Hypertension Treatment Using an Internet-Based Lifestyle Intervention

by

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A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy
Institute of Medical Science
University of Toronto

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2015

Abstract

Lifestyle change is important to blood pressure (BP) management. A health care challenge is to extend the reach of these lifestyle programs without over taxing health care resources. The rapid growth of Internet use presents an opportunity to tackle this challenge. However, meta-analytic data examining the efficacy of Internet-based lifestyle interventions to reduce BP in patients with hypertension is lacking. The optimal design strategies of effective Internet-based interventions also remain unclear; specifically, the effectiveness of clinical methods used (User- vs. Expert-driven protocols). Furthermore, self-monitoring of physical activity (PA) can help participants improve adherence to PA and reduce BP. Thus, it is important to find a user-friendly, low-cost and valid tool to measure PA that can be used in an Internet-based intervention.

To address these questions, the first study examined the efficacy of Internet-based interventions in reducing BP in a meta-analysis and identified key components of an Internet-based intervention that are associated with BP control. The second study validated the XL-18 pedometer, which was a critical instrument in measuring daily steps used in the third study. The third study examined the influence of User- vs. expert-driven approaches used in an Internet-intervention aimed at promoting BP control and adherence to lifestyle changes.
The first study showed that self-guided Internet-based lifestyle programs can be effective in reducing BP; specifically, interventions may be more efficacious when they were 6 months or longer, delivered proactively, and provided at least five behavioural techniques. The second study found that the XL-18 pedometer is a suitable tool to measure steps under controlled and free-living conditions. The third study demonstrated that it may be advisable to integrate an expert-driven e-counselling procedure into future Internet-based interventions in order to accommodate participants with greater levels of motivation for behaviour change. Overall, these findings have significant implications in designing the next generation of Internet-based lifestyle interventions.
Acknowledgments

I would like to acknowledge my supervisor, Dr. Robert Nolan and my committee member, Drs, Dina Brooks, Scott Thomas and Gunther Eysenbach, for all of your guidance throughout my doctoral degree. I deeply appreciate all of your effort in providing me the opportunities to develop my research career and grow as a person.

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The financial funding from the Heart and Stroke Foundation, Ontario Student Opportunity Trust Fund and Canadian Institute of Health Research was extremely helpful in the pursuit of my academic goals and I greatly appreciate it. Lastly, this research could not have been possible without the enthusiastic participants who gave enormous time and effort and with whom I enjoyed many moments.
Contributions

These thesis research projects were made possible with the assistance of a larger research team. Drs. Robert Nolan, Dina Brooks, Scott Thomas and Gunther Eysenbach critically reviewed each of the Chapters in this thesis. Dr. Yvonne Leung and Ms. Sarah Dunford assisted with the meta-analysis data collection and analysis (Chapter 3). Ms. Jelena Surikova, Mr. Mike Tung and Dr. Ada Payne assisted with participant screening, data collection and participant assessment for pedometer validation study (Chapter 4) and the randomized controlled trial (Chapter 5). Drs. Robert Nolan, Dina Brooks, Scott Thomas assisted with the development of the Expert and User-driven protocols for Internet-based Intervention (Chapter 5). Dr. Robert Nolan was the principal investigator of these studies and contributed to the study conception and design, and interpretation of the data. Thank you to everyone for their contributions to these studies.
# Table of Contents

Acknowledgments .............................................................................................................. iv  
Contributions .................................................................................................................... v  
List of Tables ...................................................................................................................... viii  
List of Figures ..................................................................................................................... ix  
List of Appendices .............................................................................................................. xi  
Abbreviations .................................................................................................................. xii  

## Chapter 1. Introduction and Background ................................................................. 1  
1.1 Introduction .............................................................................................................. 1  
1.2 Classification and Prevalence of Hypertension ...................................................... 3  
1.3 Risk of Hypertension .............................................................................................. 4  
1.4 Lifestyle Counselling and Blood Pressure Control .............................................. 5  
1.5 What is an Internet-based health Intervention? ...................................................... 13  
1.6 Benefits of Self-guided Internet-based Health Interventions ............................... 14  
1.7 Measuring Behaviour Change in Internet-based Intervention ............................ 20  
1.8 Effectiveness of Internet-based Health Interventions ......................................... 22  
  1.8.1 Changes in Behavioural Outcomes ............................................................... 22  
  1.8.2 Changes in BP and Risk of Cardiovascular Disease ...................................... 23  
1.9 Model of Internet Interventions for Behaviour Change ....................................... 25  
  1.9.1 User Characteristics .................................................................................... 28  
  1.9.2 User-Friendly Design ................................................................................ 30  
  1.9.3 Intervention protocol .................................................................................. 34  
1.10 Chapter Summary ................................................................................................. 53  

## Chapter 2. Aims/ Hypotheses ............................................................................... 55  
2.1 Study Objectives .................................................................................................... 55  
2.2 Hypotheses ............................................................................................................ 56  

## Chapter 3. Reducing blood pressure using Internet-based interventions: a meta-analysis ....................................................................................... 58  
3.1 Introduction ............................................................................................................ 59  
3.2 Methods .................................................................................................................. 60
List of Tables

Table 1.1: Classification of blood pressure for adults age 18 years or older..........................3
Table 1.2: The influence of lifestyle change on resting blood pressure ..............................6
Table 1.3: Comparison of Canada’s Food guide vs. DASH diet.........................................8
Table 1.4: A list of common elements used in web page design to improve overall usability ....33
Table 1.5: The effectiveness of behaviour change techniques used in Internet-based health intervention ........................................................................................................39
Table 1.6: Summary of the main determinants and their areas of overlap in three most popular conceptual models of health behaviour.................................................................45
Table 3.1: Characteristics of reviewed clinical trials.............................................................77
Table 4.1: Absolute Percent Error (APE) under controlled and free-living condition..........88
Table 4.2: The influence of body mass index (BMI), waist size and walking speed on percent error of XL-18 Pedometer........................................................................................................88
Table 5.1: Baseline Characteristics .....................................................................................108
Table 5.2: Baseline characteristics between completers vs. non-completers (Mean ±SE) ......110
Table 5.3: Cardiovascular Outcomes at 4 months for all participants completing clinic follow-up ........................................................................................................................................112
Table 5.4: Sensitivity Analysis for primary outcome..............................................................114
Table 5.5: Behavioural Outcome at 4 months for all participants completing clinic follow-up ..115
List of Figures

Figure 1.1: Potential contributors to BP reduction as result of DASH diet .................. 9

Figure 1.2: Degree of Tailoring .................................................................................. 19

Figure 1.3: Model of Internet-based Intervention for behaviour change. ..................... 27

Figure 1.4: Display of various methods to organize content for Internet-based intervention. ..... 31

Figure 1.5: Examples of content that is organized in a shallow and deep hierarchical structure. 31

Figure 1.6: Theory of planned behaviour ........................................................................ 40

Figure 1.7: The Trans-Theoretical Model and Process of Change .................................... 42

Figure 3.1: Flowchart illustrating literature search .......................................................... 64

Figure 3.2: Forest plot for the overall change in overall effect size for systolic blood pressure (SBP) ........................................................................................................................................................................ 67

Figure 3.3: Forest plot of the overall change in overall effect size for diastolic blood pressure (DBP) effect size ........................................................................................................................................................................................................ 67

Figure 3.4: The overall change in effect size of systolic blood pressure (SBP) for short-term (<6months) versus long-term (≥6 months) Internet-based interventions ........................ 68

Figure 3.5: The overall change in effect size of systolic blood pressure (SBP; Figure A) and diastolic blood pressure (DBP; Figure B) for trials that used less than 5 versus greater or equal to 5 behaviour changing techniques ................................................................. 70

Figure 3.6: The overall change in effect size of diastolic blood pressure (DBP) for proactive versus reactive Internet-based interventions ........................................................................ 72

Figure 4.1: Bland-Altman plots depicting measurement bias of XL-18 pedometer .......... 91

Figure 5.1: Flow of participants through recruitment, intervention and follow-up assessment... 107
Figure 5.2: Distribution of readiness for exercise and diet at baseline and 4 month................. 117

Figure 5.3: Change in readiness for exercise (a) and diet (b) following the e-counselling intervention........................................................................................................ 119

Figure 6.1: A block diagram illustration of an adaptive Internet-based intervention aimed at blood pressure control........................................................................................................ 132
List of Appendices

Appendix 1: Readiness for Change Questionnaire................................................................. 167
Appendix 2: Diet History Questionnaire.................................................................................. 170
Appendix 3: Program Feedback Questionnaire....................................................................... 185
# Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>95%CI</td>
<td>95% Confidence Interval</td>
</tr>
<tr>
<td>APE</td>
<td>Absolute percent error</td>
</tr>
<tr>
<td>BMI</td>
<td>Body Mass Index</td>
</tr>
<tr>
<td>BP</td>
<td>Blood pressure</td>
</tr>
<tr>
<td>CVD risk</td>
<td>Cardiovascular disease risk</td>
</tr>
<tr>
<td>DASH</td>
<td>Dietary Approaches to Stop Hypertension</td>
</tr>
<tr>
<td>DBP</td>
<td>Diastolic blood pressure</td>
</tr>
<tr>
<td>e-counselling</td>
<td>Internet-based counselling</td>
</tr>
<tr>
<td>Effect Size</td>
<td>ES</td>
</tr>
<tr>
<td>Ehealth</td>
<td>Electronic health</td>
</tr>
<tr>
<td>g</td>
<td>gram</td>
</tr>
<tr>
<td>ICC</td>
<td>Intra-class correlation coefficient</td>
</tr>
<tr>
<td>Kg</td>
<td>Kilogram</td>
</tr>
<tr>
<td>Km/h</td>
<td>Kilometer per hour</td>
</tr>
<tr>
<td>LOA</td>
<td>limits of agreement</td>
</tr>
<tr>
<td>m</td>
<td>meters</td>
</tr>
<tr>
<td>mg</td>
<td>milligram</td>
</tr>
<tr>
<td>Min</td>
<td>Minute</td>
</tr>
<tr>
<td>ml</td>
<td>Milliliter</td>
</tr>
<tr>
<td>mmHg</td>
<td>Millimeter mercury</td>
</tr>
<tr>
<td>mmol</td>
<td>Millimole</td>
</tr>
<tr>
<td>PA</td>
<td>Physical activity</td>
</tr>
<tr>
<td>PP</td>
<td>Pulse pressure</td>
</tr>
<tr>
<td>RR</td>
<td>Risk ratio</td>
</tr>
<tr>
<td>SBP</td>
<td>Systolic blood pressure</td>
</tr>
<tr>
<td>SCT</td>
<td>Social Cognitive Theory</td>
</tr>
<tr>
<td>SD</td>
<td>Standardized Deviation</td>
</tr>
<tr>
<td>SE</td>
<td>Standard Error</td>
</tr>
<tr>
<td>SMD</td>
<td>Standardized mean difference</td>
</tr>
<tr>
<td>TPB</td>
<td>Theory of Planned Behaviour</td>
</tr>
<tr>
<td>TTM</td>
<td>Trans-theoretical model</td>
</tr>
<tr>
<td>VO&lt;sub&gt;2max&lt;/sub&gt;</td>
<td>Maximum ventilator oxygen consumption</td>
</tr>
</tbody>
</table>
Chapter 1. Introduction and Background

1.1 Introduction

Hypertension is the leading risk factor for cardiovascular disease and contributes to 7.6 million premature deaths every year (WHO, 2013). It is estimated that about one in five Canadian adults have hypertension (Wilkins et al., 2010). Lifestyle counselling is recommended as a first line therapy for reducing BP (BP) and risk for cardiovascular events. Meta-analytic reviews have demonstrated that lifestyle counselling of exercise (Cornelissen & Smart, 2013) and diet (Appel et al., 2006) can reduce systolic BP up to 3-9 mmHg relative to controls. However, a major challenge for a community-based preventive strategy is to extend the reach of therapeutic lifestyle counselling to individuals with hypertension who may have limited access to these services. With the advancement in Internet technology and improved access to the Internet, there is emerging evidence that Internet-based lifestyle interventions may be well-suited to meet this challenge (Bennett & Glasgow, 2009).

Recent studies suggest that Internet-based lifestyle interventions may be effective in evoking therapeutic change in BP (B. B. Green et al., 2008; Nolan et al., 2012) and improvements in lifestyle behaviours (Kim & Kang, 2006; Norman et al., 2007). However, BP response and adherence to exercise and diet behaviour vary significantly after e-based interventions due to differences in the core design of the programs (Neubeck et al., 2009; Wantland, Portillo, Holzemer, Slaughter, & McGhee, 2004). Currently, consensus is not yet established for a best practice guideline for Internet-based hypertension management program.

The overall aims of this thesis were to identify components of Internet-based intervention that enhance the effectiveness of a self-guided Internet-based hypertension management program, and to evaluate the effectiveness of Expert vs. User-driven approaches in Internet-based hypertension management programs. Following a detailed literature review of our current understanding of Internet-based lifestyle interventions, three studies were conducted.
The first study is a meta-analysis that assessed the efficacy of Internet-based interventions in reducing BP. The study identified key components of an Internet-based intervention that are associated with BP control.

The second study validated a tri-axial pedometer (Lifesource XL-18), which was a critical instrument in monitoring and recording daily steps used in the third study. The Lifesource XL-18 is a piezoelectric pedometer that can record steps for up to 14 days. This function makes the XL-18 pedometer an ideal tool for tracking activity level for longer periods of time. However, the psychometric properties of the Lifesource XL-18 pedometer have not been independently established. Thus, the primary purpose of this study was to examine the criterion and construct validity and test-retest reliability of the Lifesource XL-18 pedometer during controlled and free-living conditions in individuals with hypertension. The secondary objective was to study the influence of body mass index (BMI), waist size and walking speed on the validity of the Lifesource XL-18 pedometer.

The third study addressed a key gap in the Internet-based interventions literature. Based on our literature review and meta-analyses, two main clinical methods of Internet-based counselling (e-counselling) are “Expert driven” and “User-driven” programs. “Expert-driven” e-counselling programs assign goals for lifestyle change and recommend techniques for behaviour change to the participant. In contrast, “User-driven” e-counselling programs are more collaborative in prompting participants to set their own goals for lifestyle change while selecting their preferred techniques for behaviour change. It is a research priority to identify the most effective style of e-counselling for BP control. Finding out the strengths and limitations of Expert and User-driven programs can help us to create the most effective e-counselling strategy to sustain recommended lifestyle changes.
1.2 Classification and Prevalence of Hypertension

Resting BP is organized into various categories in order to help identify those individuals at risk from high BP and to facilitate therapeutic treatments. The optimal resting BP recommended by the Canadian Hypertension Education Program (Dasgupta et al., 2014) and the United States Joint National Committee for Detection, Evaluation and Treatment of High BP (Chobanian et al., 2003) is a systolic BP of less than 120 mmHg and a diastolic BP of less than 80 mmHg. Hypertension is diagnosed when high systolic (≥140 mmHg) or diastolic BP (≥90 mmHg) are recorded at two or more visits to the medical doctor (Table 1.1). Hypertension is further separated into stages. Stage 1 and 2 (80-85%) is the most common form of hypertension (Dasgupta et al., 2014).

Table 1.1: Classification of BP for adults age 18 years or older

<table>
<thead>
<tr>
<th>Category</th>
<th>Systolic BP (mmHg)</th>
<th>Diastolic BP (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal</td>
<td>&lt;120</td>
<td>&lt;80</td>
</tr>
<tr>
<td>Normal</td>
<td>120-129</td>
<td>80-84</td>
</tr>
<tr>
<td>High Normal</td>
<td>130-139</td>
<td>85-59</td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 1</td>
<td>140-159</td>
<td>90-99</td>
</tr>
<tr>
<td>Stage 2</td>
<td>160-179</td>
<td>100-109</td>
</tr>
<tr>
<td>Stage 3</td>
<td>180-209</td>
<td>110-119</td>
</tr>
<tr>
<td>Stage 4</td>
<td>≥210</td>
<td>≥120</td>
</tr>
</tbody>
</table>

The prevalence of hypertension has increased steadily from 12.5% in 1998/99 to 19.6% in 2007/08 (Robitaille et al., 2012). Currently, there are 6 million (21.8%) Canadian adults (>18 years of age) diagnosed with hypertension. The prevalence of hypertension diagnoses significantly increases with age. The proportion of the Canadian population that has been diagnosed with hypertension between the age of 18-39, 40-59 and 60-70 are 3.3%, 21.8% and 52.4%, respectively (Robitaille et al., 2012). Males and females showed similar prevalence rates.
up to 60 years old. Afterwards, the prevalence is significantly higher in females compared with males.

Hypertension is also a major health concern globally. The World Health Organization rates hypertension as one of the leading causes of premature death worldwide (WHO, 2013). In the developed world, about 330 million people have hypertension, as do around 640 million in the developing world. It is estimated there will be 1.56 billion adults living with hypertension by 2025 (WorldHeartFederation, 2013). Therefore, it is imperative to develop innovative population-based BP control strategies.

### 1.3 Risk of Hypertension

Epidemiological studies have repeatedly identified independent risk relation between hypertension and various disorders such as stroke, heart failure, coronary artery disease and renal disease (Kannel, 2000). Hypertension is a risk factor for all clinical manifestations of atherosclerosis (Chaturvedi, 2004). This section will describe the major organ complications associated with hypertension which involve the heart (Drazner, 2011), brain (Rigaud, Seux, Staessen, Birkenhager, & Forette, 2000) and kidneys (Sarnak et al., 2003).

**The Heart**

Hypertension can result in structural and functional changes in the heart leading to left ventricular hypertrophy. As a response to pressure overload, left ventricular mass can undergo concentric (increase in wall thickness) and eccentric (increase in chamber size) hypertrophy and leading to chronic heart failure (Drazner, 2011). Increased left ventricular mass was associated with death from all causes: relative risk, 1.49 [95% confidence interval (CI), 1.14 to 1.94] in men and 2.01 [95%CI, 1.44 to 2.81] in women (Levy, Garrison, Savage, Kannel, & Castelli, 1990). Furthermore, hypertension can contribute to atherosclerotic coronary artery disease, which can result in abnormalities of blood flow and may lead to myocardial infarction. Recent clinical trials have reported that control of systolic BP (target of <130mmHg versus <140 mmHg) can regress left ventricular hypertrophy and reduce the risk of cardiovascular disease (Verdecchia et al., 2009). These research studies demonstrated the importance of BP control.
The Brain

Hypertension is the leading risk factor for stroke and increases the risk for cognitive impairment and dementia (Johansson, 1999). Stroke is a generic term to describe a clinical syndrome that includes focal ischemia, brain hemorrhage and subarachnoid hemorrhage. The increased intraluminal pressure from hypertension can lead to alteration in endothelium and smooth muscle function in the intracerebral arteries. The endothelial damage can lead to local thrombi formation which can result in occlusion of the blood vessel. Degenerative changes in smooth muscle cells and endothelium can increase the chance for intra-cerebral hemorrhages (Rigaud et al., 2000).

Epidemiological studies have shown that patients with hypertension have a 3-fold greater risk of stroke than individuals with normal BP (Johansson, 1999). In the Framingham study, 56% of stroke incidence in men and 66% in women were attributed directly to hypertension (Levy et al., 1990). Reduction of BP by 5-6 mmHg are likely to induce a 4-45% decrease in stroke risk in middle-aged and older individuals (Johansson, 1999).

