Journal of Sustainability Science and Management
Volume 17 Number 12, December 2022: 188-226
eISSN: 2672-7226

THE USE OF INTERNET-BASED TECHNOLOGIES IN DIETARY AND PHYSICAL ACTIVITY INTERVENTION FOR PATIENTS WITH HYPERTENSION: A SYSTEMATIC REVIEW

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Submitted final draft: 14 July 2022 *Accepted: 4 August 2022* http://doi.org/10.46754/jssm.2022.12.017

Abstract: The Internet of Things (IoT) is widely used in Internet-based technology (IBT) interventions for hypertension management. However, little is known about the impact of IBT and how the IoT is used to manage hypertension. This article analysed the types of IBT, the features of IoT and the impact of IBT. This review included 14 articles selected from the following databases: Scopus, Web of Science, PubMed, ScienceDirect and Google Scholar. Randomised controlled trials (RCT) and quasi-experimental studies published from 2014 to 2021 in English focused on managing dietary intake and physical activity (PA) via IBT for hypertensive adults were included. The IoT features, Mobile IoT and Wi-Fi communication protocols were covered by three articles while six digital platforms (smartphone applications, email, WeChat, url, web page and online multimedia) were utilised for the non-pharmacological management. The current review identified the important features of IoT and how implementing IBT in hypertension management can effectively improve blood pressure and bring about behavioural and psychological changes. Finally, this study highlighted only limited IoT systems that had been integrated into IBT, thus, warranting the need for further studies in the future.

Keywords: Diet, exercise, hypertension, Internet of Things, Internet-based intervention.
Abbreviations: Internet-based technology (IBT), Internet of Things (IoT), blood pressure (BP), physical activity (PA), control group (CG), intervention group (IG), hypertension (HTN).

Introduction

The increasing prevalence of hypertension (HTN) is alarming and is becoming a burden worldwide as it is one of the most critical risk factors for high morbidity and mortality globally (Haileamlak, 2019). The World Health Organization (WHO) reported that almost 1.28 billion adults had been diagnosed with hypertension worldwide and it is estimated that 46% of hypertensive patients are unaware of their condition. A study by Mills *et al.* (2016) found a difference in hypertension cases with high-income countries having a lower number of hypertensive patients compared to low and middle-income countries (LMIC). This trend is attributed to the higher level of hypertension-related knowledge, treatment and monitoring in high-income countries compared to LMIC. Online health literacy is beneficial as it helps patients to obtain medical information and improve hypertension conditions.

The Internet is recognised as one of the potential platforms for individuals. It is being rapidly used in the healthcare sector to educate people about their disease and for self-monitoring as they can search for disease-related information freely with guidance from the healthcare provider to achieve better disease management (Jin *et al.*, 2019). Integrating the Internet in the healthcare sector enables people to have a better experience in disease management as healthcare professionals and physicians can remotely monitor their health and offer better online consultations without geographical barriers (Aghdam *et al.*, 2021). This situation can ease the burden on the healthcare sector while enhancing healthcare quality and reducing the cost of treatment for chronic disease patients. Therefore, a large amount of medical information and efficient healthcare services are available via online digital technologies to improve patient's quality of life and self-care (Meskó *et al.*, 2017).

The rapid advancement in the implementation of healthcare via the Internet has led to the evolution of the latest electronic and wireless network known as the Internet of Things (IoT). The IoT has features to transform and enhance the efficiency of the patient's self-care function and monitoring for example, the self-monitoring of blood pressure (BP) (Baig Mohammad & Shitharth, 2021). The IoT is a system or network consisting of physical objects connected to various sensors and digital devices for communication, data collection and exchange using the Internet (Haghi Kashani *et al.*, 2021). Lohiya and Thakkar (2021) added that IoT systems have evolved due to the rapid expansion of smart devices and have significant functions in collecting and exchanging real-time health data among the collaborating devices between healthcare providers and patients. These will aid health professionals in analysing health data and diagnosing a disease efficiently.

The literature on the potential of the IoT in the management of hypertension has grown steadily, but it is dispersed and only a few attempts have been made thus far to synthesise this research. In addition, even fewer studies have been conducted to determine how IoT helps to improve hypertension and the findings regarding its effectiveness are inconsistent. Several studies have reported that the use of the Internet is effective as it can provide support on dietary intake and PA self-monitoring while communicating with healthcare providers, thereby improving the BP status in pre-hypertensive and hypertensive patients (Liu *et al.*, 2013; Alessa *et al.*, 2018; Lisón *et al.*, 2020). On the contrary, other studies have found that using Internet-based interventions for dietary intake and physical activity (PA) does not affect BP status (Thiboutot *et al.*, 2013; Rubinstein *et al.*, 2016; K. Liu *et al.*, 2020). These studies concluded that patients are uninterested and lack the awareness to manage their BP through the Internet, thus, suggesting that patients use of Internet-based interventions or unrelated smartphone applications to manage hypertension is limited. Since there is mixed evidence about the impact of Internet-based technology (IBT) on dietary intake and PA in managing hypertension, this review was conducted to address the gap.

This study was carried out to synthesise the evidence from the existing literature on the impact of IBT on dietary management and physical activity interventions for the hypertensive population. Specifically, this review was aimed at determining the types of IBT in managing dietary intake and PA for hypertensives, discovering the features of the IoT systems implemented in the IBT and identifying the impact of IBT interventions on the physiological, behavioural and psychological aspects, and the acceptance of such interventions among hypertensive patients. The findings of this review will provide a better understanding of the application of IoT and IBT including their characteristics and features in managing hypertension.

Materials and Methods

Eligibility Criteria

The Preferred Reporting Items for Systematic Review (PRISMA) checklist was used in this research to report on the evidence obtained from the literature to ensure that the recommended information was included in the review (Page *et al.*, 2021). In addition, the PICOS framework was employed to limit the number of irrelevant articles in the review (Methley *et al.*, 2014) (Table 1). This review has been registered in the PROSPERO database to avoid duplication (registration number ID: CRD42021283188).

Table 1: The inclusion criteria of the study

Criteria	Description
Population	The targeted population aged above 18 years with hypertension. Animal studies and individuals with other specific diseases were excluded
Intervention	The studies include dietary management and/or physical activity as interventions delivered via IB technologies
Comparison	The comparator intervention was control care or no comparison
Outcome	The outcomes focused on physiological, behavioural and psychological changes, user satisfaction, and acceptance of the intervention
Study design	Randomised controlled trials or quasi-experimental studies published in peer-reviewed journals

Information Source

A literature search was performed on five bibliographic databases: Scopus, PubMed, ScienceDirect, Web of Science and Google Scholar (Appendix 1). The selected articles were published from 2014 onwards to avoid duplication from existing reviews published in 2013 and earlier.

Search Strategy

The search was confined to English articles published from 2014 to 2021. The possible synonyms from the main keywords such as ‘Internet-based’, ‘hypertension’ and ‘patient’ were used to obtain the related articles (Table 2). In addition, reverse and forward snowballing searches were done to increase the search result.

Data Selection Process

The articles were considered in three stages: Selection based on titles, review of abstracts and evaluation of the full text by two different reviewers. The reviewers independently assessed the articles for eligibility.

