The intervention group was given access to the web portal.</p>	<p>Theory of Planned Behaviour</p>	<p>Statistically there were significant differences with intention and attitude in the intervention participants. The overall activation (PAM) score was 66.5 in the intervention group and 61.9 in the control group.</p> <p>Empirical: Yes</p>



<p>Developing and evaluating a website to guide older adults in their health information searches: A mixed-methods approach [28]</p>	<p>General health for older adults: Website</p>	<p>The participants were 50 years of age or older and had gone online for health related information at least once in the past year. First phase: Pilot test (N=4) of the ‘Your Health Online’ website for 90 minutes. Second phase: Comparative evaluation (N=36, experimental group) of the ‘Your Health Online’ website for 70 minutes to complete online educational program and questionnaire. Control group participants (N=29) used the National Library of Medicine’s website.</p>	<p>Self-care or Partnership Model, Health Belief Model</p>	<p>97.2% of the experimental group said the exercises from the site were useful and 75% said it was extremely easy. No one said they didn’t learn anything compared to the control group where 15% said they didn’t learn anything. 77.8% of the experimental group were extremely or very confident in finding valid information from the ‘Your Health Online’ website. Empirical: Yes</p>
<p>Identification of behavior change techniques and engagement strategies to design a smartphone app to reduce alcohol consumption using a formal consensus method [29]</p>	<p>Alcohol: Mobile Application</p>	<p>First phase: 7 participants (international academic experts) from health psychology, biological psychology, developmental psychopathology and addiction research were identified. They had the knowledge of the alcohol literature, and/or experience of designing or delivering behaviour change interventions. They were to answer questions to identify the effective BCTs using online survey tool Qualtrics. Second Phase: 43 participants from the journal Addiction were selected to validate the BCTs ranking.</p>	<p>BCTs – self-monitoring behaviour, goal setting, action planning, feedback, behaviour substitution, advise on environmental restructuring, provide information, normative information about others’ behaviours and experiences, motivational interviewing, rewards and habits reversal.</p>	<p>Through the studies, 12 effective BCTs were identified to include into mobile application to reduce alcohol consumption. This information was validated by larger independent group of alcohol experts. Empirical: Yes</p>

<p>Impact of mobile diabetes self-care system on patients' knowledge, behaviour and efficacy [30]</p>	<p>Diabetes: Mobile application</p>	<p>28 participants with Type 2 diabetes used the Mobile Diabetes Self-Care System. Length of study was 6 weeks.</p>	<p>Self-care behaviour, Goal setting</p>	<p>The study evaluated the system's effectiveness in the participants' self-care knowledge, behaviour and efficacy. The study resulted on improving the participants' self-care knowledge and behaviour by 17% and 22%. Statistically, the efficacy in performing the daily self-care activities was found to be insignificant.</p> <p>Empirical: Yes</p>
<p>Development and formative evaluation of a web-based self-management exercise and diet intervention program with tailored motivation and action planning for cancer survivors [31]</p>	<p>Cancer: Web-based application</p>	<p>29 breast cancer survivors participated in testing the perceived ease of use of the web program with questionnaires. They used the program for 12 weeks.</p>	<p>Transtheoretical Model</p>	<p>The program was easy to understand and use (total usability score of 81.3 points). Feasibility of program was tested by using the percentage of patients (27/30) who consistently used the program. The participants felt confident using the program and they could carry out the tasks in the program.</p> <p>Empirical: Yes</p>
<p>Web-based intervention support system for health promotion [32]</p>	<p>Multiple Sclerosis: Web-based application</p>	<p>The study involved a treatment group (n=171) and a control group (n=195) with total 366 patients diagnosed with multiple sclerosis. Length of study was 3 months. The treatment group received intervention supported by WISS, a web-based system.</p>	<p>Transtheoretical Model</p>	<p>The WISS was effective in motivating the patients to continue taking medication. In the treatment group, there were only 2 patients who discontinued the medication, where else in the control group, there were 17 patients who discontinued the medication.</p> <p>Empirical: Yes</p>