The Kidney

Hypertension is the second leading cause of chronic kidney failure in North America (CDC, 2010). High BP can damage blood vessels in the kidney, which can affect glomerular filtration rate. The decreased rate of removing waste and extra fluids from the body can then elevate BP, creating a dangerous positive feedback cycle. Reduced glomerular filtration rate (30 ml/min per 1.73 m²) is associated with an increased cardiovascular disease risk of 22% (Sarnak et al., 2003). BP control is critical in preventing chronic kidney disease and cardiovascular disease.

1.4 Lifestyle Counselling and Blood Pressure Control

The Canadian Hypertension Education Program recommends a combination of lifestyle behaviour change and pharmacotherapy to manage hypertension (Dasgupta et al., 2014). Lifestyle behaviour management aimed at BP control includes regular physical exercise, a healthy and balanced diet, restricted sodium intake and limited alcohol consumption. The magnitude of BP change as a result of adopting these lifestyle behaviours is listed in Table 1.2.
Table 1.2 The influence of lifestyle behaviour on changes in resting BP

<table>
<thead>
<tr>
<th>Lifestyle</th>
<th>Objective</th>
<th>SBP/DBP Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Exercise Training</td>
<td>30-60 min of exercise</td>
<td>-4.9/3.7 mmHg</td>
</tr>
<tr>
<td></td>
<td>Moderate intensity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4-7 days per week</td>
<td></td>
</tr>
<tr>
<td>Dietary</td>
<td>DASH-like diet</td>
<td>-5.5/3.0 mmHg</td>
</tr>
<tr>
<td>Sodium Intake</td>
<td>2000 mg (5g of salt or 87 mmol of sodium) per day</td>
<td>-5.4/2.8 mmHg</td>
</tr>
<tr>
<td>Alcohol Consumption</td>
<td>≤2 drinks per day; consumption should not exceed 14 standard drinks per week for men and 9 standard drinks per week for women</td>
<td>-3.3/2.0 mm Hg</td>
</tr>
</tbody>
</table>

Physical Exercise Training

The benefits of aerobic exercise in chronic BP control have been reported in numerous studies. Several longitudinal studies have reported that increased physical activity level is positively correlated with lower BP (Cornelissen & Smart, 2013; Lacombe, Goodman, Spragg, Liu, & Thomas, 2011; Liu, Goodman, Nolan, Lacombe, & Thomas, 2012). A meta-analysis of 54 trials showed that regular aerobic exercise could decrease systolic BP by 3.8 mm Hg (95% CI, 2.7 to 5.0 mm Hg) and diastolic BP by 2.6 mm Hg (95%CI, 1.8 to 3.4 mm Hg). However, in patients with hypertension, a greater magnitude of systolic (4.94 mmHg (95%CI, 7.17 to 2.70mmHg) and diastolic BP (3.73 mmHg (95%CI, 5.69 to 1.77mmHg) is observed with regular aerobic exercise (150 minutes of moderate intensity aerobic exercise per week)(Whelton, Chin, Xin, & He, 2002).
Several studies have examined the optimal dosage of aerobic exercise in reducing BP. Studies have shown that the magnitude of BP reduction was greater in the group who exercised 61 to 120 min/week (~SBP/DBP: -12/-7 mmHg) than in the group who exercised 30 to 60 min/week (~SBP/DBP: -6.5/-6 mmHg) at moderate intensity (50-70% of maximum ventilator oxygen consumption) (Jennings et al., 1991; Whelton et al., 2002; Ishikawa-Takata, Ohta, & Tanaka, 2003). Moderate intensity translates into walking at a pace of 15-20 minute per mile (1.6km) or walking at a speed of 100 steps per minute. The Canadian Hypertension Education Program’s stand on exercise and hypertension recommends dynamic aerobic endurance training for 30 minutes daily, 4 to 7 days per week (Dasgupta et al., 2014). The American College of Sports Medicine has also recommended similar guidelines of aerobic exercise for BP management(Hagberg, 2011). Dynamic aerobic endurance exercise is defined as involving large muscle groups in dynamic repetitive activities that result in elevated heart rate and increased energy expenditure. These activities include brisk walking, jogging, cycling or swimming.

Resistance training is associated with health benefits such as improved muscle strength, weight management and increased muscle to fat ratio. Studies have shown that resistance training does not have adverse effects on resting BP for individuals with hypertension (Collier et al., 2009; Dasgupta et al., 2014). Meta-analyses have shown that the average magnitude of BP reduction (SBP: -1.7 mmHg [-5.5, 2], DBP: 1.1mmHg [-3.1/0.91]) is relatively small in patients with hypertension using this type of training (Cornelissen et al. 2011). The dynamic resistance training protocols consisted of training at an intensity of 30-100% of 1 repetition max, 3-6 sets, 6-30 reps and 1-14 exercises. The frequency of training ranged between 2-3 times per week, 6-52 weeks in length (medium, 16 weeks) (Cornelissen et al. 2011). More studies are needed to determine the optimal dynamic resistance training intensity, frequency and duration for patients with hypertension (Cornelissen et al. 2011). The current Canadian Hypertension Education Program has recommended it as a supplement to aerobic training for non-hypertensive or stage 1 hypertensive individuals(Dasgupta et al., 2014).

Based on previous literature, the majority of the BP reduction associated with exercise training would take place during the first 10 weeks of training (Whelton et al., 2002). Reduction in resting BP can occur as early as 1 week after aerobic training with no further significant reduction occurring during week 3 to 4 (Meredith et al., 1991). The current training length selected for this study is 16 weeks to allow for chronic adaptation of BP.
Dietary Recommendations

Diet is an important component in hypertension management. The Canadian Hypertension Education Program guidelines recommend that hypertension patients consume a diet that emphasizes fruits, vegetables, low-fat dairy products, dietary fiber, whole grains, protein from plants sources, and low saturated fat and cholesterol, such as the DASH (dietary approach to stop hypertension) diet (Dasgupta et al., 2014). The DASH diet is similar to Canada’s Food Guide, except that the DASH diet recommends 8-10 servings instead of 7-10 servings of fruit and vegetables per day. Participants are also encouraged to choose fish and chicken rather than red meat, and eat food with low saturated fat (Table 1.3)

Table 1.3 Comparison of Canada’s Food guide vs. DASH diet.

<table>
<thead>
<tr>
<th>Food Groups</th>
<th>Canada’s Food guide (Servings per day)</th>
<th>DASH diet (Servings per day)</th>
<th>Example of serving size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grains</td>
<td>6-8</td>
<td>6-8</td>
<td>• 1 slice whole grain bread</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• ½ cup cooked brown rice or whole wheat pasta</td>
</tr>
<tr>
<td>Vegetables/Fruit</td>
<td>7-10</td>
<td>8-10</td>
<td>• ½ cup any raw or cooked vegetable</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• 1 medium fruit</td>
</tr>
<tr>
<td>Low fat dairy products</td>
<td>2-3</td>
<td>2-3</td>
<td>• 1 cup skim or 1% milk</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• 1.5 oz. low fat cheese (19% milk fat or less)</td>
</tr>
<tr>
<td>Lean meat, poultry and fish</td>
<td>2-3</td>
<td>2 or less</td>
<td>• 3 oz. cooked lean meats, skinless poultry, or fish</td>
</tr>
</tbody>
</table>

Several large-scale randomized controlled trials have reported that the DASH diet is effective in reducing resting BP in patients with hypertension (Sacks et al., 2001). One study worth mentioning was the randomized controlled trial by Appel et al., (2006) that compared BP reduction after feeding participants either i) a diet rich in fruits (5 servings/day) and vegetables (3 servings/day) (N=151; 51% female), ii) a "combination" diet rich in fruits, vegetables, and
low-fat dairy products with reduced saturated and total fat (DASH Diet) (N=154; 48% female), or iii) a control diet that resembled customary intake in the United States (N=154; 47% female). All diets consisted of similar amounts of sodium (3000 mg/day), and energy intake was adjusted to maintain the initial body weight for each participant (N=154). The participants (mean age 44 years old; baseline SBP/DBP of 132/85mmHg) were placed in the dietary intervention for 8 weeks. Results showed that the DASH diet was the most effective in reducing SBP/DBP (-5.5/-3.0 mmHg), relative to Control. The Fruit and vegetable diet reduced BP by about half the amount of the DASH diet (-2.8/-1.1mmHg), relative to control. Out of those participants with hypertension (n=133), the DASH diet reduced SBP/DBP by11.4/5.5mmHg relative to control. The authors of the study attributed the increased magnitude of SBP reduction seen in the DASH diet compared with the fruit and vegetable alone diet to the low-fat dairy products, fish, and lower levels of red meat, sugar and refined carbohydrates (Figure 1.1). The nutrient differences in the DASH diet that likely led to the greater reduction in resting BP included complex carbohydrates higher in fibre, increased protein and calcium, and lower sugar, saturated and total fat. Consequently, in the clinical trial conducted in Chapter 4, participants were given dietary recommendations based on these studies which were also consistent with the guidelines proposed by the Canadian Hypertension Education Program (Dasgupta et al., 2014).

**Figure 1.1 Potential contributors to BP reduction as result of DASH diet**

- Fruit
- Vegetables
- Dairy products
- Fish
- Less meat
- Less saturated Fat
- Fewer Snacks & Sweets
Sodium Intake

The Canadian Hypertension Education Program guidelines recommend that Hypertension patients reduce sodium intake to 2000 mg (5g of salt or 87 mmol of sodium) or less per day (Dasgupta et al., 2014). Studies of clinical trials and epidemiological studies have reported that lower dietary sodium intake is associated with reduced BP (Midgley, Matthew, Greenwood, & Logan, 1996; Sacks et al., 2001). A recent meta-analysis with 34 trials (N=3230; Mean age: 50 years old; mean baseline SBP/DBP: 141/86 mmHg) demonstrated that a 100 mmol reduction in 24 hour urinary sodium (6 g/day salt) was associated with a fall in systolic BP of −5.39 mm Hg (−6.62 to −4.15) and diastolic BP of −2.82 mm Hg (−3.54 to −2.11) in patients with hypertension after adjusting for age, ethnic group and baseline BP (He, Li, & Macgregor, 2013). Recent evidence also suggests that there is a non-uniform association between sodium consumption (measured by 24-h sodium excretion) and resting blood pressure (Mental et al., 2014). In this large epidemiology study (N=102,216, 18 countries), the authors reported that participants with a higher sodium excretion of more than 5g per day had a steeper slope of association between sodium excretion and resting blood pressure (increment of 2.58mmHg in SBP per gram for sodium) than individuals with sodium excretion of 3 to 5 g per day (increment of 1.74mmHg in SBP per gram for sodium) (Mental et al., 2014).

Individual differences in salt sensitivity may also influence the relationship between sodium intake and BP reduction. Salt sensitivity was arbitrarily classified as a decrease in mean arterial pressure greater or equal to 10 mmHg and salt resistance was defined as a reduction less than or equal to 5 mmHg relative to baseline (Sullivan, 1991). Salt-sensitivity can increase with age. It is estimated that in individuals with hypertension that are 30 years or younger, 50% were salt-sensitive and 50% were not; whereas in the 50 years old category, 85% of the individuals were salt-sensitive and 15% were not (Weinberger & Fineberg, 1991).

A multi-centered, randomized controlled trial demonstrated that the addition of low levels of sodium (50 mmol per day) to the DASH diet could result in an additional 1.7mmHg of SBP reduction (Control: N=204, female= 54%, mean Age(SD)= 49(10) years; Baseline SBP(SD)/DBP(SD)= 135(10)/86(4) mmHg; DASH: N=208;female= 59%, mean Age(SD)= 49(10) years; Baseline SBP(SD)/DBP(SD)= 134(10)/86(5)mmHg) (Sacks et al., 2001). Overall, as compared with the control diet of a high sodium level (≥ 150mmol per day or 3.4g/day), a 4
weeks DASH diet with a low sodium level (50mmol/day or 1.1g/day) led to a mean systolic BP that was 7.1 mmHg lower in participants without hypertension, and 11.5 mm Hg lower in participants with hypertension (Sacks et al., 2001). Therefore, lifestyle interventions aimed at BP reduction should consider recommending both DASH and a low sodium diet.

**Alcohol Consumption**

Heavy alcohol consumption (≥4 drinks per day) is associated with an increase in BP (Briasoulis, Agarwal, & Messerli, 2012). One standard drink is equivalent to 13.6g or 17.2 ml of ethanol, such as a standard bottle of beer (341ml with 5% alcohol), a shot (43ml, 40% alcohol) of hard liquor (e.g. vodka, rum, whisky, gin), or a glass of wine (142ml, 12% alcohol).

Observational epidemiologic studies have reported that individuals who drank 300 to 499 mL alcohol/week (2.8 to 4.8 drinks/day) had a 2.7 mmHg higher level of systolic BP and 1.6 mmHg higher level of diastolic BP than did non-drinkers after adjustment for age, body mass index, smoking, and urinary excretion of sodium and potassium (Marmot et al., 1994). Several clinical trials have shown a dose-response relationship between the magnitude of BP reduction and decrease in alcohol consumption (Abramson, Lewis, & Murrah, 2010; Hansel et al., 2010). In a meta-analysis examining the effects of alcohol reduction on BP, Xin and colleagues (Xin et al., 2001) report that alcohol reduction (67% from Baseline) was associated with significant reductions in mean systolic and diastolic BPs of −3.31 mm Hg (95%CI, −2.52 to −4.10 mmHg) and −2.04 mm Hg (95%CI −1.49 to −2.58 mm Hg), respectively. The mean baseline alcohol consumption in this study population was 3 to 6 drinks per day. This study included 15 randomized controlled trials with a total sample size of 2234 participants. Subgroup analyses identified that the magnitude of BP reduction was similar between interventions that lasted 6-8 weeks (SBP: -3.92, 95% CI -5.05 to -2.79 mmHg/ DBP: -2.10, 95%CI -2.96 to 1.24mmHg) vs. 12 weeks or longer (SBP: -3.24, 95%CI, -4.64 to -1.84, mmHg/ DBP: -2.22, 95%CI -2.91 to -1.54 mmHg).

However, there is some evidence from epidemiological studies to indicate that individuals with a low to moderate (≤2 drinks per day) alcohol consumption may have reduced risk for coronary heart disease, stroke, and all-cause mortality compared with non-drinkers (Sacco et al., 1999;
Shaper, Wannamethee, & Walker, 1988). More research in this area is needed to understand the “threshold” for alcohol consumption and BP reduction. Currently, these findings support the alcohol consumption recommendation by Canadian Hypertension Education Program. Adults should limit alcohol consumption to $\leq 2$ drinks per day and consumption should not exceed 14 standard drinks per week for men and 9 standard drinks per week for women (Dasgupta et al., 2014).

Section Summary

Lifestyle interventions can have a profound anti-hypertensive effect on individuals diagnosed with hypertension. However, a major challenge is to extend the reach of these lifestyle interventions to individuals with hypertension. The rapid growth of Internet use presents an amazing opportunity for preventive health initiatives. The following sections will explore the role that the “Internet” can play in delivering these lifestyle interventions and identify gaps in the literature for Internet-based interventions.
1.5 What is an Internet-based health Intervention?

Internet-based health interventions (also referred to as “web-based interventions”, “eHealth Interventions” or “e-Counselling interventions”) are “treatments, typically behaviour-based, that are operationalized and transformed for delivery via the Internet” (Ritterband, Andersson, Christensen, Carlbring, & Cuijpers, 2006). Internet-intervention programs are usually structured, self-guided or partly self-guided and are generally constructed based on effective face-to-face interventions. Internet-based interventions contain various health-related content, multimedia choices (e.g. text, videos, audio), interactive online tools (e.g. activity or BP trackers) and supportive feedback options. Internet-based interventions can be accessed using Internet browsers or emails on desktop, laptop, smartphones and tablets.

The use of Internet to deliver health-related interventions has gained popularity since the emergence of the Internet in the mid-1990s. The field of Internet-based health interventions is a relatively young field but is growing at a rapid pace. In 2002, only a dozen randomized controlled trials were published (Ritterband et al., 2006). In September 2014, there were 1714 published randomized controlled trials indexed in PubMed with the search term containing “randomized controlled trial” and “Internet”.


i) An Internet-based education intervention is designed to allow the user to access information about a particular health problem area (e.g. diagnosis of a condition, potential symptoms, or treatment options). Examples of these types of websites include WebMD or Wikipedia. The aim of these sites is to improve the knowledge, awareness and understanding of a particular health-related problem of the user. The delivery of the information does not form a highly structured treatment program.

ii) Self-guided Internet-based therapeutic interventions are designed to create positive cognitive, behavioural and emotional changes. The contents delivered to the users are presented in a modularized and structured format. The content is usually constructed based on behavioural change techniques or theories and modeled after effective face-to-face behaviour counselling

iii) Human supported Internet-based therapeutic interventions are similar to self-guided interventions, which are designed to create positive cognitive, behavioural and emotional changes. Human-supported Internet-based therapeutic interventions incorporate a human profession (e.g. health professional or peer-support). The amount of human support can vary depending on intervention design. The form of support may come in the form of personalized messages (e.g. text message, emails) or one-on-one or group meetings.

The three sub-types of Internet-interventions mentioned above are not mutually exclusive, but can be integrated into a single intervention. For example, a self-guided Internet-based intervention can also incorporate human support components. In this thesis, the primary focus is on evaluating and finding ways to improve the effectiveness of a self-guided Internet-based intervention.

1.6 Benefits of Self-guided Internet-based Health Interventions

The rapid growth of Internet use presents an incredible opportunity for preventive health initiatives. Currently, approximately 83% of Canadians had personal access to the Internet. This includes 63-78% of Canadians who are in the lowest income quartiles, and 84% of Canadians between 45 to 64 years, which is an age group with increased risk for cardiovascular disease (Canadian Institute of Health Research., 2013). Moreover, 72% of Americans and 67% of Canadians reported health information-seeking behaviours over the Internet (Pew Research Center, 2012), which suggests that there may be significant public interest in Internet-based lifestyle programs that promote self-care for heart health.

The potential benefits of Internet-based hypertension management programs include extending the scope of traditional programs, improving efficiency, empowering patients, promoting health equality and delivering tailored health interventions. These potential benefits are described in detail below.
1) Extending the scope of traditional hypertension programs:

Patient education about hypertension management is typically offered during their visit to primary health care, hospitals or community care services. However, geographic barriers and program availability can challenge the accessibility of these in-person programs. Studies have shown that individuals living in rural communities have higher risk of cardiovascular disease and more difficulties accessing preventive health care services than individuals living in urban centers (Canadian Institute for Health Information, 2006). In Canada, a significant proportion of the total population (~20%) currently lives in rural and remote areas. Even for individuals living in urban centers, the ability for health care providers to deliver a comprehensive hypertension lifestyle program may be restricted by health care resources such as the amount of time allocated for a typical office visit. Furthermore, many of the lifestyle counselling services (e.g. exercise training) aimed at BP reduction are not covered under the provincial health care plan in Canada. Thus, these factors may act as barriers for individuals diagnosed with hypertension to access hypertension management programs. Internet-based health interventions can help overcome these barriers by enabling patients to access relevant health information and support anywhere with Internet access. An example of this is the eHealth program offered by the Heart and Stroke Foundation aimed at weight and BP management. (https://etools.heartandstroke.ca/HeartStroke/BPAP.Net/Tracker.aspx).