Table 2: The list of possible synonyms from the main keywords that are used

Main Keywords	Synonyms
Internet-based	Smartphone app-based OR tablet-based system OR telemedicine OR technology-assisted OR web-based OR e-health OR Internet-based web portal OR mobile phone OR telemonitoring system OR mobile sensor OR web portal OR Android OR home BP telemonitoring OR digital therapeutics OR device algorithm OR telehealth OR electronic OR e-counselling OR email OR Wi-Fi technology OR digital health OR health information technology OR telehealth system OR web application OR smartphone apps OR smartphone application OR game-based OR gamification OR Facebook OR Instagram OR Twitter OR TikTok OR online OR virtual OR social media OR online coaching OR remote monitoring OR wearable OR Apps store OR Bluetooth OR cloud platform OR IOS OR mobile health apps OR mobile android based OR iPhone based telehealth OR Android apps lifestyle OR e-tablet OR AI OR artificial intelligence OR low energy technology OR cloud portable apps OR WIFI OR wireless sensor network OR WSN OR IoT OR Internet of Things OR handphone sensor data OR nutrition monitoring system OR smart log OR wireless system OR wireless fidelity OR smart mobile
Hypertension	Hypertensive OR high blood pressure
Patient	Patients OR individual

Quality Assessment

The included articles were assessed independently for their methodological quality and possible bias by two different reviewers. The assessment results were compared and a consensus meeting was held to resolve the discrepancies between the reviewers to reach an agreement (Appendix 2). The risk of bias was assessed using the critical appraisal tools from the Joanna Briggs Institute (JBI). For the assessment, the reviewers were given the JBI manual which explained the checklist of the tools to minimise the risk of misjudgement. In response to the checklist, the bias was assessed as Yes (√), No (X), Unclear (?) or N/A. The randomised controlled trial (RCT) studies were evaluated using the JBI Critical Appraisal Checklist for Randomized Controlled Trials. The included quasi-experimental studies were examined using the JBI Checklist for Quasi-Experimental Studies (Non-Randomized Experimental Studies). As the number of studies was limited, only those studies that scored a minimum of 40% of the total checklist were included while any articles that achieved scores of less than 30% were considered as having a high risk of bias and were excluded from the study, and those with scores of 70% and above were considered as having a low risk of bias (Warren *et al.*, 2016). Any articles that achieved scores of between 30% to 70% were considered to have a moderate risk of bias.

Data Extraction

The data extraction for this research was conducted using a spreadsheet's standardised data extraction form. The data was extracted based on the: (a) Study characteristics, (b) IB intervention characteristics, (c) IoT features and (d) Outcomes of the study. The components under the study characteristics included the author, year of publication, setting of the participants' recruitment, the country of study and study design. The IB intervention characteristics included the type of IBT, the intervention's content and the intervention duration extracted from the studies. Additionally, the IoT features assessed the IoT communication protocols and services implemented in the studies. The final section gave the outcomes of the selected studies which measured the impact of the IBT interventions, including the physiological, behavioural and psychological changes and user satisfaction and acceptance.

Data Analysis and Synthesis

A descriptive analysis was used for this research, whereby a narrative summary and tabulation were used to summarise the findings from the included studies. A narrative synthesis was done by explaining and summarising the findings using words and text. The tabulation approach was used to summarise the study characteristics such as the setting of the study, study design and targeted population, outcomes measured and other results in the form of a table to facilitate the process of comparing the results between the studies and for concluding the included articles.

Results and Discussion

Search Result

From the five online databases, 10,239 articles were identified and 125 duplicates were removed while 10,172 articles were excluded after the screening of titles. In addition, 67 articles were assessed for abstracts, 22 full-text articles were assessed for eligibility and 8 were excluded while 14 articles were included in the study (Figure 1).

Quality Assessment

For the RCT studies, all the articles were included, where nine articles were considered as having a low risk of bias (total score: 70% to 92%) and three articles were regarded as having a moderate risk of bias (total score: 62%) (Appendix 3 and Appendix 4). However, out of 12 articles, only three articles (Abu-El-Noor *et al.*, 2020; Steinberg *et al.*, 2020; Sun *et al.*, 2020) had unclear information about randomisation for the treatment groups and two articles (Abu-El-Noor *et al.*, 2020; Lee *et al.*, 2020) did not provide sufficient information on allocation

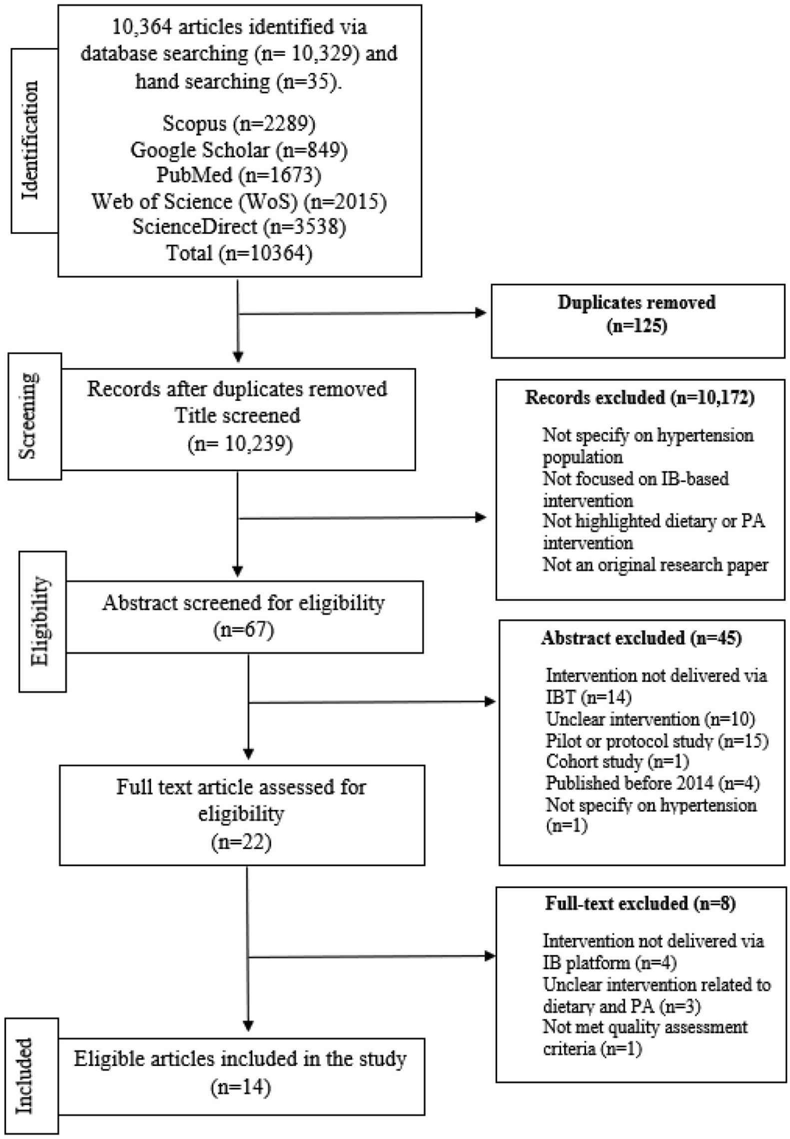

Figure 1: Study selection flow

concealment which could lead to a higher risk of selection bias. In addition, two studies (Persell *et al.*, 2020; Sun *et al.*, 2020) did not blind the participants throughout the experiment while two studies (Tanaka & Nolan, 2018; Li *et al.*, 2019) did not have clear information on it, thus, resulting in performance bias. Furthermore, most of the articles did not blind the assessor or had unclear information about the assessor blinding which could lead to detection bias. These were particularly difficult to do since the interventions included an educational intervention. For the quasi-experimental studies, one study was excluded (total score: 0%) due to a high risk of bias since the study focused on introducing the concept of self-care by innovating an application for the elderly with hypertension. At the same time, the remaining two articles were considered as having a low risk of bias (total score: 89%) (Appendix 5 and Appendix 6).

Study Characteristic

14 articles were included in the study. One article (7%) was published in 2021, seven (50%) in 2020, one (7%) in 2019, three (21%) in 2018, one (7%) in 2017 and one (7%) in 2014. The studies were conducted in Canada (29%, n=4), United States (21%, n=3), Iran (7%, n=1), Palestine (7%, n=1), United Kingdom (7%, n=1), China (21%, n=3) and Italy (7%, n=1). Half of the studies recruited participants from primary healthcare centres (PHCs) (71%, n=10), three from websites (21%, n=3) and one from social media (7%). Most of the studies were conducted as randomised controlled trials (86%, n=12) and two studies were non-randomised experimental studies (14%) targeting the adult population (100%, n=14) with hypertension (100%, n=14) as shown in Table 3.