<p>Evaluating the effectiveness and efficacy of unguided internet-based self-help intervention for the prevention of depression: A randomized controlled trial [33]</p>	<p>Depression: Web application</p>	<p>163 participants with depression (81 in the Internet intervention group and 82 in control condition group). Length of study was 8 weeks. Participants were given access to 2 online website: MoodGYM and BluePages.</p>	<p>Cognitive Behaviour Therapy</p>	<p>The Internet intervention participants had lower levels of depressive symptoms, lower levels of negative automatic thoughts and improved depression literacy ($F[1,42] = 6.97, p < 0.05$, $F[1,42] = 9.12, p < 0.01$ and $F[1,41.28] = 5.61, p < 0.05$, respectively) than the control group participants. Empirical: Yes</p>
<p>An eHealth intervention for patients in rural areas: Preliminary findings from a pilot feasibility study [34]</p>	<p>Multiple Chronic Diseases: Web and Mobile application</p>	<p>8 participants with various chronic diseases participated in an online management program which incorporated contents from Flinders Chronic Condition Management Program and goACT platform. Length of study was 29 weeks.</p>	<p>Cognitive Behaviour Therapy, Motivational Interviewing</p>	<p>This pilot study revealed that the existing Flinders Chronic Condition Management Program can be transferred to an existing eHealth platform and the statistics shows improvement in health changes. Empirical: Yes</p>
<p>Effects of motivational interviewing on lifestyle modification and diabetes prevention in adults with prediabetes [20]</p>	<p>Prediabetes: Self-care through counselling (no application)</p>	<p>149 participants (78 in the intervention group and 71 in the control group) who were 35-79 years old with prediabetes were tested. Length of study was 12 months. The participants were given training and support in motivational interviewing group to modify their lifestyle.</p>	<p>Transtheoretical Model of Change, Motivational Interviewing, Self-care behaviour</p>	<p>Compared to the control group (traditional health education method), the intervention group had a better average change values on fasting blood glucose, postprandial blood glucose and body mass index. There were significant differences in behaviour changes after 12 months. Empirical: Yes</p>

Table 2: Common Health Behavioural Change Theories Noted in the Studies that were reviewed

Theory	Description
Social Cognitive Theory	Part of an individual's knowledge development can be directly related to observing others via social interactions, experiences, and media influences. Individual's behaviour is influenced by goals which determines the amount of effort that need to be put in order to change his/her behaviour [35].
Transtheoretical Model	Based on individual's readiness to act on a new healthier behaviour, and provides strategies of change to guide the individual through the stages of change to act and maintain the new behaviour. The five stages of change are pre-contemplation, contemplation, preparation, action and maintenance [35].
Theory of Planned Behaviour	An extension of the Theory of Reasoned Action. Behaviour is determined by how strongly the individual is willing to perform the behaviour and how much control does he/she has over performing the behaviour. An individual's attitude towards the behaviour, subjective norms, and perceived behavioural control, shapes the individual's behavioural intentions and behaviours [35].
Health Belief Model	The model explains and predicts health-related behaviours such as people's beliefs about their health problems, perceived benefits of action, barriers, and self-efficacy in health-promoting behaviour. Cues to action should be available to trigger the health-promoting behaviour. This model was originally developed by social psychologists at the U.S. Public Health Service [36].

Based on our review of existing studies, self-care applications that are designed based on behavioural change theories are found to be effective not only in managing prediabetes but many other diseases as well. Besides that, common theories that are being incorporated in the design of such applications has been found. It is interesting to note that Bandura Social Learning Theory has been recently used in predicting self-care behaviours in people with prediabetes and it has showed positive results, although in the past it was rarely used for this group of people [19].

Health behavioural theories interventions are the only acceptable way to promote behaviour changes in healthy diets and physical activities as these are equivalent to the evidence-based interventions and it depends on the quality of the theories and how these theories are applied in the development of the interventions [37]. Although technology can have positive impact on self-management of chronic illnesses, technology by itself will not suffice unless the patients themselves are motivated, information is tailored systematically and appropriate feedback is provided [38]. It has been highlighted in a systematic review on behavior change techniques that highlighted the effectiveness of web-based self-management interventions is associated with more extensive use of theories [16].

Development of self-care applications or self-care behaviour for prediabetes using the behavioural change theories is a novel approach. It is an essential emerging aspect in the field of Health

Informatics as there have not been many studies conducted yet in this area. Yet the studies which have been undertaken so far confirm that prediabetes applications that are designed based on health behavioural change theories achieve better health outcomes [17, 18, 19, 20]. Hence, it can be argued that novel self-care applications should integrate behavioural change theories in their design in achieving sustainable solutions that promote continuous use by health consumers in meeting their health goals.

5. CONCLUSION AND FUTURE WORK

Prediabetes, which puts one at risk of developing Type 2 diabetes is fast becoming a growing health concern. Health behavioural change theories interventions look promising in the management of prediabetes. Integration of behavioural change theories can help to ignite the patients' motivation to change their behaviours, improve their lifestyle and self-care capabilities. The extensive usage of web and mobile health apps allow patients to save their time from visiting doctors face-to-face and provide a continuous close self-monitoring of their health.

Findings of this SLR study reveal that existing health behavioural change theories are effective in managing prediabetes and self-care applications designed using these theories are effective. This review will be helpful for application developers to design impactful self-care applications for prediabetes management.



Having identified the potential of incorporating health behavioural change theories into the design of self-care applications, formulating a framework to develop effective prediabetes self-care applications based on selected behavioural change theories needs to be urgently addressed.

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