Overall, there is potential for Internet-based interventions to extend existing hypertension management programs beyond their conventional boundaries (e.g. primary health care, hospitals or community care services) (Bennett & Glasgow, 2009).

2) Improving cost-efficiency:

Internet-based interventions have the potential to increase efficiency in health care, thereby decreasing costs (Eysenbach, 2001). One possible way to reduce costs is to substitute some in-person lifestyle counselling sessions with Internet-based interventions (Finkelstein, 2000). In a recent systematic review and meta-analysis Elbert et al., (2014) reported that eHealth interventions aimed at improving health-related effects (e.g. morbidity, mortality, quality of life, hospitalization) were cost effective in patients with heart failure, type 2 diabetes and hypertension. Similarly, Schulz et al., (2014) reported that tailored Internet-based interventions were more likely to be cost-effective in improving lifestyles as a primary outcome than that of a
control group that is non-tailored. Future research in this area is warranted; specifically, the long-term cost-benefit analyses of Internet-based interventions are needed.

3) Empowering patients:

Patient empowerment refers to the ability of patients to actively understand and influence their own health status (Bruegel, 1998). The goal of empowering patients is to promote autonomous self-regulation or management of one’s health. Internet-based interventions could empower patients in several ways. First, Internet-based programs enable patients to easily track and access their health information (e.g. physical activity level). Self-monitoring skills are important to provide the patient feedback and build intrinsic motivation to promote long-term adherence (Bennett et al., 2012; Tudor-Locke, Bassett, et al., 2004). Second, Internet-based interventions can also enhance communication between patients and health care providers. For example, in the study by Park et al., (2008) patients were able to share their BP and physical activity level with their health care provider and receive immediate feedback. This enhanced communication allowed the health care providers to capture those “teachable” moments.

In a systematic review and meta-analysis, Samooha, Bruinvels, Elbers, Anema, & van der Beek, (2010) reported that web-based interventions have a significant positive effect on empowerment measured among patients who are suffering from chronic disease such as diabetes, depression or arthritis. The authors found that Internet-based interventions were equally as effective as face-to-face deliveries in promoting patient empowerment. Overall, these results are encouraging for the continued use and development of Internet-based programs to help empower patients.

4) Promoting health equality:

Socioeconomic status is a significant predictor for health and longevity (Marmot, 2005). There are certain health conditions (e.g. cardiovascular disease) that disproportionately affect individuals that are socioeconomically disadvantaged. However, preventive treatment guidelines for these health conditions have been well established. A challenge faced by our health care system is to deliver these preventive health interventions to individuals in need.

A potential method of disseminating these interventions is through using the Internet (Bennett, 2012). Although there is currently a gap in Internet usage between income levels (high vs. low), age groups (young vs. old), and geographic location (rural vs. urban), nevertheless, these gaps
have shrunk over the past decade. In some cases, such as access to the Internet using mobile phones, the divides have been reversed (Bennett, 2012). A report published in the United States indicated that Blacks and Hispanics are significantly more likely than whites to own mobile phones (87%, 87%, and 80%, respectively) and to use them for Internet access (46%, 51%, and 33%, respectively) (Bennett, 2012; Smith, 2010).

Several recent clinical trials have demonstrated that Internet-based interventions can be effectively used to deliver health interventions to underserved communities. Herring, Cruice, Bennett, Davey, & Foster, (2014) reported that an Internet-based weight loss intervention delivered using mobile phones resulted in a significantly greater weight loss than usual care after 14 weeks of treatment in urban, low-income mothers. Similarly, Bennett et al., (2012) demonstrated that an Internet-based intervention with interactive voice response produced weight loss and improved BP control among socioeconomically disadvantaged, racial/ethnic minority community health center patients.

Additionally, other researchers have addressed health literacy barriers using Internet-based interventions. One such Internet communication technology is using an embodied conversational agent, which is an interactive, animated computer character that simulates face-to-face counselling using simple speech, hand gestures, facial cues and other nonverbal behaviour to maximize message comprehension (King, Bickmore, Campero, Pruitt, & Yin, 2013). King et al., (2013) have shown that embodied conversation agents delivering culturally and linguistically adapted physical activity advice led to a meaningful 4-month increase in daily physical activity relative to controls among underserved older adults.

Overall, current evidence suggests that Internet Interventions have the potential to make health care more equitable. However, collaboration of a multi-disciplinary team (researchers, health professionals, and public policy makers) is required to leverage Internet communication technology to close the health disparity gap.
5) Delivering tailored health interventions:

Tailored health information allows the patient to receive health information based on their characteristics and interest. Tailored communication is based on the Elaboration Likelihood Model proposed by Petty et al., (1986). The model states people are more likely to actively and thoughtfully process health information if they perceive it to be personally relevant. Therefore, when presenting a person with tailored information, the person will perceive the information with greater attention, comprehension, and will more likely discuss the content with others.

The degree of tailoring is depicted in Figure 1.2. In contrast to generic health communications, tailored material addresses factors known to be important to an individual recipient. For example, regular exercise can be beneficial for reducing BP and improving overall functional capacity. However, patients with hypertension may have various levels of motivation for physical activity. Therefore, a patient with lower motivation may find detailed information on “how to exercise” less relevant than content on helping the person build readiness or motivation for exercise. An individualized assessment can often help to determine the type of health material the individuals will receive. The tailoring approach to deliver a health intervention has been widely used in face-to-face health behaviour counselling (Kreuter, Strecher, & Glassman, 1999).

Several clinical trials and meta-analyses have shown that tailored health interventions were more effective than generic interventions (Lustria, Cortese, Noar, & Glueckauf, 2009; Noar, Benac, & Harris, 2007). Traditionally, a trade-off for tailored vs. generic health intervention is that tailoring is more complex and requires more human resources in order to extend the reach of the program. However, the use of self-guided Internet-based interventions can overcome this challenge by using “smart” algorithms in the design of the Internet-based program (Kreuter et al., 1999). For example, after the patient completes an initial patient assessment using a questionnaire about current physical activity level and motivation to perform physical activity, the self-guided intervention will be able to provide a program that is tailored to the person’s needs. Consequently, Internet-based interventions have the potential to deliver tailored health interventions at a population level without over-taxing health care resources.
**Figure 1.2. Degree of Tailoring.** The figure classifies the four approaches of health communication and the degree of tailoring. Generic communication is defined as health materials that are not individualized or based on any kind of individual assessment (e.g. hypertension management brochure). Personalized generic communication is similar to generic communication except that it uses characteristics, such as one’s name. Targeted communication refers to health message developed with a certain segment of population in mind (e.g. middle aged to older adults with hypertension). Tailored communication is designed for each person based on some sort of individualized assessment (e.g. Middle-aged to older adults with hypertension designed for individuals with high motivation for exercise). Adapted from Kreuter et al., (1999).
1.7 Measuring Behaviour Change in Internet-based Intervention

Lifestyle behaviour change such as physical activity and diet (e.g. changes in daily fruit and vegetable intake) are important to hypertension management. Therefore, measuring these lifestyle changes in an Internet-based intervention is important to both researchers for evaluation purposes as well as to research participants to self-monitor their progress. Studies have shown that self-monitoring of behaviour changes (e.g. daily steps) can be important to help motivate individuals to improve adherence (Bennett et al., 2012; Tudor-Locke, Bassett, et al., 2004). As a result, it is important to enable participants the ability to perform self-monitoring of behaviour change in a self-guided Internet-based lifestyle intervention aimed at hypertension management.

The measurement of dietary behaviours (e.g. daily servings of fruit and vegetables) has relied on participants’ reports. This method includes food diaries and food frequency questionnaires which are relatively easy to administer and low-cost (Jonson, A, 2002). Thus, in the third study, the NIH/NCI Diet History Questionnaire (DHQ) will be used to measure changes in daily servings of fruit and vegetables. The validity of DHQ has been previously established (Subar, Thompson, Kipnis, et al., 2006) and has been successfully adapted into a Canadian version (Csizmadi, Kahle, Ullman, et al., 2007) and used in a Canadian study (Bedford, Barr, 2009).

Meanwhile, there are several objective methods of measuring physical activity but each method has strengths and weaknesses related to their intended use, participant burden, cost and validity. The “gold-standard” of measuring physical activity and energy expenditure is the double-labeled water method, which can be expensive, has high burden to the participants and cannot provide “real-time” self-monitoring feedback to the participants. Alternatively, an accelerometer can measure physical activity without the high burden to participants, but each unit cost between $100-300 (Bravata et al., 2007; Melanson et al., 2004).

Pedometers are lightweight, small instruments, and lower priced ($10-30); which makes it an attractive and practical tool for individuals working in fitness, clinical, health, and research fields (De Cocker, De Bourdeaudhuij, & Cardon, 2009; De Cocker et al., 2012; Hasson, Haller, Pober, Staudenmayer, & Freedson, 2009; Schneider, Crouter, & Bassett, 2004). An advantage of pedometers is that they provide real-time feedback (e.g. steps taken per minute) to the participant during an aerobic exercise session. This feedback can be helpful for the participant to understand
whether they have reached an optimal level of exercise intensity. Several studies have shown that pedometers are accurate and valid in measuring daily steps, and can motivate individuals to set daily activity goals (Bravata et al., 2007; Melanson et al., 2004).

However, traditional spring-gauged pedometers can have decreased accuracy at slower walking speeds (<4.8 km/h), and when used by individuals with high body mass index (BMI ≥30) (Melanson et al., 2004). Recent advances in pedometer technology through the use of tri-axial accelerometer sensors (piezoelectric technology) can overcome these challenges (Crouter et al., 2005; De Cocker et al., 2012).

The Lifesource XL-18 is a piezoelectric pedometer that can record steps for up to 14 days. This function makes the XL-18 pedometer an ideal tool for tracking activity level for longer periods of time. The Lifesource XL-18 can be an extremely useful tool for self-guided Internet-based interventions. However, the psychometric properties of the Lifesource XL-18 pedometer have not been independently established. Therefore, Chapter 4 will examine the criterion and construct validity and test-retest reliability of the Lifesource XL-18 pedometer during controlled and free-living conditions.
1.8 Effectiveness of Internet-based Health Interventions

In the past decade, there have been a number of research studies demonstrating the feasibility and the efficacy of Internet-based programs in a range of health-related problems which include: anxiety (e.g. social anxiety disorder) (Botella, Hofmann, Moscovitch, 2004), depression (Clarke et al., 2005), body image (Celio, Winzelberg, Dev, Taylor, 2002), insomnia (Celio et al., 2002), back pain (Buhrman, Faltenhag, Strom, Andersson, 2004) and diabetes management (Barrera, Glasgow, McKay, Boles, Feil, 2002).

For the purpose of this thesis, the literature review will focus on the efficacy of Internet interventions to promote healthy behaviour change (e.g. physical activity, healthy diet) and reduce BP and risk for cardiovascular disease.

1.8.1 Changes in Behavioural Outcomes

One of the earliest meta-analyses comparing behaviour change outcomes of web-based vs. non-web-based interventions was conducted in 2004. Wantland et al., (2004) reported that web-based interventions were more effective than non-web-based programs in increasing exercise time, knowledge of nutritional status, knowledge of asthma treatment, participation in healthcare, slower health decline, improved body shape perception, and 18-month weight loss maintenance. This meta-analysis included 17 studies (N=11,754 participants) published between 1996 and 2003. The duration of studies ranged from 3 weeks to 78 weeks. Due to the broad variability in the focus of the studies, the authors could not calculate the overall effect size.

In a more recent meta-analysis, Davies, Spence, Vandelanotte, Caprence, & Mummery, (2012) reported a significant improvement in physical activity level following Internet-based intervention (effect size, ES, d=0.14). This meta-analysis included 34 trials of Internet-based physical activity interventions delivered to participants from 2 to 52 weeks in length. Similarly, Webb, Joseph, Yardley, & Michie, (2010) examined the effects of Internet-based health interventions on behavioural change for physical activity, diet and alcohol consumption. The authors included clinical trials of Internet-based interventions published between 2000 and 2008. Studies were included if i) the primary components of the intervention were delivered via the Internet, ii) participants were randomly assigned to conditions, and iii) a measure of behaviour
related to health was taken after the intervention. Overall, 85 studies were included in the study with a total sample size of 43,326 participants. On average, Internet interventions had a statistically small but significant effect on health-related behaviour (ES= 0.16, 95% CI 0.09 to 0.23). Webb et al. (2010) also calculated effect size separately for commonly targeted health behaviours. Internet-based interventions had significant effects on behaviour targeting only physical activity (ES= 0.24, 95% CI 0.09 to 0.38), dietary behaviour (ES= 0.20, 95% CI 0.02 to 0.37), or alcohol consumption (ES= 0.14, 95% CI 0.00 to 0.27).

Overall, a consistent message emerged from these meta-analyses to suggest that Internet-based health interventions are effective in promoting healthy lifestyle change including physical activity, dietary behaviour and alcohol consumption. Although these effect sizes are considered “small” according to Cohen’s criteria, it is important to note that the statistical effectiveness (Cohen’s effect size) is not necessarily the same as clinical effectiveness (Thomas, 2010). For example, an Internet-based intervention that produces a small increase in physical activity level can be clinically significant if it has the potential of reaching a very large number of individuals. Therefore, this can have significant impact for population health.

1.8.2 Changes in BP and Risk of Cardiovascular Disease

In addition to the behavioural outcome, several meta-analyses have examined the clinical outcomes associated with Internet interventions. Neubeck et al., (2009) reported in a meta-analysis that tele-health and Internet-based interventions were effective in improving a diverse number of health outcomes which included systolic BP (mean= –4.7 mmHg; 95% CI –6.6, –2.9 mmHg) and total lipoprotein cholesterol (–0.37 mmol/l; 95% CI –0.56, –0.19). The authors of this study included 11 trials (N=3145) published between 1996 and 2008. The average study lasted between 6-48 months for patients with cardiovascular conditions. Similarly, Verberk, Kessels, & Thien, (2011) reported in a systematic review and meta-analysis that e-health interventions (delivered using telephone or Internet) significantly decreased systolic (5.2±1.5 mmHg) and diastolic BP (2.1±0.8 mmHg) compared with controls in patients diagnosed with hypertension. It is worth noting that both of these meta-analyses combined telephone and Internet-based interventions. Currently, the change in BP as the result of an Internet-based intervention in patients with hypertension has not been exclusively examined in a meta-analysis.
Nevertheless, there have been several clinical trials that have examined the effectiveness of Internet interventions in reducing BP. A randomized controlled trial conducted by Bond et al., 2007 reported that a 6-month Internet-based intervention was more effective in reducing systolic (-6.8 ±1.6 mmHg) and diastolic BP (-5.2 ±1.2 mmHg) than usual care in older adults (60 years or older) with diabetes. In this Internet-based intervention, the patients were taught self-management skills about exercise and diet, cues to modify perceptions of self-efficacy and personal beliefs regarding the ability to affect the progress of the disease. Another study by Park, Kim, & Kim, (2009) reported that an 8-week Internet combined with mobile text-based intervention significantly reduced systolic BP and diastolic BP by 9.1 and 7.2 mmHg in obese patients (Body mass index, BMI>30 kg/m²) with hypertension, respectively. In the intervention, patients could upload BP information via their mobile phone and access their BP and health information by using a web portal. The participants were then given tailored feedback and weekly recommendations based on their health information.

A recent randomized trial by our team observed a similar magnitude of BP reduction. Nolan et al., (2012) reported that a 4-month Internet-based hypertension management program vs. a wait-list control group significantly reduced systolic BP (mean, -8.9 mm Hg; 95% CI, -11.5 to -6.4 vs. -5.0 mmHg; 95% CI, -6.7 to -3.3) as well as total cholesterol (-0.24 mmol/L; 95% CI, -0.43 to -0.06 vs. 0.05 mmol/L; 95% CI, -0.06 to 0.16). The Internet-based intervention was designed to proactively deliver 8 e-mails over the 4-month interval according to the following schedule: weekly e-mails in month 1, bi-weekly e-mails in month 2, and monthly e-mails in months 3 and 4. The emails provided key messages to promote participants’ motivation by validating their efforts of working toward their goals for change.

The outcomes from these Internet-based intervention trials aimed to improve BP and lifestyle behaviours are encouraging. However, it is important to note that there have also been several Internet-based studies that reported null findings for changes in BP (Bennett et al., 2010; Verheijden et al., 2004; Yoo et al., 2009). A current challenge in Internet-based interventions is the variability of the intervention outcome due to differences in intervention protocol and design.

Statistical heterogeneity for Internet interventions is a problem well documented in systematic and meta-analytic reviews in this field. There are substantial differences in the content, intervention design or clinical methods among Internet-based interventions (Ritterband et al.,
2006; Ritterband, Thorndike, Cox, Kovatchev, & Gonder-Frederick, 2009). Intervention protocols may differ in duration, target behaviours to be modified (exercise or diet), clinical method, and use of an explicit behavioural theory or repertoire of techniques. In some cases, studies may lack sufficient details of the intervention to allow replication or theory building. Currently, the critical components and design protocol for e-counselling interventions promoting BP management remain unclear.

Summary

Based on the current literature, there is clear support to further develop Internet interventions to help individuals control their BP. However, meta-analytic data examining the efficacy of Internet-based lifestyle interventions in reducing BP in patients with high BP is lacking. Furthermore, in order to improve the effectiveness of Internet-based interventions, it is important to understand the “core” components that are critical to their success. In the next section, the various components of Internet-based interventions are explored.

1.9 Model of Internet Interventions for Behaviour Change

Although there has been a proliferation of research studies evaluating the effectiveness of Internet-based health interventions, the critical components that are linked to intervention efficacy is an area of research that needs further development. By understanding the effects of the various components of Internet-based intervention, it will enable us to better tailor the intervention based on user characteristics as well as set best-practice guidelines for designing Internet-based health interventions.

In order to explore the critical components of Internet-based interventions, the model of behaviour change for Internet interventions proposed by Ritterband et al., (2009) needs to be highlighted. The model aimed to 1) address how behaviours change and symptoms improve (e.g. change in BP) through the use of Internet interventions, and 2) guide program development and facilitate testing of the intervention. Ritterband et al. (2009) used multiple theories, models and techniques from numerous disciplines (e.g. theories of motivation, Web-based design techniques,
models of knowledge transfer and behaviour change, clinical experience) to help conceptualize this model. Similarly, other reviews have also attempted to categorize the various components of Internet-based health interventions (Brouwer et al., 2011; Neve, Morgan, Jones, & Collins, 2010). Therefore, these components of Internet-based interventions have been summarized in Figure 1.3.