Characteristics of IB-based Intervention

i. Types of IBT Used in the Intervention

Six different media were identified. Email is a popular platform for delivering the intervention in the studies (36%, n=5). Since the intervention focused on the IB platform, smartphone applications (21%, n=3), WeChat (21%, n=3), url (7%, n=1), web (7%, n=1) and online multimedia (7%, n=1) were implemented to deliver the intended intervention (Table 4).

ii. Intervention Communication Feature

The interaction model was used in nine articles (64%) to communicate with the participants throughout the study, while the rest applied the transmission model of communication (36%, n=5). Among the studies that utilised the interaction model, four (44%) involved research teams communicating with the participants and two involved cooperation with the physicians (22%) during the intervention, respectively. A nurse (11%, n=1), pharmacist (11%, n=1) and healthcare practitioner (11%, n=1) also participated in the interaction with the participants in the research (Table 4).

iii. Targeted Intervention

The intervention focused on two distinct methods of delivery: Education and behavioural changes. Eight studies used the educational method to control the blood pressure of the participants (57%). Furthermore, the participants were encouraged to manage hypertension by practising the behavioural changes throughout the intervention (43%, n=6) and two studies included both methods to assess whether any greater changes occurred among the participants on the completion of the intervention (14%) (Table 4).

Education

Adherence to medication, smoke-free living, diet and exercise were the most frequently highlighted behavioural changes in the included studies. Additionally, the participants in one study were provided with either a user-driven intervention where they could choose and determine their own goals or an expert-driven intervention to change their behaviour according to prescribed guidelines (Table 4).

Behavioural Changes

Adherence to the medication, smoke-free living, diet and exercise were the most frequently highlighted behavioural changes in the included studies. Additionally, the participants in one study were provided either user-driven intervention as they could choose and determine their own goals or expert-driven intervention to change their behaviour following the prescribed guidelines (Table 4).

iv. IoT Features

After all the articles had been analysed for their content, only three articles (21%) were integrated into the IoT system in the IB-based platform while the rest were not (79%, n=11). Wi-Fi was the only primary communication protocol in the three included studies. One study did not mention the communication protocol used during the intervention (25%). Mobile IoT (m-IoT) was the only applied service in the

Table 3: The study characteristics of the articles (n=14)

Author (Year)	Targeted Population	Disease	Country of Study	Study Design	Setting of Participant's Recruitment
McManus *et al.* (2021)	Above 18 years	HTN	United Kingdom	RCT	PHC
Abu-El-Noor *et al.* (2020)	Above 18 years	HTN	Palestine	RCT	PHC
S. Liu *et al.* (2020)	35 to 74 years	HTN	Canada	RCT	Website
Steinberg *et al.* (2020)	21 to 70 years	HTN	United States	RCT	PHC
Persell *et al.* (2020)	18 to 84 years	HTN	United States	RCT	PHC
Sun *et al.* (2020)	Adult	HTN	China	RCT	PHC
Mostafa Bijani (2020)	Adult	HTN	Iran	Quasi-experimental	PHC
Lee *et al.* (2020)	Adult	HTN	China	RCT	PHC
Li *et al.* (2019)	45 to 70 years	HTN	China	RCT	PHC
Tanaka and Nolan (2018)	35 to 74 years	HTN	Canada	RCT	PHC
Liu *et al.* (2018)	35 to 74 years	HTN	Canada	RCT	Website
Nolan *et al.* (2018)	35 to 74 years	HTN	Canada	RCT	Website
Milani *et al.* (2017)	Adult	HTN	United State	Quasi-experimental	PHC
Cicolini *et al.* (2014)	Adult	HTN	Italy	RCT	Not stated

associated technologies that implemented the IoT system as presented in Table 5.

Impact of the Interventions

The intervention outcomes were the markers to assess the impact of the IBT on managing hypertension. The impact of the intervention was assessed by analysing four distinct factors: Physiological, behavioural and psychological changes, user satisfaction and acceptance of the intervention. The longest duration to complete the studies was 12 months of intervention (25%, n=4), followed by six (19%, n=3), five (6%, n=1), four (6%, n=1) and three months (31%, n=5) (Table 6).

i. Physiological Changes

Blood Pressure

The changes to the BP after the experiment between the intervention group (IG) and control group (CG) were measured in 12 articles where 11 articles showed a positive effect on the SBP and DBP status after the intervention (Cicolini *et al.*, 2014; Milani *et al.*, 2017; Liu *et al.*, 2018; Li *et al.*, 2019; Sun *et al.*, 2020; McManus *et al.*, 2021). Even so, there was no significant mean difference in the changes between the groups in four studies (Nolan *et al.*, 2018; S. Liu *et al.*, 2020; Persell *et al.*, 2020; Steinberg *et al.*, 2020). Additionally, Tanaka and Nolan (2018) combined the IG and CG and separated them

Table 4: The characteristics of the intervention (n=14)

Name (Author)	Types of IBT Used	Comparator	Model of Communication Used	Types of Sender-receiver Used in Interaction Model of Communication	Platform Used to Deliver the Dietary and PA Intervention	Targeted Intervention
McManus *et al*. (2021)	Email	Usual care Had online access to general information about hypertension	Interaction model	Healthcare practitioner	Email	Education on: • Healthy eating • PA • Weight loss • Salt and alcohol reduction
Abu-El-Noor *et al.* (2020)	Smartphone application	Usual care Received no intervention and continued with daily routine	Transmission model	-	Daily short messages from the app	Education on: • Hypertension • Treatment • Diet therapy • Complication
S. Liu *et al.* (2020)	Email contained web link to the counselling sessions	Control group Received an email educating on heart-healthy lifestyle changes	Transmission model	-	Video	Behavioural change on: • Medication adherence • Diet adherence • Appointment adherence Used motivational interviewing and CBT components to promote behavioural change

Steinberg *et al.* (2020)	Smartphone application	Active comparator arm used the app to track the diet but no feedback or skill training videos were given	Interaction model	Research team	Video to introduce the DASH dietary pattern	Behavioural change on: • DASH diet adherence by tracking the food consumed • Feedback text on daily intake
Persell *et al.* (2020)	Smartphone application	Control group Received home blood pressure monitoring connected to a smartphone application	Interaction model	Physician	Coaching through the app	Behavioural change by coaching on: • Promoting diet • PA • Medication adherence • Blood pressure measurement • Sleep and stress management Receive feedback on behavioural and educational coaching
Sun *et al.* (2020)	WeChat	Control group Received conventional hypertension management	Interaction model	Research team	Group chat	Education on: • Basic knowledge and signs of hypertension • Complication • Drug treatment • Health behaviour • Lifestyle intervention Behavioural changes promotion

Mostafa Bijani (2020)	Online multimedia	Control group Provided with traditional care and no education interventions were given	Interaction model	Research team	Educational video and pamphlet	Education on: • Pathophysiology and complications of hypertension • Factors to control blood pressure • Right method to measure BP • Types of medication used • PA Effect of medication adherence and food regimens
Lee *et al.* (2020)	WeChat	Control group Received traditional doctor's face-to-face education	Interaction model	Physician	Text message via WeChat	Education on: • Diet • Exercise • Mental care • Medication precautions • Regular examination and a follow-up visit
Li *et al.* (2019)	WeChat	Control group Received the usual community healthcare service	Interaction model	Research team	Articles and quizzes in group chat	Education on: • Common hypertension problems • Medication treatment • Complication prevention • Healthy lifestyle

						Health promotion on: • Medicine intake • Healthy eating • Exercise • Smoking • Alcohol intake • Regulating mood Encourage the participants to: Ask questions, share the experience, report the BP, discussing lifestyle topics
Tanaka and Nolan (2018)	Url	Control arm Received the content from the heart health organisation	Transmission model	-	Videos, online handouts and monitoring forms	Behavioural change by promoting on: • Exercise • Diet • Prescribed medication • Smoke-free living The intervention used the key component of motivational interviewing and CBT
Liu *et al.* (2018)	Email	Control group Received weekly emails that were limited to general information on BP management	Transmission model	-	Text and video web links	Behavioural change on: • Exercise • Diet User-driven group: Enabled the participants to determine their own goals