The effectiveness of the Internet-based interventions in changing behaviour (e.g. increase in physical activity or fruit and vegetable consumption) and symptoms (e.g. reduction in resting BP or risk for cardiovascular disease) is influenced by usage. Usage is, in turn, influenced by user characteristics, user-friendly design and intervention protocol. An important aspect that needs to be highlighted is that user characteristics, intervention protocol and user-friendly design are not mutually exclusive, but rather are interconnected. For example, a specific intervention protocol (e.g. hypertension management program) with certain usability features (e.g. easy to read, intuitive navigation) may appeal to a certain type of user (e.g. individuals diagnosed with hypertension), and will result likely in increased intervention adherence and improvement in behavioural and clinical outcomes. Therefore, an effective intervention may require a careful consideration of all three areas. The following section will explore the components within user-characteristics, user-friendly design and intervention protocol as well as identify gaps in the literature.
Figure 1.3: Model of Internet-based Intervention for behaviour change. Adapted from Ritterband et al. (2009)
1.9.1 User Characteristics

According to Ritterband et al. (2009), the areas of user characteristics that may be important to consider for Internet-based interventions include:

1) *Demographics of the user.* This includes factors such as age, gender, education, ethnicity and cultural background.

2) *Type of disease* and severity of the disease. For example, there are often no physical symptoms associated with hypertension and people can develop cardiovascular complications without knowing that they have hypertension. Therefore, it is a priority to educate regarding the importance of hypertension management.

3) *Beliefs, attitudes and motivation* refer to the person’s treatment expectations, readiness for change (stage of change), perceived benefits and barriers to treatment.

4) *Skills* related to both psychological (e.g. cognitive strategies to manage stress) and physical (e.g. knowledge about exercise training) knowledge about carrying out the behaviour change goal.

5) *Personality and cognitive factors,* including cognitive style (verbal vs. visual), information processing, and self-efficacy.

6) *Physiological factors* refer to motor functioning capacity as well as overall functional capacity.

These user characteristics can be helpful for Internet-based interventions in three different ways (Ritterband et al., 2009). First, the user-characteristics can be used to predict intervention outcome. In one of the recent studies in our lab using a large sample (n=142,726), we found that individuals were more likely to engage with an email-based Internet-based heart health program if they were older than 60 years of age (Odds Ratio, OR: 12.56; 95% CI: 5.66-27.8; P<.001), were female (OR: 1.27; 95%CI: 1.09-1.46; P= .002) or had one or more modifiable risk factors (OR: 1.38; 95%CI: 1.31-1.45; P<.001) (Liu, Hodgson, Zbib, Payne, & Nolan, 2014). In another study, the authors found that individuals less interested in physical activity at baseline engaged in more physical activity at 12 months when assigned to a human advisor whereas those with more
initial interest in becoming more active responded better to an automated e-based physical activity intervention (Hekler et al., 2013).

Second, some of the modifiable user-characteristics can be targeted for change in the Internet-intervention along with the identified health issues (e.g. reducing BP). These characteristics may include a person’s attitude, beliefs or self-efficacy (Ritterband et al., 2009). According to the health belief model, the key determinants of whether an individual adopts a healthy behaviour are dependent on the person’s belief about the threat of the disease, perceived benefits and barriers of their actions, perceived barriers and self-efficacy. In addition, the theory of planned behaviour states that a person’s intention to carry out a behaviour is influenced by one’s attitude (e.g. belief about consequences of the particular behaviour), subjective norms (e.g. other peoples’ perceptions of one’s behaviour) and self-efficacy (Glanz, Rimer, & Viswanath, 2008). Therefore, designing an Internet-based program that targets these user-characteristics can be important in promoting health behaviour change.

Third, Internet-based interventions can be tailored based on user characteristics. Tailored health interventions based on patient characteristics have been shown to be more effective than “generic” interventions. As mentioned in section 1.6, there is potential to deliver tailored health interventions to the masses using Internet-based interventions. Tailoring the intervention based on subject characteristics such as motivation is well supported by theoretical behaviour change models such as the Transtheoretical model (TTM) (see section 1.8.13 for detailed description of TTM) (Glanz et al., 2008). The TTM suggests that since an individual’s attitude, readiness, and skill differ at various stages of change, the intervention should be uniquely tailored. Current literature supports providing patients with tailored health interventions. However, a number of questions remain for Internet-based interventions. For instance, is there a user-characteristic (e.g. motivation) towards which it is most important for Internet-based intervention to be tailored? What type of tailored intervention protocol (see section 1.8) will be most effective for individuals with various levels of readiness for behaviour change? Future research is warranted to help answer these important questions.
1.9.2 User-Friendly Design

Usable design describes the ease of use and learnability of the Internet intervention. A well designed Internet intervention enables the user to comprehend the content easily and help the user to complete their tasks successfully and efficiently (Leavitt & Shneiderman, 2015).

Usability is important in order to engage users to continuously use the Internet intervention. Studies have shown that usability ratings are positively associated with usage of an Internet program (Downing & Liu, 2009). A detailed literature review of usability is outside of the scope of this thesis. However, user-friendly design guidelines for web pages (which were relevant to developing the Internet-intervention in Chapter 5) are highlighted below. These best practice guidelines are based on The Research-Based Web Design & Usability Guidelines published by the U.S. Department of Health and Human Services (Leavitt & Shneiderman, 2015).

1) All content information presented to the user should be in an organized and structured fashion so that the user can find the information and navigate through the content easily. There are three main ways that content can be organized for a website: hierarchical, sequential and matrix structures (Figure 1.4). In a hierarchical structure, content are organized into broader categories and then filtered down into narrow topics. This is a common way to organize content in health education settings. In order to avoid confusion for the users in finding specific content, it is ideal to avoid hierarchical structures that are too shallow or too deep (Figure 1.5). Shallow structures can lead to a long list of menu options for the user to choose from. In contrast to shallow structures, deep structures can burden the user to have to navigate through numerous levels to find relevant content.

![Shallow Hierarchical Structure](image)

**Figure 1.5:** Examples of content that is organized in a shallow and deep hierarchical structure. Adopted from Leavitt et al., (2015)
Figure 1.4: Display of various methods to organize content for Internet-based interventions. Adopted from Leavitt et al., (2015)

A: Hierarchical Structure

B: Sequential Structure

C. Matrix Structures
Sequential structures require the user to follow a specific path through content (Figure 1.4 B). This type of structure assumes that there is optimal ordering of the content. However, users may feel restricted in the amount of choices that are available. A matrix structure allows the user to access content in several different ways using web links (Figure 1.4 C). For example, the user could access information about the recommended aerobic exercise guidelines through the navigation bar at the top of the web-page or by hyperlinks listed on a webpage with similar topics such as resistance exercise. A matrix structure can help make the user feel that they can determine their own path since content is linked in various ways. However, the user may be confused and feel a lack of structure if there are too many ways to access the same content. All three types of organizational structures may be used in a complementary manner in order to optimize content organization.

2) Common elements should be used to achieve consistent and easy-to-access user-interface design. This is particularly important in making specific tasks intuitive to the user and so that he/she will remember how to use the system in the future. Common elements of user-interface design include: input controls (e.g. radio buttons, dropdown lists), navigational components (e.g. Breadcrumb, Tags) and informational components (e.g. Progress bars, message boxes). Please see table 1.4 for a detailed description of the common list and how they may be used to enhance user-interface design. The application of these elements should be tailored to users’ characteristics. For example, larger font size or bright contrast to highlight important messages on a page may be particularly salient for older users.

3) The number of ways to interact with the webpages need to be clearly communicated to the user. The goal is to provide the users with possible methods of interaction before actions are taken. This can be accomplished by the use of labeling, picture icons or increased font size. For example, users should be able to clearly understand that one of the ways to enter BP onto the online tracker is by adjusting the value on a slider. The web page should be able to provide appropriate, clear and timely feedback to the user so that they can see the results of their actions. For example, a message box can pop up to alert the users when they are about to update their BP value on an online tracker.
Table 1.4. A list of common elements used in web page design to improve overall usability. The table is adopted from (Leavitt & Shneiderman, 2015). For a full list of elements, please visit http://www.usability.gov/how-to-and-tools/methods/user-interface-elements.html

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Controls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radio buttons</td>
<td>Radio buttons are used to allow users to select one item at a time.</td>
<td><img src="image" alt="Radio buttons example" /></td>
</tr>
<tr>
<td>Dropdown lists</td>
<td>Dropdown lists allow users to select one item at a time, similarly to radio buttons, but are more compact allowing you to save space.</td>
<td><img src="image" alt="Dropdown list example" /></td>
</tr>
<tr>
<td>Navigational Components</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breadcrumb</td>
<td>Breadcrumbs allow users to identify their current location within the system by providing a clickable trail of proceeding pages to navigate by.</td>
<td><img src="image" alt="Breadcrumb example" /></td>
</tr>
<tr>
<td>Tags</td>
<td>Tags allow participant to find content in the same category. Some tagging systems also allow users to apply their own tags to content by entering them into the system.</td>
<td><img src="image" alt="Tags example" /></td>
</tr>
<tr>
<td>Informational Components</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Progress Bars</td>
<td>A progress bar indicates where a user is as they advance through a series of steps in a process. Typically, progress bars are not clickable.</td>
<td><img src="image" alt="Progress bar example" /></td>
</tr>
<tr>
<td>Message Boxes</td>
<td>A message box is a small pop-up window that provides information to users and requires them to take an action before moving forward.</td>
<td><img src="image" alt="Message box example" /></td>
</tr>
</tbody>
</table>
4) The health content presented to the user should be presented in ways that minimize health literacy barriers and enhances readability (NIH, 2014). Text comprehension can be improved by avoiding technical language, putting key messages first, writing in an active voice, and by keeping paragraphs and sentences short. Readability of online text can be enhanced by allowing sufficient white space on the webpage, around clickable buttons or links, and between paragraphs. This creates an overall uncluttered look and a more appealing user interface. The web page should utilize a typeface that is not condensed (e.g. sans serif). The use of pictures and videos can also help enhance content comprehension and engage and support learning for a wider range of individuals (Aging, 2014). The National Health Institute recently published a guideline to help create user-friendly webpages for older adults (Aging, 2014).

Overall, these best-practice guidelines are important in creating a usable website. Research in usable design is becoming one of the fastest growing fields (NIH, 2014). A good, user-friendly design does not always lead to good user experience. User experience is how a person feels both cognitively and physically when they interact with the Internet intervention. In order to create a user-experience that facilitates behaviour change in patients with hypertension, it is important to consider the influence of the other components such as user-characteristics, and intervention protocol. Section 1.9.3 will explore the various attributes of intervention protocol.

### 1.9.3 Intervention protocol

The intervention protocol is a critical component in Internet-based interventions as it guides the user through behaviour change. There are six main attributes including: intervention dosage, method of delivery, behaviour target, supplemental components, behaviour change theories and techniques, and clinical methods (Ritterband et al. 2009; Brouwer et al., 2011; Neve, Morgan, Jones, & Collins, 2010). Detailed descriptions of each attribute are provided below.

#### 1.9.3.1 Intervention dosage

A self-guided Internet intervention can be characterized by the frequency of contacts (e.g. receiving an email once a week), duration of each contact (e.g. 15 minutes to read over the new content) and overall length of the program (e.g. number of weeks) (Brouwer et al., 2011; Wantland et al., 2004). Based on previous Internet-based health interventions, the frequency of
contacts can vary between weekly, bi-weekly or monthly, and the duration of each contact may take as little as 5 minutes to 1 hour or more to complete. The length of existing intervention can typically range from 1 week long to over a year (Brouwer et al., 2011; Webb et al., 2010).

A recent study in our lab showed that the magnitude of BP reduction was proportional to the number of Internet-based lifestyle counselling messages sent to participants. Nolan et al. (2012) reported that in a 4-month Internet-intervention for patients with hypertension, the groups who received 0, 1 to 7, and 8 or more e-counselling emails reduced systolic BP by −5.0 mmHg (95%CI, −6.7 to −3.3), −5.8 mmHg (95%CI, −9.1 to −2.6) and −8.9 mmHg (95%CI, −11.5 to −6.4), respectively. Donkin et al., (2013) reported a significant positive linear relationship between the amount of time that participants spent with an Internet-based mental health program and improvement in their clinical depression score. These studies suggest that the frequency of contacts and duration of each contact may follow a dose-response relationship for Internet-based interventions.

Currently, the influence by intervention duration (short-term vs. long-term) on the effectiveness of Internet-based intervention aimed at BP reduction remains unclear. Based on in-person lifestyle counselling, a minimum of 4-6 weeks is required in order to learn the skills to successfully carry out lifestyle changes, as well as to allow symptom changes (e.g. reducing resting BP) (Glanz et al., 2008). Internet-based interventions may also require similar program length in order to show a positive effect; future research in this area is warranted.

1.9.3.2 Method of delivery

Method of delivery can be classified according to whether the Internet-based intervention proactively or reactively engages participants (Bendtsen, McCambridge, Bendtsen, Karlsson, & Nilsen, 2012; Brouwer et al., 2011; Webb et al., 2010). In proactive Internet-based interventions, the e-platform initiated the contact to provide health information or feedback to subjects. Conversely, reactive Internet-based interventions required participants to request and extract health materials or feedback from the e-platform (Bendtsen et al., 2012). Proactive approaches may be advantageous in reminding the user about their behaviour change plan. However, participants may also find the proactive approach too invasive and thus deter the participants from accessing the Internet program. Reactive approaches may be advantageous to make the user feel that they are progressing at their own pace; however, participants may also simply forget
about the intervention. Internet-based health intervention trials aimed at BP control have used both proactive and reactive approaches, but no study has directly compared the effectiveness of each type of approach. A previous study published in the communication and marketing field showed that proactive approaches may enable the user to feel more supported (Noort & Willemsen, 2012). Future studies are warranted to determine the influence of proactive vs. reactive on the effectiveness of the Internet health intervention aimed at BP reduction.

1.9.3.3 Behaviour target

*Behaviour target* is defined as the specific lifestyle behaviour (e.g. physical activity, daily fruit and vegetable intake) that the participants would focus on during the Internet-based intervention. Some Internet-based interventions may target a single behaviour at a time while others may focus on multiple health behaviour changes (Bennett et al., 2010; Nolan et al., 2012; Park et al., 2009). Single health behaviour change may enable the participant to be more focused on tackling one behaviour change at a time. Single health behaviour change is supported by social cognitive theory (SCT), which emphasizes the importance of breaking complex behaviour into smaller steps in order to promote self-efficacy (Glanz et al., 2008; King, Castro, et al., 2013). In contrast to the single health behaviour change, exposure to changing multiple health behaviours (2 or more) may evoke a greater magnitude of symptom improvement. Furthermore, many chronic diseases share similar lifestyle interventions (e.g. exercise, diet, reduced alcohol consumption). Thus, targeting multiple behaviour changes early on could be advantageous for those facing multiple risk factors (Johns, Hartmann-Boyce, Jebb, & Aveyard, 2014; King, Castro, et al., 2013).

Currently there is limited data regarding whether it is advantageous for interventions to focus on one versus multiple lifestyle behaviours. However, several studies have examined this topic in behavioural interventions delivered face-to-face. A recent systematic review by Johns et al., (2014) examined diet or exercise interventions vs. combined diet and exercise interventions on weight management. The authors included 8 randomized controlled trials that have at least 12 months of follow-up. Results indicate that combined exercise and diet programs were more effective in promoting weight loss in the long-term (12month). Similar weight loss results were observed in the short term (3 to 6 months) for diet or exercise alone versus combined diet and exercise weight loss programs. King, Castro, et al., (2013) also found that simultaneously
delivering a 12-month dietary plus physical activity program was more effective than sequentially delivering a 6-month dietary followed by physical activity (or reversed) program in promoting behaviour adherence. Overall, current evidence suggests that targeting multiple behaviours may be more beneficial; however, future research is needed when applying these findings to Internet interventions.

1.9.3.4 Supplemental components

Supplemental components include the use of emails, telephone support, text message and face-to-face interaction in addition to the self-guided web-based program. Based on the meta-analysis published by Webb et al. (2010), these supplemental components can have positive effects on behaviour change with Internet-based interventions. Internet-based interventions that also used text messages had the largest effects on behaviour (ES = 0.81, 95% CI 0.14 to 1.49), followed by Internet-based interventions using the telephone (ES = 0.35, 95% CI 0.09 to 0.61), and email (ES = 0.18, 95% CI 0.07 to 0.29). The addition of supplemental components (e.g. email, text message and telephone) may help support behaviour change by making the intervention interactive and reminding the individual of the benefits of the behaviour change (Brouwer et al., 2011; Webb et al., 2010). Future studies need to examine the influence of supplemental components on Internet-based intervention aimed at BP control.

1.9.3.5 Behaviour Change Theories and Techniques

Behavioural theories refer to the specific theories used to develop an Internet-based intervention. Behaviour theory can be helpful in informing the design of Internet-based interventions by identifying theoretical constructs to be targeted and understanding the mechanisms underlying behaviour change. For example, Hurling et al. (2007) used the theory of planned behaviour (TPB) to design an Internet-based intervention that delivers emails to help individuals improve their daily physical activity level. The intervention targeted the person’s attitude about and perceived control of physical activity, and social norms surrounding physical activity. Behaviour change techniques refer to the specific strategies used in the intervention to promote behaviour change. For example, in the same study by Hurling et al. (2007), the specific behaviour techniques used to enhance the person’s attitude about the physical activity included providing information on the consequences of the current behaviour. In order to design effective Internet-
based interventions aimed at BP reduction, it is important to understand how these behaviour theories and techniques have been applied in the current literature.

In one of the most comprehensive meta-analyses conducted on this topic, Webb et al., (2010) the use of behaviour theories and techniques on the effectiveness of Internet-based interventions aimed to promote health behaviour change were examined. The meta-analysis included 85 studies between 2000 and 2008. The authors found that Internet-based interventions that used behaviour change theories more extensively (e.g. targeted a larger number of available constructs within the theory) and used more behaviour techniques were significantly associated with increased intervention effect size. The most common theories used in Internet-based intervention aimed at behaviour change were the theory of planned behaviour (TPB), the trans-theoretical model (TTM) and social cognitive theory (SCT). Out of these three theories, the use of the TPB (ES=0.36) to inform intervention design led to a larger effect compared with SCT (ES=0.2) and TTM (ES=0.15). The effect size associated with using these behaviour change techniques is listed in Table 1.5. The critical number or the combination of behaviour techniques required for an effective Internet-based intervention aimed at BP control remains unclear. This is an important future research area for Internet-based interventions.

Behaviour theories can help guide our understanding of the behaviour techniques required in a theory (Glanz et al., 2008). In the meta-analysis by Webb et al. (2010), the most commonly used behaviour change techniques identified (e.g. Prompt self-monitoring of behaviour, barrier identification/problem solving, provide instruction and goal setting) target many of the constructs identified in several behaviour theories (TPB, TTM, SCT).