						Expert-driven group: Prescribed specific lifestyle behaviour changes to participants
Nolan *et al.* (2018)	Email	Control group Get access to an e-info on hypertension management	Transmission model	-	Articles	Behavioural change on: • Exercise • Diet • Smoke-free living • Adherence to medication The intervention was based on motivational interviewing and CBT
Milani *et al.* (2017)	Website	Usual care Received routine care through primary care physicians	Interaction model	Pharmacist	Custom videos and downloadable handouts	Education on: • Depression or sleep apnea • Dietary sodium intake • Medication adherence Feedback was given on the patient's progress monthly
Cicolini *et al.* (2014)	Email	Usual care Received usual CVD prevention and a guideline-based educational program	Interaction model	Nurse	Attachment to the email	Education on: • Healthy diet • Exercise • Smoking cessation • Alcohol consumption • Blood pressure self-monitoring Medication adherence

Table 5: The IoT features used in the intervention (n=14)

Name (Author)	Integrating IoT System in the Intervention	IoT Communication Protocol Used	Services of IoT Used
McManus *et al.* (2021)	No	-	-
Abu-El-Noor *et al.* (2020)	No	-	-
S. Liu *et al.* (2020)	No	-	-
Steinberg *et al.* (2020)	Yes	Wi-Fi	Mobile IoT
Persell *et al.* (2020)	Yes	Not stated	Mobile IoT
Sun *et al.* (2020)	No	-	-
Mostafa Bijani (2020)	No	-	-
Lee *et al.* (2020)	No	-	-
Li *et al.* (2019)	No	-	-
Tanaka and Nolan (2018)	No	-	-
Liu *et al.* (2018)	No	-	-
Nolan *et al.* (2018)	No	-	-
Milani *et al.* (2017)	Yes	Wi-Fi	Mobile IoT
Cicolini *et al.* (2014)	No	-	-

according to their psycho-behavioural profiles into adaptive adjustment (AA) and effectively distressed (AD) groups. It was reported that the IG in the AA and AD groups presented a lower mean BP reading after the intervention ended compared to the control group. These findings contradicted another RCT study which showed that the mean SBP and DBP readings after three months of intervention were higher in the IG compared to the CG (Lee *et al.*, 2020).

ii. Behavioural Changes

Physical Activity

Two studies assessed the daily step counts and recorded a significantly increased number of daily steps after the intervention (Liu *et al.*, 2018; S. Liu *et al.*, 2020). Two articles examined the time spent exercising and discovered that the time spent exercising among the intervention group increased from the baseline to the control group (Cicolini *et al.*, 2014; Persell *et al.*, 2020). One study by Li *et al.* (2019) measured exercise management using the Hypertension Patient Self-Management Behaviour Rating Scale (HPSMBRS). It revealed that the IG had a higher score than the CG but it was insignificant.

Dietary Intake

A total of eight articles measured dietary intake and all the articles showed positive outcomes after the intervention was administered. A study by Abu-El-Noor *et al.* (2020) reported that the mean changes in adherence to hypertension therapy through dietary intake after three months improved among the IG. The diet management was assessed by Li *et al.* (2019) and it was discovered that the mean score after the intervention was significantly higher in the IG. In their study, Liu *et al.* (2020) also observed a significant elevation in the total serving of fruits with vegetables and improved sodium consumption compared to the baseline in both groups. However, after 12 months of

Table 6: The outcomes of the study in the intervention group (IG) compared to the control group (CG) (n=14)

Author (Year)	Duration of Intervention	Outcomes			
		Physiological	**Behavioural**	**Psychological**	**Satisfaction and Acceptance of the Intervention**
McManus *et al.* (2021)	12 months Participants attended the follow-up appointment after the intervention ended	• Mean BP changes: IG: Dropped from 151.7/79.8 mmHg to 138.4/80.2 mmHg CG: Dropped from 141.8/79.8 mmHg to 138.4/80.2 mmHg • Mean difference SBP: -3.4 mmHg (95% CI: -6.1, -0.8) • Mean difference DBP: -0.5 mmHg (95% CI: -1.9, 0.9)	-	QoL (EuroQoL-5D-5L): No significant difference between the two groups	Engagement with the digital intervention was high: • 281/305 (92%) participants completed the two core training sessions • 268/305 (88%) completing a week of practice blood pressure readings • 243/305 (80%) completing at least three weeks of blood pressure entries
Abu-El-Noor *et al.* (2020)	3 months No additional follow-up was done after the intervention ended	-	Significantly improving in the IG group: • Mean difference changes in diet adherence: IG: -2.63, P=0.000 CG: -1.25, P=0.000 • Mean difference changes appointment adherence: IG: -0.94, P=0.000 CG: -0.52, P=0.000	-	-

S. Liu *et al.* (2020)	12 months No additional follow-up was done after the intervention ended	• SBP changes from the baseline: Significantly higher in the IG IG: -10.1 mmHg (95% CI: -12.5, -7.6) CG: -6.0 mmHg (95% CI: -8.5, -3.5) P=0.02 • DBP changes: No significantly different between the two groups	• Daily steps: Significantly increased in the IG from baseline IG: 962 steps (95% CI: 105,1820), P=0.02 CG: -312 steps (95% CI: -1198,574), P=0.90 • Fruit and vegetable consumption (after 4 months): Significantly increased from baseline in both groups 0.72 servings/day; (95% CI, 0.01,1.4), P=0.045 • Sodium consumption: In women, significantly greater reduction in the IG Urinary sodium: -23.4 mmol/24 h (95% CI, -43.4, -3.3); p=0.02 No significant changes in both group from the baseline in men IG: 7.2 mmol/24 h (95% CI, -26.6, 12.0); p=0.46 CG: -20.6 mmol/24 h (95% CI, -40.4, 0.4); p=0.46	-	-

Steinberg *et al.* (2020)	3 months No additional follow-up was done after the intervention ended	• Mean SBP changes from the baseline: Not significantly higher in IG compared to CG -2.8 mmHg (95% CI, -1.8, 7.4), P=0.23 • Mean SBP changes from the baseline: Not significantly higher in IG compared to CG 3.6 mmHg (95% CI - 0.2, 7.3), P=0.07	• Mean difference in DASH scores: Significant increases in both groups from the baseline IG: 0.8 (95% CI 0.2, -1.5), P=0.02 CG: 0.8 (95% CI 0.4, -1.2), P<0.001 • Mean difference fibre intake: Significant increases in both groups from the baseline IG: 2.1 (95% CI 0.7, 3.5), P=0.004 CG: 1.9 (95% CI -0.04, 3.8), P=0.054 • Mean difference in saturated fat intake: Significant decrease in both groups from the baseline IG: -1.4 (95% CI -2.6, -0.2), P=0.03 CG: -1.5 (95% CI -1.9, -0.1), P=0.03 • Mean difference in magnesium intake: Increased in both groups from the baseline IG: 28.3 (95% CI: 7.5, 49.0), P=0.01 CG: 14.0 (95% CI -6.9, 34.9), P=0.18 • Mean difference in total fat intake within the IG: Decrease in both groups from baseline	-	• Engagement with diet tracking: A steeper reduction with rates decreasing by 0.23 (95% CI 0.16, -0.29) days per week (P<.001) • 82% (24/29) of the participants in the IG agreed that the app was easy to use