The following section will provide an overview of these behaviour theories used in Internet-based interventions that aim to promote health behaviour change. Examples of how Internet-based health programs have used these behaviour theories to design their intervention will also be discussed. The following section will also describe the similarities and differences as well as the strengths and limitations associated with these behaviour theories.
Table 1.5: The effectiveness of behaviour change techniques used in Internet-based health interventions. This table is adopted from the meta-analysis published by Webb et al. (2010)

<table>
<thead>
<tr>
<th>Behaviour Change Technique</th>
<th>k</th>
<th>Effect Size</th>
<th>95%CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress management</td>
<td>5</td>
<td>0.50</td>
<td>0.27 to 0.72</td>
</tr>
<tr>
<td>General communication skills training</td>
<td>3</td>
<td>0.49</td>
<td>0.25 to 0.73</td>
</tr>
<tr>
<td>Model/demonstrate the behaviour</td>
<td>5</td>
<td>0.35</td>
<td>-0.01 to 0.70</td>
</tr>
<tr>
<td>Relapse prevention/coping planning</td>
<td>14</td>
<td>0.32</td>
<td>0.17 to 0.47</td>
</tr>
<tr>
<td>Facilitate social comparison</td>
<td>4</td>
<td>0.29</td>
<td>0.04 to 0.55</td>
</tr>
<tr>
<td>Goal setting (behaviour)</td>
<td>25</td>
<td>0.27</td>
<td>0.16 to 0.38</td>
</tr>
<tr>
<td>Action planning</td>
<td>18</td>
<td>0.25</td>
<td>0.13 to 0.37</td>
</tr>
<tr>
<td>Provide feedback on performance</td>
<td>19</td>
<td>0.22</td>
<td>0.09 to 0.34</td>
</tr>
<tr>
<td>Barrier identification/problem solving</td>
<td>26</td>
<td>0.20</td>
<td>0.10 to 0.30</td>
</tr>
<tr>
<td>Provide instruction</td>
<td>25</td>
<td>0.20</td>
<td>0.13 to 0.28</td>
</tr>
<tr>
<td>Provide normative information about others’ behaviour</td>
<td>16</td>
<td>0.18</td>
<td>0.07 to 0.28</td>
</tr>
<tr>
<td>Plan social support/social change</td>
<td>15</td>
<td>0.18</td>
<td>0.10 to 0.27</td>
</tr>
<tr>
<td>Provide rewards for behaviour</td>
<td>7</td>
<td>0.18</td>
<td>0.09 to 0.28</td>
</tr>
<tr>
<td>Prompt self-monitoring of behaviour</td>
<td>28</td>
<td>0.16</td>
<td>0.07 to 0.24</td>
</tr>
<tr>
<td>Provide information on the consequences for individual</td>
<td>12</td>
<td>0.14</td>
<td>0.04 to 0.24</td>
</tr>
</tbody>
</table>

k = the number of interventions included in the estimate of effect size; 95%CI= 95% confidence interval

Theory of reasoned action/planned behaviour (TPB)

TPB was developed from the theory of reasoned action by Icek Ajzen (Glanz et al., 2008). TPB suggests that a person’s behaviour is determined by his/her intention to perform the behaviour (Figure 1.6). Interventions that use this theory can attempt to enhance behaviour intention (motivations) by targeting a person’s attitude toward the behaviour (e.g. knowledge of the outcome of the behaviour), subjective norm (e.g. whether a person’s social circle approve or
disapprove the behaviour) and perceived behavioural control (e.g. self-efficacy, the belief that the person is able to carry out the behaviour change) (Glanz et al., 2008).

**Figure 1.6 Theory of planned behaviour**

Several Internet-based interventions have successfully used TPB to guide the intervention design. For example, Bersamin, Paschall, Fearnow-Kenney, & Wyrick, (2007) reported that a self-guided Internet-based alcohol education program was able to reduce the frequency of heavy drinking, drunkenness, and negative alcohol-related consequences in college students. The Internet-based intervention targeted participants’ attitudes through interactive assignments, video clips and personalized feedback on harm related to alcohol use (e.g. physiological effects of alcohol). The Internet-intervention targeted social norms by using online discussion forums. Finally, perceived behaviour control was enhanced by having the students generate harm prevention plans and providing personalized feedback on their progress. In another study, Hurling et al. (2007) reported that an Internet-based program designed using TBP significantly increased the level of physical activity in healthy adults. Similar to the Internet-intervention created by Bersamin et al., (2007) the program was designed to enhance the participants’
attitudes towards regular physical activity. This was done by proactively engaging participants to complete online education modules that aimed to increase their awareness and knowledge about the positive health outcomes associated with the behaviours. Subjective norms were improved by having the individuals interact with an online message board. Participants’ perceived control of behaviours was enhanced by having them identify and overcome barriers to physical activity (Hurling et al., 2007).

Despite the success of this theory, there are several limitations related to this theory. The TPB does not account for variables such as fear, threat, mood, or past experience as contributing factors to behavioural intention and motivation. Furthermore, behaviour intention does not always lead to behaviour change, as there are other variables that may be at play such as environmental or economic factors. The long-term maintenance of the behaviour is not fully addressed (Glanz et al., 2008).

**The transtheoretical model (TTM)**

The TTM was developed by Prochaska and DiClemente in an attempt to integrate various theories of behaviour change (e.g. TPB, self-efficacy) into a framework that can be easily applied (Glanz et al., 2008). The TTM model differs from other behaviour theories as it is a stage-based model. The TTM attempts to initiate behaviour change by tailoring the intervention according to the person’s motivation or stage of readiness to act on the new behaviour. The stage of readiness consists of the following: pre-contemplation (benefits of lifestyle change are not being considered in the next 6 month); contemplation (starting to consider change but not yet ready to act on this intention in the next 6 month); preparation (ready to change the behaviour and preparing to act in the next 4 weeks); action (carrying out the behaviour change up to past 6 months); and maintenance (maintaining behaviour change for more than 6 months) (Glanz et al., 2008).
**Figure 1.7.** The Trans-Theoretical Model and Process of Change. Adopted from (Glanz et al., 2008).

<table>
<thead>
<tr>
<th>Pre-Contemplation</th>
<th>Contemplation</th>
<th>Preparation</th>
<th>Action</th>
<th>Maintenance</th>
</tr>
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</table>

Consciousness Raising
- Environmental Reevaluation
- Dramatic Relief
- Social Liberation

Self-Reevaluation

Self-Liberation
- Helping Relationships
- Counter Condition

Reinforcement Management
- Stimulus Control

Increase in Self-efficacy
Depending on the participant’s stage of readiness, specific processes of change can be used to progress through the stages (Figure 1.7). The process of change (e.g. Consciousness Raising, Environmental Reevaluation, Dramatic Relief and Self-Reevaluation) in the pre-action stages (e.g. precontemplation, contemplation, preparation) helps individuals build their motivation for change and increasing the “pros” while decreasing the “cons” for changing their behaviour (Glanz et al., 2008). For example, in an Internet-based intervention aimed at BP reduction, consciousness raising involved increasing awareness about the danger of hypertension through videos or articles. Dramatic relief was involved in showing the participants videos of others who have made healthy changes so that they may feel inspired. Participants were encouraged to self-re-evaluate through online worksheets to reflect on the pros and cons of changing their behaviour. Self-reevaluation is an important aspect in enabling individuals to realize that the behaviour change is a critical part of one’s identity (Nolan et al., 2013).

The process of changes in the action stages (e.g. action, maintenance) help individuals carry out their behaviour change plan (Glanz et al., 2008) (Figure 1.7). For example, in the same Internet-based intervention mentioned above, participants were taught how to make a firm plan using self-liberation. Counter conditioning taught the participants to use healthy alternative behaviours instead of risk behaviours. Helping relationships involved using social support to make and sustain changes. Finally, stimulus control taught the participants to remove cues for unhealthy habits. Promoting self-efficacy is an important aspect to the TTM (Nolan et al., 2013). As individuals move through the stages, the feeling of self-efficacy is also enhanced (Glanz et al., 2008). Overall, TTM is intuitive and helps to match the appropriate process of change to the participant’s stage of change.

Although TTM has been used in many health behaviour change programs with various populations from different countries, the model has limitations that need to be considered. TTM focuses on the influence of personal motivation on behaviour change. However, there is evidence to suggest that other external social factors – such as age, gender, socioeconomic positions and environmental factors – influence behaviour change. Furthermore, the time individuals need to spend at each stage before progressing to the next stage remains unclear (West, 2005).
Social Cognitive Theory

SCT is a model that emphasizes elements in the interpersonal environment that affect individuals’ health behaviours. In contrast, the TTM and TPB focus on variables within individuals that influence their health behaviour. Social cognitive theory emphasizes that learning a new behaviour (e.g. eating 8-10 servings of fruit and vegetables per day) occurs in a social context with reciprocal interaction between a person’s cognition, behaviour and environment (Bandura, 2004). The key concepts of the social cognitive theory used in health promotion and chronic disease prevention can be grouped into 5 categories that can be used to promote behaviour change in an Internet-based intervention. These include: Outcome expectation, self-efficacy, observational learning, environmental determinants of behaviour and self-regulation (Bandura, 2004; Glanz et al., 2008).

Outcome expectation is defined as a person’s beliefs about the likelihood of various outcomes that might result from the behaviour that a person might choose to perform. A key outcome expectation in the SCT allows the individuals to realize how they will feel if they do or do not perform a certain behaviour. Self-efficacy is the person’s belief about their capacity to carry out a specific behaviour. Observational learning is defined as learning to perform new behaviour through peer modeling or entertainment education. As mentioned earlier, one of the core concepts of SCT is that no amount of observational learning may lead to behaviour change unless the environment is able to support the new behaviour. One of the environmental determinants of behaviour is through incentive motivation, which consists of the use and misuse of rewards and punishment to modify behaviour. The other approach to influence behaviour through environmental change is facilitation, which is the provision of new structures or resources that enable behaviour or make them easier to perform (Glanz et al., 2008).

Self-regulation consists of controlling oneself through self-monitoring, goal setting, feedback, reward, self-instruction and enlistment of social support. The self-regulation strategies overlap with approaches to change behaviour by increasing self-efficacy (Bandura, 2004). Strength of the SCT is that it takes into consideration a person’s social and environmental influences. One of the criticisms of SCT is that the extent to which the person, behaviour and environment influence each other is unclear. This may result in difficulties determining the areas of focus when creating a behavioural intervention. Furthermore, SCT does not attempt to tailor the intervention to
personal motivation or readiness to carry out a behaviour, such as in the TTM (Glanz et al., 2008).

Overall, the TPB, TTM and SCT each have their own strengths and limitations. There are many overlapping constructs shared among these models but there are also unique aspects to each model (Bandura, 2004). Table 1.6 summarizes the similarities and differences between these models.

Table 1.6 Summary of the main determinants and their areas of overlap in the three most popular conceptual models of health behaviour. Adopted from (Bandura, 2004)

<table>
<thead>
<tr>
<th>Main Determinants</th>
<th>TTM</th>
<th>TPB</th>
<th>SCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome expectation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Outcome expectations</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Social outcome expectation</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Self-evaluation</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Goal Setting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short term</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Long term</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Impediments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Environmental &amp; health care system</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Consideration of Readiness for Change</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
All three theories initiate behaviour change by altering outcome expectations either for physical outcome (e.g. increasing physical activity can decrease BP), social outcome (e.g. others will also view the importance of physical activity) and self-evaluation (e.g. how the individual will feel if they become more physically active). Goal setting is a common attribute to all theories; however, TPB focuses more on changing behaviour intention, which is short-term goal setting.

Impediments, which act as barriers to healthy behaviour change, can be divided into either personal or environmental. For example, personal impediments for regular exercise might be lack of time or energy level. Environmental impediments are rooted in social and economic structure. For example, environmental impediments for a healthy diet can be limited access to fresh fruit and vegetables at the local store. Promoting self-efficacy is one of the constructs that all of these model share. As the individual adopts the behaviour, the feeling of self-efficacy increases (Bandura, 2004). According to Bandura, self-efficacy can be developed through mastery of experience (e.g. performance based feedback, enabling the person to succeed in attainable but increasingly challenging performances of desired behaviour), social modeling (e.g. demonstrating to the person that others like themselves can do it), improving physical and emotional state (e.g. ensuring individuals develop positive emotions with the behaviour) and verbal persuasion (e.g. encouragement) (Bandura, 2004). Finally, the TTM is the only model described that tailors the behavioural intervention based on motivation or readiness for behaviour change.

As a result of these overlapping and unique constructs of behaviour change theory, some Internet-based behavioural interventions may use multiple behaviour theories to guide the intervention design (Cintron, Phillips, & Hamel, 2006; Etter, 2005; Spittaels, De Bourdeaudhuij, & Vandelanotte, 2007). A common challenge in the field of Internet and health research is to determine the extent to which a behaviour theory is used. For example, simply mentioning that the SCT and TTM are used to develop an Internet-based intervention may not be enough to replicate the intervention, as there are various constructs in these theories that can be incorporated as part of the intervention. Therefore, identifying the behaviour techniques used in an Internet-intervention can also be extremely useful. This is consistent with the recommendation by the Consolidated Standard of Reporting Trials (CONSORT) for eHealth trials (Eysenbach, 2011).
In the meta-analysis by Webb et al. (2010) mentioned earlier, the most common and effective behaviour theories and techniques in Internet-based interventions aimed at behaviour change were identified. The behaviour theories included TPB, TTM and SCT. The behaviour change techniques included stress management, general communication skills training, modeling, relapse prevention planning, facilitating social comparison, goal setting, action planning, and provision of feedback on performance. It is not clear how many of the studies in the meta-analysis included only patients with hypertension. Therefore, future studies need to examine the behaviour theories and techniques associated with effective Internet-based intervention aimed at hypertension management.

1.9.3.6 Clinical Methods (User- and Expert-driven Approach)

Clinical methods are the styles or counselling approaches used to deliver a health behaviour intervention. It is important to note that a clinical method is different from a behaviour theory or technique. A behaviour theory, such as the TPB, is intended to provide a comprehensive conceptual model of how and why behaviour change occurs (e.g. attitude, social norm, and self-efficacy). Similarly, a behaviour technique (e.g. goal setting) is intended to provide a specific strategy for behaviour change. Meanwhile, it is the clinical method that applies the behaviour theory or technique and puts it into a context in which it can be used effectively to evoke therapeutic change. The clinical method used can influence the way a person feels both cognitively and physically, and affects the efficacy of the intervention (Miller & Rollnick, 2009).

Many Internet-based health interventions are modeled after selected features of successful in-person behaviour interventions. Consequently, the clinical methods used in these Internet-based interventions also share similarities with the clinical methods used in face-to-face counselling. Thus, this section will provide an overview of the main clinical methods used in face-to-face counselling (e.g. MI and CBT) and the adaption of these clinical methods in Internet-based health interventions (e.g. User and Expert-driven approach).

The most extensively researched and widely used styles of clinical methods in face-to-face counselling include motivational interviewing (MI) and cognitive behaviour theory (CBT) (Enright, 1997; Miller & Rollnick, 2009). The counselling approaches of these clinical methods are very different. MI enables the opportunity for the patient to explore and choose their
behaviour change plan. Meanwhile, therapists delivering CBT assume the expert knowledge in educating and guiding the patient (Miller & Rollnick, 2009).

MI evolved from Miller’s experience with treatment of problem drinkers and CBT was first used to treat depression. However, both MI and CBT have been applied to treat other diseases. Specifically, MI has since been used to help patients adhere to diet, exercise programs and reducing risk for CVD (Britt, Hudson, & Blampied, 2004; Knight, McGowan, Dickens, & Bundy, 2006). CBT has been used to treat stress and anxiety that may influence cardiovascular events. A systematic review of meta-analysis conducted by VanBuskirk & Wetherell, (2014) reported that MI delivered in-person was significantly more effective than no-treatment or placebo controls in quitting smoking, reducing alcohol consumption and adherence to regular exercise and diet. Similarly, Butler, Chapman, Forman, & Beck, (2006) conducted a review of 16 meta-analyses and found that CBT was more effective than control in treating stress, depression, anxiety and anger.

**Motivational Interviewing (MI)**

MI was developed by Miller and Rollnick during 1970s and it is used to facilitate behaviour change by helping participants to explore and resolve their ambivalence about the behaviour change (Miller & Rollnick, 2009). MI involves a collaborative, non-confrontational and autonomous rather than authoritative approach to counsel a patient. The therapist creates an atmosphere that promotes behaviour change by the following five general principles (Britt et al., 2004; Miller & Rollnick, 2009). First, the therapist expresses empathy towards the patient to demonstrate nonjudgmental understanding of the patient’s point of view. Second, the therapist helps the patient to develop discrepancy by exploring the gaps between the patient’s current behaviour and future goals. Third, the therapist should avoid argumentation or direct persuasion to prevent the patient from feeling a sense of defensiveness or resistance. Fourth, rolling with resistance involves the patient exploring his/her view without breakdown in communication between the patient and the therapist. The final principle is for the therapist to support patients’ self-efficacy. These five general principles make up the “spirit of MI” (Miller & Rollnick, 2009).

Practicing MI with a patient is guided by these five general principles, but there is no set “gold standard” structured treatment manual or formulaic practice for MI; it is the patient who determines the path of the intervention. In fact, a meta-analysis by Hettema and colleagues
Hettema, Steele, & Miller, 2005 found that studies in which there was no specific manual to guide MI resulted in a doubled effect size compared to studies with structured MI therapy manuals. This finding is opposite to the usual assumption about other counselling therapy (e.g. CBT) that the use of a structured treatment manual is essential in assuring the quality of the intervention. A reason that highly structured MI is less effective is because every individual may require a different amount of time in order to be ready to set a behaviour change plan. A highly structured MI manual may suggest to begin a change plan by the end of first session. However, a skilled MI counselor that sees a client not ready for change would not continue to press for a behaviour change plan (Miller & Rollnick, 2009). Therefore, by adhering to a particular sequence of techniques, rather than allowing the patients to decide when they are ready, alters the fundamental principles or spirit of MI (Miller & Rollnick, 2009).

Cognitive Behaviour Theory (CBT)

CBT was pioneered by Beck in the 1960s and it is based on the idea that our cognition, emotion and behaviour interact together (Hobbis & Sutton, 2005). CBT involves the therapist working with the patient to teach them emotional and behavioural coping strategies to achieve their behaviour change goals (Enright, 1997). It is important to note that MI does not take the approach of an expert who assumes that “I have what you need” but rather a User-driven and facilitative style that says, “you have what you need, and together we’ll find it” (Miller & Rollnick, 2009).

In a typical CBT treatment program, each session has an agenda with a specific theme and learning objective (Enright, 1997). A CBT program used in a randomized control trial that aimed to prevent cardiovascular disease through stress management incorporated the following 5 key components: patient education, self-monitoring, skills training, cognitive restructuring, spiritual development (Gulliksson et al., 2011).

The goal of patient education is to develop specific knowledge about manifestation and treatment procedures of CVD. Specifically, the participants will be taught about signs of stress reaction, the relationship between stress and CVD, the importance of health behaviours and lifestyle changes using slide presentations and written, multimedia materials. Self-monitoring may take the form of a diary being filled out by the participants, with the goal of increasing awareness of body signals (e.g. muscular tension, heart rate) and cognitive and behavioural triggers. Skills
training involve teaching the participant to reduce negative affect and learn to act constructively (rather than merely react) to daily challenges faced by the patient. This may include helping the patient develop specific problem solving and communication skills to deal with stressors. The goal of teaching cognitive restructuring is to help the patient to recognize negative, hostile and stress-triggering cognitions and attitudes and instead develop positive self-talk to reduce stress reactivity. Spiritual development involves the patient reflecting on the life value in order to see the change process in the broader context of a future meaningful life.

CBT treatment programs are mostly structured (Enright, 1997; Miller & Rollnick, 2009). In this example mentioned above, the authors started the session with progressive muscular relaxation, followed by reviewing and reflection homework assignments from the previous session. Afterwards, the current learning objectives of the session were introduced. The new learning objectives usually build on previous sessions. The session ends with new homework such as self-monitoring or additional readings. Within the structure of the program, the specific contents can be tailored to participants. In this example, the authors introduced different skills training based on gender. For the women, skills training were more focused on self-confidence and self-assertion, while in contrast, men focused more on developing skills to cope with aggressive and hostile behaviour. Despite the tailoring, the overall CBT program allows the patients to follow a set protocol guided by experts (Welschen et al., 2007).