			IG: -0.2 (95% CI: -2.7, 2.4), P=0.89 CG: -3.9 (95% CI: -6.7, -1.0), P=0.01		
Persell *et al*. (2020)	6 months No additional follow-up was done after the intervention ended	• Mean SBP changes (SD) from baseline: Not significantly higher in IG IG: -8.3 mmHg (13.8) CG: -6.8 mmHg (13.7) P=0.16 • Mean DBP changes (SD) from baseline: Not significantly higher in IG IG: -4.3 mmHg (8.4) CG: -3.6 mmHg (9.5) P=0.61	• Mean different changes in practices: No significant increase in IG compared to CG 26.7 minutes per week (95% CI, -5.4 to 58.8 minutes per week), P=0.10 • Mean difference DASH-Questionnaire score compared to baseline: Both groups increased but CG achieved a higher score than IG -0.7 (95% CI: -2.8, 1.4), P=0.52 • Mean difference in consumption of processed meat, fried foods, sugar-sweetened beverages and sweetened food from baseline: Decrease in both groups but CG was not significantly lower consumption Processed meat: -0.2 (95% CI:-0.6, 0.1), P=0.15 Fried foods: -0.03 (95% CI: -0.31, 0.24), P=0.81 Sweetened beverages: -0.1 (95% CI: -0.5, 0.3), P=0.66 Sweetened foods: -0.2 (95% CI: -0.6, 0.2), P=0.35	-	-

Sun *et al.* (2020)	3 months • Patients in the low-risk group were followed up every 3 months • Intermediate groups were followed up every two months • High-risk group was followed up every month	• SBP and DBP changes: Significantly lower in IG compared to CG, $P<0.001$	• Mean different changes in hypertension self-management behaviour: HPSMBRS scores are significantly higher in IG IG: 74.57 ± 5.84 CG: 70.85 ± 5.78 $P<0.001$	-	-
Mostafa Bijani (2020)	5 months The follow-up was done by contacting the participants at the end of the fourth, fifth and sixth week of the intervention	-	Mean adherence score to treatment regimen changes (medication adherence, refraining self-medication, dietary intake and PA) after one month of the intervention (SD): Statistically higher in IG IG: 95.54 (4.56) CG: 81.19 (6.65) $P<0.001$	-	-
Lee *et al.* (2020)	12 weeks No additional follow-up was done after the intervention ended	• Mean SBP (SD): Not significantly higher in IG IG: 135.39 mmHg (16.76) CG: 130.92 mmHg (13.58) $P=0.078$	-	-	-

		• Mean DBP (SD): Not significantly higher in IG IG: 79.19 mmHg (11.12) CG: 77.85 mmHg (9.48) P=0.433 • Hypertension control: Not significantly lower in IG IG: 46% (62.20) CG: 56% (76.70) P=0.056			
Li *et al*. (2019)	6 months No additional follow-up was done after the intervention ended	• Mean SBP changes from baseline between groups: Significantly higher in IG compared to CG -6.9 mmHg (95% CI, -11.2, -2.6), P= 0.002 • Mean DBP changes between groups from baseline: Significantly higher in IG compared to CG -3.1 mmHg (95% CI, -5.7, -0.6), P=0.016	The result from the Hypertension Patient Self-Management Behavior Rating Scale (HPSMBRS) showed that: • Mean score difference in self-management between groups: Significantly higher in IG compared to CG IG: 7.3 (95% CI: 4.3, 10.3) CG: -1.4 (95% CI: -4.0, 1.2) P<0.001 • Mean score difference in diet management between groups: Significantly higher in IG compared to CG 4.2 (95% CI, 2.7, 5.6), P<0.001 • Mean score difference in exercise management between groups: Not significantly higher in IG compared to CG 0.5 (95% CI, -0.7, 1.7), P=0.389	• Mean difference in emotion management between groups: Significantly higher in IG compared to CG 1.9 (95% CI, 0.3, 3.4), P=0.019	-

Tanaka and Nolan (2018)	12 months No additional follow-up was done after the intervention ended Consists of two groups for intervention: • Adaptive adjustment (n=176) (low distress, high motivation and satisfactory engagement in health behaviour) • Effectively distressed (n=20) (clinically significant distress)	• Mean SBP change (SD) from baseline: i. Adaptive adjustment group: Significantly higher in IG IG: -10.51 (1.31) CG: -5.81 (1.44) P=0.02 ii. Effectively distressed: Higher in IG IG: -12.00 (8.25) CG: -6.63 (15.01) • Mean DBP change (SD): i. Adaptive adjustment group: Not significantly higher in IG IG: -5.15 (0.78) CG: -3.40 (0.86) P=0.13 ii. Effectively distressed: Higher in IG IG: -11.00 (8.29) CG: -4.25 (8.51)	-	-	-
Liu *et al*. (2018)	4 months No additional follow-up was done after the intervention ended	• Mean SBP change from baseline: i. User-driven group (UDG): Not significantly higher in UDG than CG UDG: -7.8 mmHg (95% CI, -10.7, -4.9) CG: -4.3 mmHg (95% CI, -7.2, -1.5) P=0.14	• Mean daily steps change: i. User-driven group: Not significantly higher in UDG than CG UDG: 192 (95% CI, -560 to 943) CG: -423 (95% CI, -1158 to 311) P=0.74	-	-

ii. Expert-driven group (EDG): Significantly higher in EDG than CG EDG: -11.9 mmHg (95% CI, -14.9, -9.1) CG: -11.9 mmHg (95% CI, -14.9, -9.1) CG: -4.3 mmHg (95% CI, -7.2, -1.5) P<0.01 • Mean DBP change from baseline: i. User-driven group: Higher in UDG than CG UDG: -5.3 mmHg (95% CI, -7.1, -3.4) CG: -3.4 (95% CI, -5.6, -1.9) ii. Expert-driven group: (EDG): Higher in EDG than CG EDG: -5.2 mmHg (95% CI, -7.3, -3.0) CG: -3.4 (95% CI, -5.6, -1.9)	ii. Expert-driven group: Significantly higher in EDG than CG EDG: 2036 (95% CI, 1263, 2809) CG: -423 (95% CI, -1158 to 311) P<0.01 • Mean daily fruit intake change: i. User-driven group: Not significantly lower in UDG than CG UDG: 10.1 servings/day (95% CI, -0.7, 0.7) CG: 0.5 servings/day (95% CI, -0.2, 1.3) P=0.92 ii. Expert-driven group: Significantly lower in EDG than CG EDG: 2.1 servings/day (95% CI, 1.3, 2.8) CG: 0.5 servings/day (95% CI, -0.2, 1.3) P=0.01 • Mean daily vegetable intake change: i. User-driven group: Not significantly lower in UDG than CG UDG: 1.1 servings/day (95% CI, 0.3 to 1.8) CG: 0.8 servings/day (95% CI, -0.1, 1.5)

			ii. Expert-driven group: Lower in UDG than CG EDG: 0.33 servings/day (95% CI, -0.37, 1.0) CG: 0.8 servings/day (95% CI, -0.1, 1.5)		
Nolan *et al.* (2018)	12 months No additional follow-up was done after the intervention ended	• Mean SBP change from the baseline: Significantly higher in IG IG: -10.1 mmHg (95% CI, -12.5, -7.6) CG: -6.0 mmHg (95% CI, -8.5, -3.5) P=0.02 • Mean DBP changes from the baseline: Not significantly higher in IG IG: -4.9 mmHg (95% CI, -6.4, -3.5) CG: -3.5 mmHg (95% CI, -4.9, -0.9) P=0.17			
Milani *et al.* (2017)	90 days No additional follow-up was done after the intervention ended	• Mean SBP (SD) (mmHg): Significantly lower in IG IG: 133(12), P<0.001 CG: 143 (14), P<0.001 • Mean DBP change (SD) (mmHg): Significantly lower in IG IG: 76 (9), P<0.001 CG: 79 (9), P<0.001	• High dietary sodium intake: Significantly improved from the baseline in the IG After 90 days: 8% Baseline: 32% P<0.001	-	-

Cicolini *et al.* (2014)	6 months No additional follow-up was done after the intervention ended	• Mean SBP change from the baseline (SD) (mmHg): Significantly higher in IG IG: -14.9 mmHg (8.1) CG: -10.00 mmHg (11.6) P<0.001 • Mean DBP change from baseline (SD) (mmHg): Significantly higher in IG IG: -11.0 (5.7) CG: -7.6 mmHg (3.4) P<0.001	• Mean alcohol consumption change (SD) (unit alcohol/day): Significantly lower in IG IG: -0.68 (0.86) CG: -0.41 (0.51) P=0.038 • Mean fruit intake change (SD) (servings/day): Significantly higher in IG IG: 0.7 (1.1) CG: 0.2 (0.4) P<0.001 • Mean salt consumption change (SD) (small spoon/day): No changes in both group Mean physical activity change (SD) (minutes/day): Significantly higher in IG IG: 16.2 (9.0) CG: 4.9 (8.8) P<0.001

intervention, only the females in the IG recorded a significant improvement, as observed in their 24-hours urinary sodium reading, compared to the CG. A three-month RCT reported that the mean difference in the DASH score for the consumption of fibre and magnesium increased while the saturated and total fat intake decreased from the baseline in both groups (Steinberg *et al.*, 2020).

The mean difference in the consumption of unhealthy foods such as processed meat, fried foods, sugar-sweetened beverages and foods was lower than the baseline in both groups after the intervention was administered (Persell *et al.*, 2020). Cicolini *et al.* (2014) measured the alcohol, fruit and salt consumption and observed three different trends in which the alcohol intake was lowered, there was a higher intake of fruits in both groups compared to the baseline. However, no difference was observed in the salt intake. In contrast, the percentage of participants who had a high sodium intake in a study by Milani *et al.* (2017) showed a significant improvement after 90 days of intervention through a website in IG. The mean intake of vegetables and fruits in one RCT by Liu *et al.* (2018) also indicated an improvement in both groups; however, the user- and expert-driven intervention groups recorded a lower improvement than the CG, except for the intake of vegetables in the user-driven group.

Treatment Adherence

The changes in treatment adherence were examined in two studies. Abu-El-Noor *et al.* (2020) found in their three-month study that the appointment adherence among the participants improved from the baseline but even so, the mean change in the adherence score was significantly higher in the IG than in the CG. Furthermore, a study by Mostafa Bijani (2020) assessed treatment adherence using the resulting scores from the questionnaire and it was discovered that the mean total score improved in both groups after five months of intervention.

Hypertension Self-management

The HPSMBRS was used in two studies. This scale examined the changes in six management domains: Medication, disease monitoring, PA, diet, work, rest and emotion. Li *et al.* (2019) and Sun *et al.* (2020) reported that the scores after the intervention were significantly higher in the IG than the CG.

iii. Psychological Changes

The psychosocial changes were assessed only in two out of 16 articles. McManus *et al.* (2021) reported that the health-related quality of life among the intervention and control groups in their study showed no difference after the intervention was done for 12 months. In addition, a study by Li *et al.* (2019) found that the intervention group showed a higher improvement in emotion management than the control group.

iv. Satisfaction and Acceptance Towards the Intervention

Two studies assessed the participants' satisfaction and acceptance throughout the intervention. First, McManus *et al.* (2021) evaluated the participants' engagement with the digital intervention via email and found high adherence. The assessment included the number of participants who completed two core training sessions (92%), a week of BP reading practices (88%) and a three-week complete BP reading submission. Even so, the engagement with a diet tracker in a study conducted by Steinberg *et al.* (2020) found that those participants who used the tracker showed a significantly decreasing pattern of 0.23 days per week, even though 82% of the users agreed that the app was easy to use.

Discussion

Types of IBT

Communication in the healthcare sector is a building block for the preservation of the patient-practitioner relationship, where it helps the patient to make decisions and exchange information and encourages adherence to health management (Lum *et al.*, 2020). Therefore, the use of the Internet focuses mainly on the communication function which is fundamental in the healthcare industry to achieve the intended treatment outcomes. This evolution has also received special attention in the healthcare sector as healthcare providers can continuously educate patients about treatments or interventions via an online platform (Schouten *et al.*, 2020). Therefore, through a systematic review of the 14 studies, it was found that two models of communication were used in the included IBT to deliver information to patients, namely, one-way and two-way communication.

The two-way online communication function mostly installed in the included IBT showed a higher usage with great influence on hypertension intervention. In the traditional form of medical consultation, health professionals and patients are required to interact physically, but since the demand for healthcare is increasing each year, there are long queues of patients waiting for their turn for consultations. Since the Internet is an excellent medium for real-time online consultations, applying this communication model can help healthcare professionals and patients interact easily (Guo *et al.*, 2016). Three characteristics of the online doctor-patient interaction are effective: (a) Bidirectional selection where the patient needs to choose the physician for consultation and the doctors share their medical knowledge after screening the patient, (b) Cyclicity where the sustainable online interaction moves in a cyclical process, whereby patients choose the doctors who share the knowledge and eventually, the patients give their feedback on the service to increase the service reputation of the doctors and (c) Stability where a stable interaction involves cooperation between doctors and patients, both benefit from the interaction. Active participation from the patients and high professionalism among the doctors are needed to keep the communication between the two parties going smoothly throughout the treatment and intervention process. A systematic review by Qudah and Luetsch (2019) examined the influence of the Internet-based mHealth application on the relationship between patients and healthcare professionals in 37 articles and it was discovered that a higher quality of clinical consultation and decision-making was achieved as access to both parties was easier, regardless of place and there was a quicker response.

Features of IoT Used

It was discovered that only a few of the included studies implemented the IoT system, m-IoT, in which the main functions namely, sensing, storing and analysing data played a huge role in bringing about changes to the healthcare sector. These functions can greatly help in healthcare to minimise human error during treatment and the cost and need for experts (Awad *et al.*, 2021).

The sensor function is used extensively in technology nowadays, especially in tracking and healthcare to help promote an accurate diagnosis and treatment including self-monitoring in Non-Communicable Disease (NCD) patients. One review concluded that there are two type of sensors: On-body and on-object sensors. On-body sensors include inertial sensors that can detect any dynamic activities, physiological sensors that are usually used to observe medical health data and location sensors that enable tracking of user locations while on-object sensors are those that are installed on objects (Qi *et al.*, 2018). Khowaja *et al.* (2018) stated that the sensor layer in IoT usually consists of multiple sensors on a device and is responsible for connecting the physical world to gather health data from the user. They added that the sensed data would be transferred to middleware such as smartphones via various communication protocols (Wi-Fi, bluetooth, Zigbee and others) which act as a gateway before the data is sent to cloud computing.

Data storage and analysis are also the core parts of an integrated IoT system. All the data are collected continuously and in real-time to provide an accurate diagnosis and to be more organisable. Rajabion *et al.* (2019) suggested that cloud computing has become an ideal and cheap location for the storage of unlimited information, and it enables the service provider to process the data of patients to help the healthcare sector plan for the best medical treatment. The stored data from the medical centre's cloud will be transmitted to the middleware so that the raw data can be processed before it is shared with third parties to enable a direct assessment and visualisation by the healthcare worker regardless of the time and location (Botta *et al.*, 2016). However, despite the promising benefits of sharing data through the Cloud platform, the issue of the privacy of confidential data is always being argued. Many healthcare facilities doubt the ability of Cloud technology to prevent breaches in patient data during storage for the data to be manipulated by irresponsible parties (Shin *et al.*, 2011). Abraham *et al.* (2019) added that IoT-integrated devices are vulnerable to attacks by hackers as they have a lower level of security protection due to low encryption protocols that are below the standard.

In addition, data protection laws have been enacted to protect shared data and Malaysia has also taken the initiative to enact the Personal Data Protection Act 2010. This act was purposely enacted to preserve the collection, holding, processing and usage of individual sensitive data as the data cannot be disclosed to any individual or organisation without the owner's consent (Ong, 2012). This act does not apply to the federal or state governments as all the ministries representing the Malaysian Government can access personal data including personal healthcare data without the individual's consent. Therefore, in their experiment, Thilakanathan *et al.* (2014) proposed a solution by implementing an additional security protocol to strengthen cybersecurity in the healthcare sector by providing the patient with a private key or password. In simpler words, any healthcare professional or data consumer who requires access to a patient's data in the cloud to analyse and diagnose the patient's health will need to request the key from the Data Sharing Service (DSS) to decrypt the data. If the patient decides to cancel the data consumer's right to access the data, the patient can simply call the DSS to remove the corresponding key. This study found out that although a longer period is needed to retrieve the data from the patient, the performance test showed that this protocol is feasible for use in the healthcare sector.