Using MI and CBT with Behaviour Change theories

MI has been used to deliver health promotion interventions designed using behaviour theories such as the TTM. The stages of change in the TTM help to tailor the intervention according to the person’s current level of readiness. MI is particularly important in early stages of change. Pre-contemplators or contemplators do not want to be lectured to or given “action” techniques when they are not ready to change (Miller & Rollnick, 2009). MI enables the patient to resolve their ambivalence and to build their motivation to progress towards the action stages. CBT can also be applied to the TTM, but specifically to later stages of change (action, maintenance) to help the participant learn cognitive behaviour skills such as counter conditioning or stimulus control to overcome beliefs or skill deficits to many otherwise or act as barriers to behaviour change.
Welschen et al., 2007) have also used CBT and MI to deliver interventions designed by TPB that aimed at lifestyle modification for type 2 diabetes management. Based on TPB, the person’s attitude, social influence and self-efficacy influence behaviour intention (Glanz et al., 2008). The intervention used MI to help the patient increase their motivation and resolve ambivalence for behaviour change. CBT provided the patient with a structured program that taught behavioural and cognitive skills needed to successfully carry out behaviour change. Overall, these clinical methods are important in applying behaviour theories to promote behaviour change.

Clinical Methods used in Internet Intervention

The clinical methods used in Internet-based health interventions demonstrate similarities with components of MI and CBT. However, it remains a challenge currently to fully replicate the in-person counselling experience in an automated, self-guided Internet-based program. Internet-based interventions that attempted to replicate the face-to-face clinical methods could only capture certain components of these clinical methods. As a result, the term “User- and Expert-driven”, are used here to describe the clinical method for Internet-intervention.

The User-driven Internet-based program attempts to capture components of MI by prompting the user to set their own goals for lifestyle change while selecting their preferred techniques for behaviour change. The Expert-driven approach attempts to capture components of CBT where the users are taught technical skills to carry out behaviour change as directed by the “expert”. The Expert-driven program assigns goals and recommends techniques for behaviour change to the participant.

The clinical method used in any behavioural intervention is important as these methods can influence the way a person feels both cognitively and physically (e.g. User-experience) and can influence the efficacy of the intervention. Currently, the effectiveness of User- vs. Expert-driven procedures in Internet-based programs aimed at reducing BP is unclear.

Based on the research conducted in face-to-face counselling, an Expert-driven approach can be advantageous in situations when individuals are motivated and are ready for lifestyle change. However, this type of approach may place the individual in a passive role in self-care and may not necessarily be effective if the individual lacks motivation. In contrast, a User-driven
approach enables the participant to actively focus on intrinsic motivation for change and engage in their self-care.

As mentioned earlier, it is not uncommon during a face-to-face clinical counselling session for a therapist to use a combination of clinical methods (e.g. MI and CBT) to help patients change their health behaviour. For example, in a clinical trial using lifestyle modification to manage type 2 diabetes, MI was used to help individuals resolve their ambivalence and become motivated to initiate behaviour change (Welschen et al., 2007). Meanwhile, CBT was offered to help participants gain specific knowledge and technical skills to achieve their behaviour change goals (Welschen et al., 2007). An effective Internet-based intervention may also require a combination of User and Expert-driven protocols. However, before combining User- and Expert-driven approaches for Internet intervention, it is essential to establish the strengths and limitations of each clinical method for Internet-based interventions aimed at hypertension management. Understanding the effectiveness of User and Expert-driven approaches in hypertension management can also help guide design for future Internet-based interventions in other areas of health.
1.10 Chapter Summary

Hypertension is the leading cause of cardiovascular disease in adults. Lifestyle interventions can be an effective way to manage hypertension. As the incidence rates are expected to increase, there is a need to develop strategies to prevent and manage hypertension. The use of Internet technology can be an effective way to extend the reach of traditional in-person hypertension lifestyle management programs without over taxing health care resources.

Current literature supports the further development of Internet-based health interventions. However, the first main gaps that emerged from the literature review were that meta-analytic data examining the efficacy of Internet-based lifestyle interventions to reduce BP in patients with hypertension remains unclear. Second, the optimal design strategies of an Internet-based intervention that aims to promote BP reduction and adherence to health lifestyle remains unclear. Based on the Model of Internet-based Interventions, the intervention protocol components that could influence the effectiveness of an intervention may include: Intervention Dosage, Method of Delivery, Supplemental components, Behaviour Target, Behaviour Theories and Techniques, and Clinical Method (User vs. Expert-driven approach). A specific area that has not been explored in Internet-based intervention is the effects of User vs. Expert-driven programs in reducing BP while modifying lifestyle behaviour.

Furthermore, self-monitoring of aerobic physical activity is important in self-guided internet-based interventions to help participants improve adherence to physical activity and resting BP. Piezoelectric pedometers (Life Source XL-18) are compact, lightweight, lower priced and can track daily steps up to 14 days. These qualities make XL-18 an attractive and practical tool to be used in an Internet-based lifestyle intervention in patients with hypertension. However, the criterion and construct validity and test-retest reliability of XL-18 pedometer during controlled and free-living conditions has not been independently established.

Therefore, the following chapters will attempt to address these questions in the literature by i) determining the efficacy of internet-based interventions aimed at BP reduction in a meta-analysis (Chapter 3), ii) evaluating the psychometric properties of the Lifesource XL-18 pedometer (Chapter 4) and iii) examining the effectiveness of User- vs. Expert-driven Internet based
lifestyle intervention aimed at hypertension management. The detailed objectives and hypothesis of these three studies are highlighted in Chapter 2.
Chapter 2. Aims/ Hypotheses

2.1 Study Objectives

Chapter 3 Objectives

1) To conduct a meta-analysis to determine the effectiveness of Internet-based lifestyle interventions in reducing BP

   i) The primary objective of this review was to examine the efficacy of Internet-based interventions in reducing systolic BP (SBP) and diastolic BP (DBP).

   ii) The secondary objective was to identify intervention protocol components that may have contributed to BP reduction. The components include: Intervention duration, Method of Delivery (Proactive vs. reactive), Supplemental Components, Behaviour Targets, Behaviour theories and Techniques, and Clinical Method (Expert-, User-driven or combined).

Chapter 4 Objectives

2) To validate an activity monitor that would be used in a randomized controlled trial examining the effectiveness of User- vs. Expert-driven Internet-based lifestyle intervention on hypertension control (study #3)

   i) The primary purpose of this study was to examine the criterion and construct validity and test-retest reliability of the Lifesource XL-18 pedometer during controlled and free-living conditions.

   ii) The secondary objective was to study the influence of BMI, waist size and walking speed on the validity of the Lifesource XL-18 pedometer.
Chapter 5 Objectives

3) To examine the influence of clinical methods (Expert vs. User-driven) on the effectiveness of Internet-based lifestyle interventions in reducing BP

i) The primary objective was to assess whether systolic BP (SBP) improved with Expert-driven or User-driven e-counselling over usual care in patients with hypertension over a 4-month period. Secondary outcomes included diastolic BP (DBP), pulse pressure (PP), proportion of individuals with BP control (SBP<130mmHg, DBP<85mmHg), total cholesterol, 10 year Framingham cardiovascular risk, daily physical activity as measured by 4-day step count, and diet as measured by validated food frequency questionnaire.

ii) To conduct exploratory analyses to evaluate the relationship between readiness for behaviour change at baseline and the effectiveness of Expert and User-driven groups.

2.2 Hypotheses

Chapter 3 Hypotheses:

i) Internet-based intervention will be more effective in reducing SBP and DBP than Controls.

ii) We hypothesized that there are several features of Internet-based intervention that will enhance intervention effectiveness in reducing blood pressure, which includes: longer intervention duration (6 months or longer), design based on behavioural theory, the use of multiple behaviour change techniques, the use of supplemental components (e.g. text message, in-person visits), the incorporation of Expert and User-driven clinical methods, the adoption of a proactive method of delivery, and design to targeted both exercise and dietary behaviour change.
Chapter 4 Hypotheses

i) Lifesource XL-18 will show acceptable levels of criterion and construct validity and test-retest reliability during both controlled and free-living conditions.

ii) XL-18 pedometer’s validity will not influenced by BMI and waist size. However, slower walking speed will decrease the accuracy of XL-18 pedometer.

Chapter 5 Hypotheses

i) Both User and Expert-driven approaches will be more effective than controls in improving primary and secondary outcomes.

ii) User-driven Internet interventions will be more effective for individuals with lower levels of baseline readiness for lifestyle behaviour change. Expert-driven Internet interventions will be more effective for individuals with higher levels of baseline readiness for lifestyle behaviour change.
Chapter 3. Reducing blood pressure using Internet-based interventions: a meta-analysis

Abstract

Background: Elevated blood pressure is a leading risk factor for cardiovascular disease and mortality. Internet-based interventions (e-counselling) have the potential to deliver a wide range of preventive counselling services. The purpose of this review was to 1) assess the efficacy of e-counselling in reducing blood pressure and 2) identify key components of successful trials in order to highlight factors that may contribute significantly to blood pressure control.

Method: MEDLINE, Pubmed, Embase, PsycInfo and Cochrane Library were searched up to June 2012 using the following keywords: web-based, Internet-based, e-counselling, mobile health, blood pressure and hypertension. Blood pressure was reported as a primary or secondary outcome. Subjects in each trial needed to have baseline systolic and diastolic blood pressure within the pre-hypertensive (120-139/80-89 mmHg) or hypertensive range (≥140/90 mmHg).

Results: The search strategy identified 13 trials and the mean reduction of systolic and diastolic blood pressure was -3.9 mmHg (95% confidence interval [CI], -5.64 to -1.93 mmHg, P<0.01) and -2.01 mmHg (95% CI, -2.64 to -0.02 mmHg, p<0.05) respectively. Greater magnitude of blood pressure reduction was found in those interventions that were either 6 months or longer, used more than five behaviour techniques, or delivered health messages proactively.
Conclusion: Research on preventive e-counselling for blood pressure reduction is at an early stage of development. This review provides preliminary evidence of blood pressure reduction using Internet-based interventions. Future studies need to compare the contribution of specific intervention components in order to establish a best practice e-counselling protocol that is efficacious in reducing blood pressure.

3.1 Introduction

Hypertension is a leading risk factor for cardiovascular disease as well as a precursor for many other debilitating chronic health problems such as renal diseases and dementia. It is estimated that hypertension contributes to 7.6 million premature deaths globally every year (Lawes, Vander Hoorn, & Rodgers, 2008). Lifestyle counselling is recommended as a first line therapy for the treatment of hypertension and to lower the risk for cardiovascular events (Rabi et al., 2011). Systematic reviews have reported that lifestyle interventions including exercise training and diet modification can reduce systolic blood pressure by 3.0-8.7 mmHg relative to Controls (Dickinson et al., 2006; Whelton et al., 2002). However, a major challenge for community-based preventive programs is to extend the reach of preventive programs to individuals with hypertension.

The rapid growth of Internet use presents an incredible opportunity for preventive health initiatives. Internet-based health interventions can now be delivered through the Internet using web pages and emails that can be accessed by multiple devices such as a desktop computer, laptop, tablet or Smartphone. Approximately 80% of adults in Canada have personal access to the Internet (Canada., 2013), which includes 70-76% of Canadians in the 2 lowest income quartiles, 71% of older Canadians (aged 55 to 64 years) and 71% of individuals living in rural areas. Moreover, growth in the technical sophistication of the web has been remarkable over the past decade and this has supported the development of e-based interventions that are increasingly self-guided, interactive, and tailored to individual priorities for behaviour change. Meta-analyses and systematic reviews of Internet-based interventions have reported therapeutic benefit in improving daily physical activity, reducing symptoms of anxiety, and increasing quality of life for diverse patient groups (Griffiths, Lindenmeyer, Powell, Lowe, & Thorogood, 2006; Kuhl,
Sears, & Conti, 2006; Vandelanotte, Spathonis, Eakin, & Owen, 2007). However, to our knowledge, no meta-analysis has examined the efficacy of Internet-based lifestyle interventions to reduce blood pressure. There are substantial differences in the content or clinical methods among Internet-based interventions (Neubeck et al., 2009). Intervention protocols may differ in duration, target behaviours to be modified (exercise or diet), method of delivery (proactive vs. reactive), clinical methods (User-driven or Expert-driven), and use of an explicit behavioural theory or repertoire of techniques (Webb et al., 2010). These differences make it challenging to specify critical components of preventive e-counselling that are designed to reduce blood pressure.

The primary objective of this review was to examine the efficacy of Internet-based interventions in reducing systolic blood pressure (SBP) and diastolic blood pressure (DBP). Our secondary objective was to identify intervention components that may have contributed to blood pressure reduction.

3.2 Methods

This meta-analysis was based on guidelines from the Cochrane Handbook for Systematic Reviews of Interventions (Green, 2006). Reporting of results followed the Preferred Items of Systematic Reviews and Meta-analyses guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009).

Search strategy

MEDLINE, Pubmed, Embase, PsycInfo and Cochrane Library were searched up to June 2012 using the following key words: web-based intervention OR Internet intervention OR e-counselling OR mobile health AND blood pressure OR hypertension. Reference lists were also searched from the relevant identified articles, recent review articles or reports of clinical trials.
Inclusion Criteria

Human trials that investigated the effect of Internet-based lifestyle interventions on SBP and DBP were included. We operationally defined an Internet-based intervention as preventive e-counselling or advice using websites or emails to modify exercise or diet as a means of improving blood pressure control. These Internet-based interventions were primarily self-guided and access was gained via desktop computer, laptop, tablet or smart phone. The duration of each intervention had to be at least 8 weeks in order to achieve clinically meaningful outcomes, including the participant’s ability to learn and adhere to complex new behaviours, and to allow for sufficient time to demonstrate a stable reduction in blood pressure (Dickinson et al., 2006). SBP and DBP must have been reported as a primary or secondary outcome, measured at a clinic or office. Subjects were required to have blood pressure in the range of prehypertension (SBP/DBP: 120-139/80-89 mmHg) or hypertension (≥140/90 mmHg) (Chobanian et al., 2003). By using the blood pressure classification defined by the Joint National Committee (JNC) we were able to capture additional studies for a more comprehensive analysis of the efficacy of Internet-based interventions. Furthermore, the majority of the studies (56%) in this meta-analysis were conducted in the U.S. where the JNC blood pressure classification guideline was likely to have influenced the inclusion criteria for trials of e-counselling. Studies that included supplemental components such as mobile text messages, telephone, or in-person support were also included. Randomized controlled trials or case-control studies where included.

Data Extraction and quality assessment

Studies that met the inclusion criteria had their study characteristics and results extracted independently by two reviewers (S.L. and S.D.). In the event of conflicting opinions, resolution was achieved by consensus. The data review form was comprised of the following categories: 1) authors and year of publication 2) sample characteristics (sample size, BMI, age, blood pressure, attrition), 3) study design (randomization method, target behaviour, interventions, additional components to Internet-based intervention, method of delivery and clinical method), 4) behavioural theories 5) behavioural techniques and 6) study outcome (reduction of SBP and DBP).
Intervention duration was classified as short- (<6 months) or long-term (≥6 months). A coding scheme developed by Michie et al., 2011; Michie & Prestwich, (2010) was used to categorize behavioural theories and techniques that were utilized in each trial. Interventions were coded as using a particular theoretical basis only if there was an explicit reference to a theory that was used to develop or guide an intervention. In contrast, coding for behavioural techniques referred to specific strategies that were used to evoke change in exercise or diet, such as problem solving, goal setting, or self-monitoring. The total number of behaviour change techniques was summed for each trial.

Method of delivery for each Internet-based intervention was defined by whether it proactively or reactively engaged the subjects. In proactive Internet-based interventions, the e-platform initiated the contact to provide health information or feedback to subjects. Conversely, reactive Internet-based interventions required subjects to request and extract health materials or feedback from the e-platform. The clinical methods were also categorized into Expert-driven (protocol driven, prescriptive messaging), User-driven (collaborative protocol with supportive messaging) or a combined approach. Expert-driven support prescribed specific changes for lifestyle behaviour. This approach was designed to present an explicit goal for behaviour change without allowing the subject to alter the therapeutic plan. In contrast, the User-driven method allowed the subject to identify the behaviour to be modified (e.g. exercise or diet), the goal for behaviour change, or the techniques used to reach this goal. The combined approach reinforced collaboration between the e-platform and the subject through the use of Expert- and User-driven features, as described above.

Baseline and post-intervention mean ±SD for SBP and DBP were recorded when provided as well as any reported p-values for differences between pre and post treatment. Trials that did not report post-intervention values had these computed from the available data in the publication (mean difference within or between groups) using standard formulas(S. Green, 2006). Authors were contacted to request additional information when necessary. In keeping with conventional practice(Furukawa, Barbui, Cipriani, Brambilla, & Watanabe, 2006) missing SD values were imputed from the pooled SD of trials used in this meta-analysis.
The evaluation of study quality was based on the method used by Haynes et al. (Haynes, 1979) which was adapted to focus on Internet-based interventions (Wantland et al., 2004). Each study was evaluated based on five criteria: i) study design; ii) selection and specification of the study sample; iii) specification of the illness/condition; iv) reproducibility of the study; and (v) outcome specification or the validity and reliability of the measurement instruments. Studies could receive a maximum score of 18 points and studies with a score of ≥12 were retained for the meta-analysis.

**Statistical Analysis**

Meta-analyses were performed using Comprehensive Meta-Analysis (version 2). Mean end points of SBP and DBP were compared for the Internet-based intervention vs. Control. The effect size (ES) of each trial was calculated with the Hedges’ g statistic using baseline and post-treatment SBP and DBP for Treatment and Control groups. Data were expressed as standardized mean differences (SMD) with the 95% Confidence Interval. The use of SMD allowed the pooling of blood pressure results among interventions that varied in duration and intensity. Publication bias was assessed by conducting a funnel plot, the Begg and Mazumdar rank correlation tests (Begg & Mazumdar, 1994). Heterogeneity statistics were assessed by calculating the Q-statistic and I² statistics.

Pooled analyses for the overall effect-size were conducted using a random effects model. The influence of the intervention components on the ES of blood pressure reduction was investigated by performing a series of subgroup analyses. Thus, studies were divided into categorical subgroups according to: the duration of the study (<6month vs. ≥6months), use of behavioural theories, number of behaviour change techniques (<5 vs. ≥5), method of delivery (proactive vs. reactive), use of supplemental components (yes vs. no), target behaviours (diet or exercise vs. diet plus exercise) and clinical methods (User-driven, Expert-driven and combined). Finally, pooled effects were calculated for each subgroup using the fixed effects model.

Two methods were used to guide the clinical interpretation of results. First, Cohen’s d criteria were used to determine whether the SMD was small (> -0.2), moderate (-0.2 to -0.5), or large (< -0.5). Second, mean change of blood pressure between Intervention and Control was also reported as a marker of clinical significance.
3.3 Results

Article Selection

A total of 908 studies were identified within our database search. After reviewing the abstract and removing duplicate publications, 54 full text studies were reviewed. Out of these articles, 13 met the inclusion criteria (Figure 3.1).