The Impact of IBT on Hypertensive Patient

Fourteen articles were identified and met the inclusion criteria to examine the impact of IBT, exclusively for the hypertensive population. The review confirmed that implementing IBT improved the physiological, behavioural and psychological status of hypertension patients as most articles reported positive outcomes. Furthermore, even though only a limited number of articles assessed the satisfaction and acceptance of users regarding IBT, the results were positive and overwhelming.

Several factors contributed to the effectiveness of intervention implementation via IBT. First, some selected studies were patient-centred in planning the intervention to control dietary intake and PA. Two of the included studies used the patient-centred counselling model to educate and guide patients toward lifestyle changes via IBT to achieve therapeutic outcomes (Liu *et al.*, 2018; Nolan *et al.*, 2018). These outcomes can be built by determining the patient's motivation to change and strengthening the skills needed to support long-term lifestyle changes. The behavioural change process of the transtheoretical model (TTM) for each stage was used to determine the readiness to change and was influenced by the patient's cognitive and behavioural levels. For example, patients in the earliest stage of TTM, the pre-contemplation stage usually did not interpret their unhealthy behaviour as a problem as they did not have sufficient information and were unaware of the consequences of their behaviour (Li *et al.*, 2020). Thus, providing relevant information regarding the disease must be a priority to enable the patients to be willing to change. Meanwhile, for patients in the advanced stage of TTM, the healthcare provider usually focuses on enhancing the patients' confidence to change and participate in disease management.

Furthermore, in their systematic review, Castro *et al.* (2016) noted that patient participation is an important precursor for patient-centredness in the decision-making process that can affect their health to more strategic levels. However, support from field experts such as health practitioners is important for improving patient adherence during the behavioural change process. Additionally, Liu *et al.* (2018) noted that the user-driven model might not be effective for creating a collaborative environment if there is no performance-based feedback from professionals. Since lifestyle changes need a long-term commitment from the individual, any intervention or change must be made attentively and collaboratively by healthcare professionals and their patients without neglecting their needs. Also, a review by Perez Jolles *et al.* (2019) stated that the decision-making style evolves as patients are more likely to experience passive shared-decision making when they first encounter the disease due to their lack of adequate knowledge. However, as the patients become more familiar with the treatment and health routine under the guidance of health providers, they will insist on playing an active role in their treatment over time and will be ready to make changes to improve their health.

Second, online support groups can be an important marker in establishing an effective online intervention for chronic disease management. One of the selected studies by Li *et al.* (2019) investigated the mechanisms that can increase self-management among middle-aged and elderly hypertensives in China via a WeChat group and discovered that sharing personal experiences among patients can help increase their confidence in disease control. An online support group is one of the alternatives for increasing the compliance of patients concerning interventions or treatment as members of the support group usually share a common identity and interest (Wentzer & Bygholm, 2013). The Social Cognitive Theory by Bandura suggests that environmental factors through social support can contribute to higher adherence and motivation to engage in self-care behaviour over a long period to improve health (Tan *et al.*, 2021). Furthermore, patients who undergo self-management intervention are more likely to reach out to people who sincerely understand them when they express their health concerns. Also, they want to receive and give feedback to avoid being left alone to manage the disease (Lin & Kishore, 2021). This statement was supported by a review in China by Wang *et al.* (2021) which revealed that emotional support from the digital community rather than close family members could result in a higher level of well-being in coping with health problems. They also noted that it is easier for patients to share their experiences especially when it comes to sensitive health problems.

However, patients are quite concerned about the issue of privacy when sharing confidential information with group members about their health such as regarding the progression of their disease (Goodyear *et al.*, 2021). This statement was supported by a study about an online support group for HIV patients in which it was reported that most of the patients expressed their concern about the risk of dishonesty by the group members since the communication among the members focused on text messaging rather than face-to-face sessions (Mo & Coulson, 2014). Thus, they may share false information and experiences that display aggressive expressions instead of motivating patients. Furthermore, a study by Walsh and Al Achkar (2021) evaluated the impact of an online support group for lung cancer patients and reported that engaging with an online support group positively impacts psychological support and the sharing of health information. However, this comes with the risk that the group participants may compare themselves with others and this can be demotivating or that the group members may share misleading information, especially if healthcare professionals do not supervise the group. The conclusion is that IBT can be a great platform for providing chronic patients with an online support group to share their personal experiences. Nevertheless, special precautions are needed to avoid any health data breach or misleading information that could harm the group members.

In addition, multiple targeted behavioural changes in IBT interventions showed higher efficacy than a single behavioural change. The behavioural changes were introduced in the intervention by giving the related information concerning hypertension and targeting multiple healthy behavioural changes that can improve BP. Liu *et al.* (2018) and S. Liu *et al.* (2020) investigated e-counselling among hypertensive patients. They reported that targeting multiple self-care behaviours simultaneously in the intervention such as daily steps, vegetable and sodium intake is way more effective than single behaviour in optimising BP. These findings were in agreement with the review by Duan *et al.* (2021) in which all of the included studies showed that multiple-health behavioural changes via eHealth did significantly improve the practice of a healthy diet and exercise among non-communicable disease patients and one of the factors that contributed to this was education and counselling on healthy behaviour. Additionally, targeting multiple behavioural changes can save time and cost in managing targeted diseases.

James *et al.* (2016) stated that it might be overwhelming and too demanding for patients to adhere to the behavioural change process. Multiple behavioural changes need extra effort from the patient to alter their routine towards a healthier lifestyle. Thus, the patients especially elderly patients may not receive the intended and suitable lifestyle interventions for disease management. As a result, they may feel they cannot achieve all the recommendations throughout the intervention and may slowly lose interest in changing their behaviour. However, no specific number of targeted behavioural changes was considered overwhelming since efficient multiple behavioural changes depending on the purpose and focus of the intervention. This review found that all the included articles implemented three to six behavioural changes that focused only on hypertension management and presented positive outcomes throughout the study. This finding agreed with a study by Thomas *et al.* (2018) which assessed the experiences of type 2 diabetes mellitus patients regarding multiple behavioural changes. It was revealed that for many successful behavioural changes, the focus was on effective patient-provider communication to discuss the concrete reasons for multiple behavioural changes. The healthcare providers had to clearly explain and guide the patients on following the recommendations to sustain their long-term changes. They added that using digital platforms is a good strategy to track several behavioural changes simultaneously and to offer feedback on their achievements to encourage individual participation.

Last, but not least, the reported usage of IBT in most articles for controlling dietary and PA practices also included implementing self-management skills among patients to improve their BP reading. This skill is crucial to enhance the quality of chronic disease care. Chronic disease patients have to live with the disease throughout their life; hence, they need to improve their self-management skills and prepare some strategies for example, to control the disease symptoms, change their lifestyle and maintain a good physical and mental state to achieve better disease control (Li *et al.*, 2019). However, good self-management skills can only be acquired if the patients are given sufficient disease-related education to optimise their awareness. Delavar *et al.* (2020) conducted a study to evaluate the efficacy of self-management education to enhance medication adherence and BP control by providing the participants with educational materials related to hypertension such as its definition, risk factors, complications and mediation of side effects management to the elderly. Eventually, these efforts gained a positive outcome as the intervention group showed a significant reduction in SBP and DBP readings while the medication adherence increased.

Comprehensive search processes conducted this study via various online databases and reported the steps to obtain the relevant articles. In addition, this study is the first systematic review to determine the different types of IBT used from the available studies while integrating IoT systems, specifically for adults with hypertension.