Figure 3.1: Flowchart illustrating literature search.
Study Characteristics

Seven of the studies were conducted in the USA, three in South Korea, two in Canada, one in Australia and one in Germany. There were a total of 11 randomized control trials and 2 studies that matched Controls by age, sex, body weight and blood pressure. See supplemental Table 2.1 for a summary of the study characteristics.

The pooled sample across the 13 studies was 2221 subjects. The sample size in each trial ranged from 49 to 778 subjects. Four of the studies had less than 100 subjects. In total, 56% of the subjects were male. The age range of subjects was 18 to 89 years, with a mean age of 55 years. The population groups studied in the 13 studies included individuals with hypertension (Bennett et al., 2010; Green et al., 2008; Nolan et al., 2012; Park et al., 2009; Verheijden et al., 2004; Yoo et al., 2009), obesity (Kraschnewski et al., 2011; McDoniel, Wolskee, & Shen, 2010; Morgan, Lubans, Collins, Warren, & Callister, 2009; Pressler et al., 2010), diabetes (Bond et al., 2007; McMahon et al., 2005) and post-menopausal females (Park & Kim, 2012).

All blood pressure measurements were assessed during a face-to-face visit with a trained research assistant (Bennett et al., 2010; Bond et al., 2007; Green et al., 2008; Kraschnewski et al., 2011; McDoniel et al., 2010; McMahon et al., 2005; Morgan et al., 2009; Nolan et al., 2012; Pressler et al., 2010; Verheijden et al., 2004; Yoo et al., 2009) or a nurse (Park et al., 2009). In the majority of the studies (Bennett et al., 2010; Green et al., 2008; McDoniel et al., 2010; McMahon et al., 2005; Nolan et al., 2012; Park & Kim, 2012; Park et al., 2009; Verheijden et al., 2004) (n=9) the baseline and post-intervention blood pressure was determined by averaging multiple (2 to 4) recordings. Studies with versus without multiple recordings for blood pressure outcome did not differ significantly in baseline adjusted SBP (mean ±SD: -4.3 ±3.9 vs. -2.9 ±4.0 mmHg, p=0.56, respectively) and DBP (-2.0 ±3.0 vs. -2.3 ±2.8 mmHg, p=0.87, respectively). Baseline blood pressure across the studies was 136 ± 6.4 /82 ±4.9 mmHg (SBP±SD/DBP±SD). The mean BMI was 31 ±3.4 kg/m² which met criteria for obesity. Nine studies included blood pressure as the primary outcome while four of the studies included blood pressure as a secondary outcome. Attrition ranged from 6% to 47% across the studies with an overall mean of 21%.
**Effectiveness of Internet-based intervention on blood pressure**

Figures 2.2 and 2.3 provide forest plots of the main effects for SBP and DBP. Overall, Internet-based lifestyle intervention significantly reduced daytime SBP (p=0.002) and DBP (p=0.03) and the ES (SMD) was -0.27 (95% CI = -0.44 to -0.10) and -0.17 (95% CI = -0.33 to -0.01), respectively; See figures 2 and 3. This translates into a SBP reduction of

-3.8 mmHg (95% CI = -5.63 to -2.06) and DBP of –2.1 mmHg (95% CI = -3.51 to -0.65); p=0.004). However, significant heterogeneity was observed for SBP (Q = 31.0, P=0.002; I² = 61) and DBP (Q = 27.6, P=0.01; I² = 57).

**Publication Bias**

There was no publication bias observed for SBP (Begg test: p=0.71), however, the Begg test was significant for DBP (p=0.04). The funnel plot for DBP indicates that there is a bias toward studies that had large standard errors, and studies with null findings tended to be missing. This may be due to i) the strict inclusion criteria which resulted in the selection of only high quality studies, ii) the smaller sample size observed in these studies. The fail safe N for DBP indicated that 27 studies with null findings would be required to assume an ES of zero.
Figure 3.2: Forest plot for the overall change in overall effect size for systolic blood pressure (SBP). CI = confidence interval.

Figure 3.3: Forest plot of the overall change in overall effect size for diastolic blood pressure (DBP) effect size. CI = confidence interval.
The influence of specific attributes on study efficacy

**Intervention duration**

The mean intervention duration was 5.6 ± 3.6 months with eight of the 13 studies being short-term (<6 months) and five being long-term (6-12 months). The ES of SBP was significantly greater (p=0.03; Q=31.9, p=0.001) for longer studies (-0.44; 95% CI: -0.58 to -0.31) than shorter studies (-0.23; 95% CI: -0.36 to -0.10). See Figure 3.4 for the forest plot. The change in mean SBP reduction for long and short term studies was -5.8 mmHg (95% CI:-6.3 to -4.1 mmHg) and -3.47 mmHg (95% CI: -5.2 to -1.7 mmHg). There was no significant group difference found for DBP (p=0.67).

**Figure 3.4:** The overall change in effect size of systolic blood pressure (SBP) for short-term (<6 months) versus long-term (≥6 months) Internet-based interventions. CI = confidence interval.
Theories and techniques of behaviour change

Only three studies (Morgan et al., 2009; Nolan et al., 2012; Verheijden et al., 2004) mentioned an explicit theoretical framework for their Internet-based intervention. Thus, this may have limited our ability to detect the effect of behaviour theories on intervention efficacy. However, we were able to identify the behaviour change techniques in all studies. The ES of SBP was significantly greater (p=0.01; Q=23.51, P=0.01) in those studies that used five or more behavioural change techniques (-0.46; 95% CI: -0.60 to -0.33) as compared to studies that used less than five behaviour change techniques (-0.19; 95% CI: -0.33 to -0.06). Similarly, a significant group difference for ES (p = 0.002; Q=16.6, P=0.12) was observed with DBP (≥5 behaviour technique: -0.31(95% CI: -0.44 to -0.18); <5 behaviour techniques: 0.001 (95% CI, -0.14 to 0.14). See Figure 5 for the forest plot. These results translate into a mean blood pressure reduction of -5.92/-2.45 mmHg (95% CI: -7.43 to -4.42 / -3.50 to -1.41) and -2.69/-0.02 mmHg (95% CI: -4.61 to -0.78/ -1.20 to 1.17) for those studies with <5 and ≥5 behaviour change techniques, respectively.

Behaviour change techniques that were used in more than 50% of the successful Internet-based interventions included the following: providing information on consequences of behaviour in general (86% of studies), incorporating feedback on performance (86%), prompting self-monitoring of behaviours (71%) and giving instructions on how to perform the targeted change in behaviour (71%).
Figure 3.5A: The overall change in effect size of systolic blood pressure (SBP) for trials that used less than 5 versus greater or equal to 5 behaviour changing techniques. CI = confidence interval.

<table>
<thead>
<tr>
<th>Group by</th>
<th>Study name</th>
<th>Comparison</th>
<th>Hedges’s g and 95% CI</th>
</tr>
</thead>
<tbody>
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<td>No. of BT &lt;5</td>
<td></td>
</tr>
<tr>
<td>No. of BT &lt;5</td>
<td>McDoniel 2010 (30)</td>
<td>No. of BT &lt;5</td>
<td></td>
</tr>
<tr>
<td>No. of BT &lt;5</td>
<td>Nolan 2012 (25)</td>
<td>No. of BT &lt;5</td>
<td></td>
</tr>
<tr>
<td>No. of BT &lt;5</td>
<td>Pressler 2010 (32)</td>
<td>No. of BT &lt;5</td>
<td></td>
</tr>
<tr>
<td>No. of BT &lt;5</td>
<td>Verheijden 2004 (27)</td>
<td>No. of BT &lt;5</td>
<td></td>
</tr>
<tr>
<td>No. of BT &lt;5</td>
<td>Yoo 2009 (28)</td>
<td>No. of BT &lt;5</td>
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<td>No. of BT &gt;5</td>
<td></td>
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<td>Morgan 2009 (31)</td>
<td>No. of BT &gt;5</td>
<td></td>
</tr>
<tr>
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<td>Park 2009 (26)</td>
<td>No. of BT &gt;5</td>
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</tr>
<tr>
<td>No. of BT &lt;5</td>
<td>Park 2011 (35)</td>
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<td></td>
</tr>
<tr>
<td>Overall</td>
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<td></td>
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</tr>
</tbody>
</table>

BT= Behavioural Technique
Figure 3.5B: The overall change in effect size of diastolic blood pressure (DBP) for trials that used less than 5 versus greater or equal to 5 behaviour changing techniques. CI = confidence interval.

Method of Delivery

We found significantly greater ES change for DBP (p=0.04; Q27.67, P=0.01) using a proactive (-0.22, 95% CI: -0.33 to -0.12) vs. a reactive method (-0.04 95% CI: -0.18 to 0.25). The mean change of DBP for proactive and reactive was -1.78 mmHg (95% CI: -2.62 to -0.93) and 0.36 mmHg (95% CI: -1.78 to 2.49), respectively. Please see Figure 3.6 for the forest plot. No significant change for the ES of SBP was observed between these groups (p=0.41).
**Figure 3.6:** The overall change in effect size of diastolic blood pressure (DBP) for proactive versus reactive Internet-based interventions. CI = confidence interval.

**Supplemental components**

Nine interventions had supplemental components that were not Internet-based such as text messages (n=3), in-person visits (n=3) and live support (n=3). There was no significant difference in ES for SBP (p=0.11) and DBP (p=0.26) found between those trials that included supplemental components versus those that did not.
Target behaviours

There were ten studies that targeted both exercise and diet behavioural changes. Targeting both versus a single behaviour did not result in significant difference in ES for SBP (p=0.20) and DBP (p=0.27)

Clinical method

The majority of Internet-based interventions in the studies used an Expert-driven style (n=9) and one study used a combined User-driven and Expert-driven approach. No significant SBP (p=0.88) was found between groups used different clinical methods. However, a statistical trend was observed for DBP (p=0.06).

3.4 Discussion

The primary aim of the present meta-analysis was to evaluate the effectiveness of Internet-based interventions in reducing blood pressure in individuals with prehypertension or hypertension. We found that Internet-based interventions significantly reduced SBP by 3.8 mmHg and DBP by 2.1 mmHg. It is noteworthy that this change in SBP was comparable to the magnitude of blood pressure reduction reported in previous meta-analyses of face-to-face lifestyle counselling (Dickinson et al., 2006; Whelton et al., 2002). A 3 mmHg reduction in SBP is associated with an 8% reduction in stroke mortality and a 5% reduction in mortality from coronary heart disease (Griffiths et al., 2006).

When evaluating specific intervention components, we found three attributes that may be associated with increased efficacy of e-counselling. First, Internet-based interventions that were at least six months in duration were associated with greater blood pressure reduction. This may be expected because the influence of lifestyle intervention on blood pressure may require a critical period of time to evoke a therapeutic change. Additionally, interventions with a longer
duration may be required to facilitate comprehensive physical changes such as weight reduction, which in turn would result in a greater decrease in blood pressure (Bacon, Sherwood, Hinderliter, & Blumenthal, 2004).

Second, we found that blood pressure was significantly reduced among interventions that provided a greater range of behaviour change techniques. The use of at least five techniques was the “tipping point” observed in our pooled sample. This finding raises several clinically relevant issues. It suggests that a critical number of techniques may be required to build a flexible repertoire of skills that are necessary to overcome situational stressors that might otherwise impede therapeutic lifestyle change. Further, the use of several techniques may be required to ensure that subjects have the opportunity to develop a select set of skills from which they can obtain positive efficacy and outcome expectations, which are necessary to sustain behaviour change and blood pressure reduction over the long-term (Nolan et al., 2012; Webb et al., 2010). Finally, our review indicated that it is rare among trials of e-counselling to use an explicit model of behavioural counselling to evaluate the independent contribution of specific behaviour change techniques for blood pressure reduction. Therefore, a priority for future trials of preventive e-counselling is to design and evaluate e-counselling protocols according to theoretically grounded hypotheses. Indeed, this initiative would be consistent with the Consolidated Standards of Reporting Trials for E-health, which advises investigators to report sufficient details about their intervention to allow for replication and theory-building (Eysenbach, 2011).

Third, the interventions that proactively sent e-messages to subjects were more effective than reactive interventions that required them to log onto a website in order to receive e-counselling support. The proactive method of delivery may have enhanced the degree to which the e-program was perceived as providing sufficient support to modify exercise or diet. In addition, it has been reported that Internet-based interventions with greater than five proactive communications (e-mails or text messages) evoked significantly greater changes in physical activity than those with fewer contacts during the treatment program (Nolan et al., 2012; Vandelanotte et al., 2007). A dose-response relationship between e-counselling and therapeutic outcome requires further study.
The findings of this meta-analysis did not uncover evidence to support the hypothesis that blood pressure reduction is augmented with e-counselling programs that target multiple lifestyle behaviours or that provide supplementary components such as text messaging, in-person visits, and telephone support. These observations may have important implications when designing Internet-based interventions, however, future studies are needed to confirm our findings.

An historical challenge for preventive e-counselling has been a high attrition rate. This is of clinical concern since previous trials have reported a dose-response relationship between the number of log-ins to the e-counselling program and incremental improvement in treatment outcome (Durrani, Irvine, & Nolan, 2012; Nolan et al., 2012). It is unclear which methods or strategies are necessary to keep the users actively engaged in an e-counselling intervention. Ritterband et al., (2009) suggested that engagement level for Internet-based intervention is influenced by both the type of support and user characteristics (e.g. readiness for change, demographics, beliefs and attitude, intervention expectation). The majority of trials (n=9) in this review used an Expert-driven support (prescriptive, protocol driven), which limited the consideration of user characteristics (motivation, previous knowledge and skills). Future studies need to examine the influence of user characteristics on Internet-based intervention usage and intervention health outcome.

There are important limitations to this review. First, the ability to generalize our findings to the wider population with pre-hypertension or hypertension is limited by (i) the small number of clinical trials (n=13) and by the restricted number of population groups that have been enrolled in the available trials, (ii) the relatively low baseline blood pressure may have contributed to a potential floor effect, and (iii) the potential for publication bias when DBP was the reported outcome. The use of matched controls in 2 of the studies in our review would have increased the uniformity of characteristics in these samples, which may have added a further limitation to the generalizability of the results in this meta-analysis. Second, not all studies indicated that the outcome analysis was based upon an intention-to-treat principle and this raises the possibility of bias in the reported results. It is important for future studies of Internet-based interventions to explicitly report whether the results are obtained according to the intention-to-treat principle by means of a per-protocol analysis, in order to highlight potential limitations about the reported effectiveness of the intervention. Finally, the majority of trials in this review did not specify
whether the intervention was designed or organized according to an evidence-based theory of behavioural counselling. This made it challenging to interpret whether the behavioural techniques were used in a coherent and effective manner, and thus to their appropriate potential.

### 3.5 Conclusion

There is preliminary evidence supporting the efficacy of e-counselling as a viable method to manage blood pressure. We found that Internet-based interventions may be more efficacious when the program was 6 months or longer, delivered proactively, and when it provided at least five behavioural techniques. In order to build an evidence-based guideline for preventive e-counselling, there is an immediate need to design trials that provide a direct comparison of specific intervention components (e.g. duration, method of delivery) when evaluating program efficacy. An Internet-based strategy for preventive counselling is a relatively new tool that has the potential to complement medical therapy for blood pressure control.
Table 3.1: Characteristics of reviewed clinical trials

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample Characterizes</th>
<th>Study Design</th>
<th>Internet-based intervention components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bennett et al.(2010) United States</td>
<td>Mean age (yrs)= 54</td>
<td>3 months, RCT</td>
<td>Target Behaviour: Exercise + Diet</td>
</tr>
<tr>
<td></td>
<td>N=101</td>
<td></td>
<td>Supplemental Components: Yes</td>
</tr>
<tr>
<td></td>
<td>Mean Baseline BP: 136/76 mmHg</td>
<td></td>
<td>Method of delivery: Passive</td>
</tr>
<tr>
<td></td>
<td>Population: hypertension, BMI (30-40 kg/m²)</td>
<td></td>
<td>Clinical method: User-driven</td>
</tr>
<tr>
<td></td>
<td>Attrition rate: 16%</td>
<td></td>
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</tr>
<tr>
<td>Bond et al. (2007) United States</td>
<td>Mean age (yrs)= 67</td>
<td>6 months, RCT</td>
<td>Number of behaviour changing techniques: 4</td>
</tr>
<tr>
<td></td>
<td>N=62</td>
<td></td>
<td>Target Behaviour: Exercise + Diet</td>
</tr>
<tr>
<td></td>
<td>Mean Baseline BP: 132/75 mmHg</td>
<td></td>
<td>Supplemental Components : None</td>
</tr>
<tr>
<td></td>
<td>Population: ≥60 yrs, T1DM or T2DM</td>
<td></td>
<td>Method of delivery: Proactive</td>
</tr>
<tr>
<td></td>
<td>Attrition rate: not specified</td>
<td></td>
<td>Clinical method: User-driven</td>
</tr>
<tr>
<td>Green et al. (2008) United States</td>
<td>Mean age (yrs)= 59</td>
<td>12 months, RCT</td>
<td>Theories: Not specified</td>
</tr>
<tr>
<td></td>
<td>N=778</td>
<td></td>
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<td></td>
<td>Mean Baseline BP: 152/89 mmHg</td>
<td></td>
<td>Target Behaviour: Exercise + Diet</td>
</tr>
<tr>
<td></td>
<td>Population: hypertension</td>
<td></td>
<td>Supplemental Components : Yes</td>
</tr>
<tr>
<td></td>
<td>Attrition rate: 6%</td>
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<td>Method of delivery: Proactive</td>
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<td></td>
<td>Mean Baseline BP: 126/74 mmHg</td>
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<td>Target Behaviour: Diet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Supplemental Components : none</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Method of delivery: Proactive</td>
</tr>
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</table>
Population: BMI (27-40 kg/m²)  
Attrition rate: 12%

Clinical method: Expert-driven  
Theories: Not specified  
Number of behaviour changing techniques: 6  
Target Behaviour: Exercise + Diet  
Supplemental Components: Yes  
Method of delivery: Proactive  
Clinical method: Expert-driven  
Theories: Not specified  
Number of behaviour changing techniques: 4  
Target Behaviour: Exercise + Diet  
Supplemental Components: Yes  
Method of delivery: Proactive  
Clinical method: Expert-driven  
Theories: Not specified  
Number of behaviour changing techniques: 5  
Target Behaviour: Exercise + Diet  
Supplemental Components: Yes  
Method of delivery: Proactive  
Clinical method: Expert-driven  
Theories: SCT  
Number of behaviour changing techniques: 6  
Target Behaviour: Exercise + Diet + Smoking

McDoniel et al. (2009)  
United States  
N=111  
Mean age (yrs) = 45  
Mean Baseline BP : 132/79 mmHg  
Population: BMI (≥30 kg/m²)  
Attrition rate: 28%

McMahon et al. (2005)  
United States  
N=104  
Mean age (yrs) = 64  
Mean Baseline BP : 140/81 mmHg  
Population: T2DM  
Attrition rate: 19.2%

Morgan et al. (2009)  
Australia  
N=65  
Mean age (yrs) = 36  
Mean Baseline BP : 135/85 mmHg  
Population: BMI (25-37 kg/m²)  
Attrition rate: 32.2%