Several limitations were acknowledged despite the findings of this review. First, the articles included in this review were heterogeneous, so interpretations of the effectiveness must be made cautiously. Second, this systematic review only included studies published in English, so there is a possibility that a few relevant articles in other languages may not have been included in the analysis. Third, the specific targeted population only focused on hypertension without any underlying disease. Thus, it cannot be representative of the entire adult population, except for hypertensives, thereby limiting the diversity and number of studies included in the research.

Conclusion

Interventions to manage hypertension through dietary and PA practices via IBT were evaluated in a few studies and presented positive outcomes regarding BP control and healthy behavioural and psychological changes. However, the implementation of IoT in IBT to manage hypertension is still in a new phase since there is limited research and no concrete or standardised concept on how IoT in healthcare should be introduced via digital platforms. Therefore, additional IBT interventions and IoT adaptations with rigorous research are needed to help hypertensive patients worldwide better self-care management.

Acknowledgements

This study was supported by a grant from the Ministry of Higher Education, Malaysia (reference number FRGS/1/2019/SS06/UiTM/03/6 and 600-IRMI/FGRS 5/3 [448/2019]). The authors would like to thank the ministry for their financial support and the experts who contributed their full commitment to this study. The data reported in this paper are those of the authors and are independent of the funding source.

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Appendices

Appendix 1: Database search and strategy

Search Database	Search String	Search Term
Scopus, WoS, PubMed, SD, GS	(“Smartphone app-based”) AND (“hypertension” OR “hypertensive” OR “blood pressure”) AND (“patient” OR “patients”)	Smartphone app-based
Scopus, WoS, PubMed, SD, GS	(“tablet-based system”) AND (“hypertension” OR “hypertensive” OR “blood pressure”) AND (“patient” OR “patients”)	Tablet-based system
Scopus, WoS, PubMed, SD, GS	(“telemedicine”) AND (“hypertension” OR “hypertensive” OR “high blood pressure”) AND (“patient” OR “patients”)	Telemedicine
Scopus, WoS, PubMed, SD, GS	(“technology assisted”) AND (“hypertension” OR “hypertensive” OR “high blood pressure”) AND (“patient” OR “patients”)	Technology assisted
Scopus, WoS, PubMed, SD, GS	(“web-based”) AND (“hypertension” OR “hypertensive” OR “high blood pressure”) AND (“patient” OR “patients”)	Web-based
Scopus, WoS, PubMed, SD, GS	(“e-health”) AND (“hypertension” OR “hypertensive” OR “high blood pressure”) AND (“patient” OR “patients”)	e-health

Notes: Web of Science (WoS), ScienceDirect (SD), Google Scholar (GS)

Appendix 2: The results of the discussion between the reviewers

Author (Year)	Before the Discussion		After the Discussion		Remarks
	Reviewer 1	Reviewer 2	Reviewer 1	Reviewer 2	
Cuffee *et al.* (2018)	√	X	X	X	Rejected as the intervention focused on the usage of home-monitoring BP (HMBP)
Tanaka and Nolan (2018)	X	√	√	√	Accepted as the study’s measured outcomes relevant to the review’s objective
Ghoshachandra *et al.* (2017)	√	X	√	√	Accepted as the study’s measured outcomes relevant to the review’s objective
Johnson *et al.* (2016)	√	X	√	√	Rejected as the intervention did not focus on IBT
Cicolini *et al.* (2014)	X	√	√	√	Accepted as the intervention used the IBT
Friedberg *et al.* (2015)	√	X	X	X	Rejected as the intervention did not focus on IBT

Appendix 3: Methodological quality and risk of bias assessment of 12 studies using the Checklist for RCT of Joanna Briggs Institute

Items	**McManus *et al.* (2021)**	**Abu-El-Noor *et al.* (2020)**	**S. Liu *et al.* (2020)**	**Steinberg *et al.* (2020)**	**Persell *et al.* (2020)**	**Sun *et al.* (2020)**	**Lee *et al.* (2020)**	**Li *et al.* (2019)**	**Liu *et al.* (2018)**	**Tanaka and Nolan (2018)**	**Nolan *et al.* (2018)**	**Cicolini *et al.* (2014)**
1. Was true randomisation used for assignment of participants to treatment groups?	√	?	√	?	√	?	√	√	√	?	√	√
2. Was allocation to treatment groups concealed?	√	?	√	√	√	√	?	√	√	√	√	√
3. Were treatment groups similar at the baseline?	√	√	√	√	√	√	√	√	√	√	√	√
4. Were participants blind to treatment assignment?	√	√	√	√	X	X	√	?	√	?	√	√
5. Were those delivering treatment blind to treatment assignment?	√	?	?	X	X	?	N/A	?	√	√	√	√
6. Were outcomes assessors blind to treatment assignment?	N/A	N/A	N/A	?	?	?	?	?	?	√	√	√
7. Were treatment groups treated identically other than the intervention of interest?	N/A	N/A	X	N/A	N/A	N/A	N/A	N/A	√	N/A	N/A	N/A

8. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?	√	√	√	?	√	√	√	√	√	√	√	√
9. Were participants analysed in the groups to which they were randomised?	√	√	√	√	√	√	√	√	√	√	√	√
10. Were outcomes measured in the same way for treatment groups?	√	√	√	√	√	√	√	√	√	√	√	√
11. Were outcomes measured in a reliable way?	√	√	√	√	√	√	√	√	√	√	√	√
12. Was appropriate statistical analysis used?	√	√	√	√	√	√	√	√	√	√	√	√
13. Was the trial design appropriate and any deviations from the standard RCT design (individual randomisation, parallel groups) accounted for in the conduct and analysis of the trial?	√	√	√	√	√	√	√	√	√	√	√	√
Overall Appraisal	**Include**	**Include**	**Include**	**Include**	**Include**	**Include**	**Include**	**Include**	**Include**	**Include**	**Include**	**Include**

Appendix 4: The total score and risk of bias of 12 studies using the Checklist for RCT of Joanna Briggs Institute

Author (Year)	Total Score (%)	Risk of Bias
McManus *et al.* (2021)	85	Low
Abu-El-Noor *et al.* (2020)	62	Moderate
S. Liu *et al.* (2020)	77	Low
Steinberg *et al.* (2020)	62	Moderate
Persell *et al.* (2020)	70	Low
Sun *et al.* (2020)	62	Moderate
Lee *et al.* (2020)	70	Low
Li *et al.* (2019)	70	Low
Liu *et al.* (2018)	92	Low
Tanaka and Nolan (2018)	77	Low
Nolan *et al.* (2018)	92	Low
Cicolini *et al.* (2014)	92	Low

Appendix 5: Methodological quality and risk of bias assessment of three studies using the Checklist for Quasi Experimental Studies of Joanna Briggs Institute

	Items	Mostafa Bijani (2020)	Ghoshachandra *et al.* (2017)	Milani *et al.* (2017)
1.	Is it clear in the study what is the 'cause' and what is the 'effect' (i.e., there is no confusion about which variable comes first)?	√	N/A	√
2.	Were the participants included in any comparisons similar?	√	N/A	√
3.	Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	√	N/A	√
4.	Was there a control group?	√	N/A	√
5.	Were there multiple measurements of the outcome both pre and post the intervention/exposure?	X	N/A	X
6.	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?	√	N/A	√
7.	Were the outcomes of participants included in any comparisons measured in the same way?	√	N/A	√
8.	Were outcomes measured in a reliable way?	√	N/A	√
9.	Was appropriate statistical analysis used?	√	N/A	√
	Overall Appraisal	**Include**	**Exclude**	**Include**

Appendix 6: The total score and risk of bias of three studies using the Checklist for Quasi Experimental Studies of Joanna Briggs Institute

Author (Year)	Total Score (%)	Risk of Bias
Mostafa Bijani (2020)	89	Low
Ghoshachandra *et al.* (2017)	0	High
Milani *et al.* (2017)	89	Low