Nolan et al. (2012)  
N=387  
Mean age (yrs) = 56  
4 months, RCT  
Target Behaviour: Exercise + Diet + Smoking
<table>
<thead>
<tr>
<th>Country</th>
<th>Mean Baseline BP</th>
<th>Population</th>
<th>Attrition rate</th>
<th>Supplemental Components</th>
<th>Method of delivery</th>
<th>Clinical method</th>
<th>Theories</th>
<th>Number of behaviour changing techniques</th>
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<td>Hypertension</td>
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<td>Mean age (yrs)= 56</td>
<td>3 months, matched control</td>
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<td>Proactive</td>
<td>Expert-driven</td>
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<td>Post-menopausal, WC&gt;80cm</td>
<td>Attrition rate: not specified</td>
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<td>Country</td>
<td>Mean age (yrs)</td>
<td>Mean Baseline BP</td>
<td>Population</td>
<td>Attrition rate</td>
<td>Duration</td>
<td>Method of delivery</td>
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<td>Verheijden et al.</td>
<td>146</td>
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<td>63</td>
<td>134/81 mmHg</td>
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<td>11%</td>
<td>8 months, RCT</td>
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<td>111</td>
<td>South Korea</td>
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<td>Hypertension, T2DM</td>
<td>9.8%</td>
<td>3 months, RCT</td>
<td>Proactive</td>
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</tbody>
</table>
Chapter 4. Lifesource XL-18 Pedometer for Measuring Steps under Controlled and Free-living Conditions

Abstract

The primary aim was to examine the criterion and construct validity and test-retest reliability of the Lifesource XL-18 pedometer for measuring steps under controlled and free-living activities. The influence of body mass index, waist size and walking speed on the criterion validity of XL-18 was also explored. Forty adults (35-74 years) performed a six-minute walk test in the controlled condition and the criterion validity of XL-18 was assessed by comparing it to steps counted manually. Thirty-five adults participated in the free-living condition and the construct validity of XL-18 was assessed by comparing it to Yamax SW-200. During the controlled condition, XL-18 did not significantly differ from criterion (p>0.05) and no systematic error was found using Bland-Altman analysis. The accuracy of XL-18 decreased with slower walking speed (p= 0.001). During the free-living condition, Bland-Altman revealed that XL-18 overestimated daily steps by 327 ±118 than Yamax (p= 0.004). However, the absolute percent error (6.5 ±0.58%) was still within an acceptable range. XL-18 did not differ statistically between pant pockets. XL-18 is suitable for measuring steps in controlled and free-living conditions. However, caution may be required when interpreting the steps recorded under slower speeds and free-living conditions.
4.1 Introduction

Regular physical activity is important to a person’s physical and mental health (De Cocker, De Meyer, De Bourdeaudhuij, & Cardon, 2012). Physical activity guidelines in Canada recommend that adults participate in at least 150 minutes of aerobic activity per week at moderate to vigorous intensity (Tremblay et al., 2011). Pedometer usage has become a popular tool to quantify daily physical activity, and to motivate individuals to set activity goals (Bravata et al., 2007; Melanson et al., 2004). Pedometers are lightweight and small instruments that can be worn around the hip, wrist, or in the pants pocket to count the number of steps walked per day (De Cocker, De Bourdeaudhuij, & Cardon, 2009; De Cocker et al., 2012; Hasson, Haller, Pober, Staudenmayer, & Freedson, 2009; Schneider, Crouter, & Bassett, 2004). Furthermore, a pedometer is lower priced ($10-30) than an accelerometer ($100-300), which makes it an attractive and practical tool for individuals working in fitness, clinical, health, and research fields (De Cocker et al., 2012; Melanson et al., 2004).

Several studies have shown evidence of acceptable accuracy and validity of pedometers (De Cocker et al., 2009; Schneider, Crouter, Lukajic, & Bassett, 2003; Tudor-Locke, Williams, Reis, & Pluto, 2004). Traditional spring-gauged pedometers need to be securely fastened at the hip or onto a belt. Step count is measured by movement of a lever arm in response to vertical hip displacement during walking. Each time the lever arm moves past its threshold, a step is counted (Crouter, Schneider, & Bassett, 2005; De Cocker et al., 2012). However, the accuracy of these pedometers is decreased at slower walking speeds (<4.8 km/h), and when used by individuals with high body mass index (BMI ≥30) (Melanson et al., 2004). The increased amount of abdominal fat prevents the pedometer being worn vertically on the hip (when secured to a belt), thus contributing to step count error (Crouter et al., 2005; Hasson et al., 2009).

Recent advances in pedometer technology through the use of tri-axial accelerometer sensors (piezoelectric technology) can detect motion between vertical and horizontal planes. Consequently, the piezoelectric pedometers need not be worn upright at the hip in order to detect motion (Crouter et al., 2005; De Cocker et al., 2012). This type of pedometer may be more convenient to wear, and may increase usability in different populations. Previous piezoelectric models have demonstrated superior accuracy in comparison to spring-gauged pedometers in
obese individuals (BMI ≥ 30) and at slower walking speeds (Colley et al., 2013; Hasson et al., 2009).

Lifesource XL-18 is a piezoelectric pedometer that can record steps for up to 14 days. This function makes the XL-18 pedometer an ideal tool for tracking activity level for longer periods of time. However, the psychometric properties of the Lifesource XL-18 pedometer have not been independently established. Thus, the primary purpose of this study was to examine the criterion and construct validity and test-retest reliability of the Lifesource XL-18 pedometer during controlled and free-living conditions. The secondary objective was to study the influence of BMI, waist size and walking speed on the validity of the Lifesource XL-18 pedometer.

4.2 Methods

Forty middle-aged individuals between the ages of 35 and 74 years volunteered to participate in the controlled test study, while thirty-five adults were recruited to participate in the free-living conditions test. All participants were recruited through the University Health Network, Toronto, Canada. Written informed consent was obtained from all research participants and the study was approved by the Research Ethics Board at University Health Network.

The XL-18 pedometer features a tri-axial accelerometer to count steps. The manufacturer suggests that this pedometer does not need to be securely attached to a belt; it can be worn in pant pockets. Participants’ height, weight and waist size were measured prior to undergoing testing of the Lifesource XL-18 pedometer. The testing protocols for controlled and free-living conditions were adapted from previous studies (De Cocker et al., 2012; Schneider et al., 2004; Schneider et al., 2003).
Protocol for Controlled Condition

Participants completed a six-minute walk test (ATS, 2002) while wearing the XL-18 pedometer. The six-minute walk test was performed in a 50-meter indoor course that was marked on the floor. The participants were asked to wear the Lifesource XL-18 pedometer in their front right and left pant pockets. All pedometers were reset before each test. Throughout the six-minute walk test, the investigators used a manual hand counter to record the actual steps taken. At the end of the six-minute walk test, registered pedometer steps and actual steps were recorded. Walking speed was calculated using the following equation: Walking speed (km/h) = 6 minute walk distance/100.

6 Minute Walk Test Protocol

The 6 minute walk test is a submaximal level exercise test that evaluates the global responses of all the physiological systems during exercise including, pulmonary and cardiovascular systems, neuromuscular units, and muscle metabolism. Participants performed the 6MWT indoors, along a long, flat, straight, enclosed corridor with a hard surface that is seldom traveled. The beginning and end points of the 50 meter course was marked with a cone. Participants were instructed to wear comfortable clothing and appropriate walking shoes. Participants was instructed not have exercised vigorously within 12 hours prior to the beginning the test. Before starting of the 6MWT, a standard set of instructions were given the patients based on the ATS Statement: Guidelines for the Six-Minute Walk Test.

“The object of this test is to walk as far as possible for 6 minutes. You will walk back and forth in this hallway. Six minutes is a long time to walk, so you will be exerting yourself. You will probably get out of breath or become exhausted. You are permitted to slow down, to stop, and to rest as necessary. You may lean against the wall while resting, but resume walking as soon as you are able. You will be walking back and forth around the cones. You should pivot briskly around the cones and continue back the other way without hesitation. Now I’m going to show you. Please watch the way I turn without hesitation.” Demonstrate by walking one lap yourself. Walk and pivot around a cone briskly. “Are you ready to do
that? I am going to use this counter to keep track of the number of laps you complete. I will click it each time you turn around at this starting line. Remember that the object is to walk AS FAR AS POSSIBLE for 6 minutes, but don’t run or jog. Start now, or whenever you are ready.”

The following standardized encouragements were given to the participants following each minute.

After the first minute, tell the patient the following (in even tones): “You are doing well. You have 5 minutes to go.” When the timer shows 4 minutes remaining, tell the patient the following: “Keep up the good work. You have 4 minutes to go.” When the timer shows 3 minutes remaining, tell the patient the following: “You are doing well. You are halfway done.” When the timer shows 2 minutes remaining, tell the patient the following: “Keep up the good work. You have only 2 minutes left.” When the timer shows only 1 minute remaining, tell the patient: “You are doing well. You have only 1 minute to go.”

During the last 15 seconds from completion of the test, participants received the following instruction:

“In a moment I’m going to tell you to stop. When I do, just stop right where you are and I will come to you.”

The distance walked by the participants was measured using a rolling tape measure. All participants completed the test without having to stop during middle of the test.

**Protocol for the free-living condition**

The Yamax Digiwalker SW-200 was used as the comparison pedometer during the free-living condition (since direct observation of the step counts was not possible). The Yamax SW-200 pedometer has been used to assess steps during free-living conditions and is one of the most accurate pedometers for counting steps in adults (mean error score = -0.1 steps, CI = 16.7 to -16.9; ±1% within actual steps; ICC = 0.98; Chronbach’s α = 0.99) (Crouter, Schneider, Karabulut, & Bassett, 2003; Schneider et al., 2003). Participants were instructed to wear Yamax SW-200 on the left side and Lifesource XL-18 pedometers in either their right or left front
pocket for a one day period (waking hours). Steps counted by both pedometers were recorded at
the end of the day.

**Statistical analysis**

All analyses were performed using SPSS 20 (SPSS Inc., Chicago, IL). Based on a previous
study, an acceptable measurement error under controlled conditions is within ±3% and under
free-living is within ±10% error (Schneider et al., 2004). Absolute percent error and percent error
(indicating the direction of the error) were calculated using the following formulas: Percent error
right pocket = (Right pocket XL18 steps - hand counted steps)/hand counted steps; Percent error
left pocket = (Left pocket XL18 steps - hand counted steps)/hand counted steps; Free living
percent error = (XL18 steps - Yamax Steps) / Yamax steps.

Criterion validity of the XL-18 pedometer was assessed during the controlled condition, while
construct validity was examined during the free-living condition. The difference score was
computed (XL-18 steps-criterion; XL18 steps– Yamax steps) and compared to zero using sample
t-tests in order to assess whether there was a significant difference between XL-18 and the
criterion or comparison pedometer (Yamax). Bland-Altman plots were also constructed to
demonstrate the distribution of the individual scores around zero (Bland, 1986). Differences in
mean absolute percent error between the pedometers worn in the right and left pant pockets in
the controlled environment were examined using paired t-tests. Test-retest reliability was
assessed between the registered steps in the left and right pant pockets during the six-minute
walk test using the Altman and Bland technique as (1) absolute limits of agreement
(heteroscedasticity absent) or (2) ratio limits of agreement (heteroscedasticity present).
Heteroscedasticity was examined by plotting the absolute differences against the individual mean
and calculating the correlation coefficient (Atkinson & Nevill, 1998). Intra-class correlation
coefficient (ICC) was also calculated. Regression analyses were used to examine whether BMI,
waist size and walking speed were associated with percent error while wearing the pedometer in
the controlled environment. All values are represented as means ± SE and a p-value of less than
0.05 was used to denote statistical significance for all analyses.
4.3 Results

All participants recruited completed the study in both controlled (n=40; 64% female; 59 ±1.4 years) and the free-living conditions (n=35; 65% female; 59 ±1.6 years). In the controlled condition, the mean BMI and waist size were 30.8 ±0.9 kg/m\(^2\) and 99.5 ±2.1 cm. In the free-living condition, the mean BMI and waist size were 30.4 ±1.0 kg/m\(^2\) and 98.6 ±2.2 cm. The mean distance walked during the six-minute walk test was 540±16.6 m, which is equivalent to 26.9 ±15% below the age-predicted norm (Hill et al., 2011). The average walking speed during the six-minute walk test was 5.4 km/h and ranged from 3.3 km/h to 7.1 km/h. Participants took an average of 8121±537 steps per day according to the criterion pedometer under the free-living condition.

During the controlled condition, no significant differences were observed between steps registered by the manual hand counter and the XL-18 pedometer in either left or right pant pockets. The percent error for the pedometer under the controlled condition ranged from -5.2% to 2.2% and -5.2% to 2.3% for left and right pant pockets, respectively. Overall, 80% of pedometers used under controlled environments achieved less than ±3% error. Figure 4.1A, B of the Bland-Altman plot of the XL-18 pedometer under the controlled condition does not show a systematic error. Percent error for the XL-18 pedometer ranged from -9% to 20% during the free-living condition. The XL-18 pedometer significantly overestimated the steps by 327 ±118 compared with Yamax during the one-day period (p=0.004), see Figure 4.1C for the Bland-Altman plot. However, 81% of the XL-18 pedometers used during the free-living condition demonstrated a less than ±10% error. Absolute percent errors under controlled and free-living conditions are presented in Table 4.1. There was no significant difference observed between wearing the XL-18 pedometer in the left versus right pockets under the controlled environment (p>0.05) and the ICC was 0.95. Bland-Altman analysis limits of agreement (LOA) did not show a systematic error when XL-18 pedometer was worn in the left versus right pockets (Figure 4.1D).
Table 4.1. Absolute Percent Error (APE) under controlled and free-living condition

<table>
<thead>
<tr>
<th></th>
<th>APE% ±SD</th>
<th>Range APE</th>
<th>%under-estimation</th>
<th>%over-estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Controlled Condition</strong></td>
<td></td>
<td></td>
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<tr>
<td>Right Pants</td>
<td>1.7 ±1.20</td>
<td>0-5.2</td>
<td>47</td>
<td>49</td>
</tr>
<tr>
<td>Left Pants</td>
<td>1.6 ±1.50</td>
<td>0-6.3</td>
<td>43</td>
<td>50</td>
</tr>
<tr>
<td><strong>Free-living Condition</strong></td>
<td>6.5 ±3.41</td>
<td>1-20</td>
<td>35</td>
<td>65</td>
</tr>
</tbody>
</table>

Table 4.2. The influence of body mass index (BMI), waist size and walking speed on percent error of XL-18 Pedometer

<table>
<thead>
<tr>
<th></th>
<th>Percent error for right pants pocket</th>
<th>Percent error for left pants pocket</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β±SE</td>
<td>P-value</td>
</tr>
<tr>
<td><strong>Walking speed</strong></td>
<td>1.06 ±0.23</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td>0.04 ±0.05</td>
<td>0.48</td>
</tr>
<tr>
<td><strong>Walking speed</strong></td>
<td>1.01 ±0.27</td>
<td>0.001*</td>
</tr>
<tr>
<td><strong>Waist size</strong></td>
<td>0.02 ±0.02</td>
<td>0.17</td>
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BMI and waist size are highly correlated; thus, to avoid multicollinearity, separate regressions were conducted for our secondary objective. We found that walking speed was a significant predictor of percent error controlling for BMI and waist size during the six-minute walk test (Table 4.2). BMI and waist size were not significantly associated with increased percent error for the pedometer (p>0.05). The percent errors in the left pocket during walking speeds of 3-4km/h, 4.1-5km/h, 5.1-6km/h and >6 km/h are -4.56 ±0.31%, 0.18±0.40%, 0.35±1.43% and 0.44 ±0.32%, respectively. The percent errors in the right pocket during walking speed of 3-4km/h, 4.1-5km/h, 5.1-6km/h and >6 km/h are -4.28 ±0.28%, -0.28±0.67%, 0.11±1.73%, and 0.18 ±0.95%. Post-hoc analyses revealed that walking speeds of 3-4 km/h resulted in significantly higher absolute percent error than 4.1-5 km/h, 5.1-6km/h or >6km/h in both left (p<0.001) and right pant pockets (p<0.001).
Figure 4.1 Bland-Altman plots depicting measurement bias of XL-18 pedometer. A) XL-18 wore in the left pocket under controlled condition; B) XL-18 pedometer wore in the right pocket under controlled condition; C) XL-18 pedometer under free living condition; D) XL-18 Pedometer wore in the left versus right pockets. XL-18 Solid horizontal line = mean error score, dashed lines = 95% predicted intervals.
4.4 Discussion

The primary aim of this study was to examine the criterion and construct validity and test re-test reliability of the Lifesource XL-18 pedometer step count under controlled and free-living conditions. Overall, absolute percent error and Bland-Altman analyses revealed that the Lifesource XL-18 pedometer is suitable to measure steps under controlled and free-living environments. The majority (~80%) of the pedometers met the standard of 3% absolute percent error during controlled conditions and 10% absolute percent error during the free-living condition (Schneider et al., 2004). However, the XL-18 pedometer could underestimate steps at slower walking speeds and overestimate steps compared to the Yamax pedometer under the free-living condition. This is the first study to our knowledge to independently validate the Lifesource XL-18 pedometer.

The percent error of the XL-18 pedometer was not influenced by wearing position (left and right pocket), waist size or BMI, which has also been demonstrated from previous studies in other models of piezoelectric pedometers (Crouter et al., 2005; De Cocker et al., 2012; Hasson et al., 2009). The tri-axial accelerometer in the XL-18 pedometer was designed to capture steps independent of the pedometer’s orientation. This allows the user to wear the pedometer in several different locations, thus potentially increasing use. The Lifesource XL-18 pedometer underestimated steps at a slower walking speed (3-4km/hour) and resulted in a higher absolute percent error than at faster walking speeds. Decreased accuracy of the pedometer may be due to the fact that lower speeds may not be able to generate enough acceleration to trigger sensors in the pedometer; thus, underestimating the number of steps (Tudor-Locke, Ainsworth, Thompson, & Matthews, 2002). Previous validation studies of piezoelectric pedometers have also reported similar findings (De Cocker et al., 2012; Schneider et al., 2004). For example, Omron HJ-720, StepMX, and the Lifestyle NL-2000 have demonstrated that the accuracy of the pedometer was decreased at slower walking speeds; between 3.2 and4km/h. This is particularly relevant in tracking activity level in individuals with gait limitations, such as in older adults or individuals with predisposed cardiovascular disease, as their aerobic exercise capacity may be limited. Therefore, caution is required when using XL-18 pedometer to record steps at a slower speed (<4km/h).
We found that the Lifesource LX-18 pedometer significantly overestimated the number of steps taken by a mean of 327 steps compared to the Yamax pedometer. However, statistical significance is a function of sample size (Thomas, 2010). Consequently, it is also important to consider practical significance of the mean difference from criterion. An individual’s physical activity level can be classified based on daily step count: <5000 steps sedentary, 5000 -7499 inactive, 7500-9999 somewhat active, and ≥10000 active (De Cocker et al., 2012; Schneider et al., 2004; Tudor-Locke & Bassett, 2004). Previous studies suggested that if a mean value is within ±10% error from criterion under the free-living condition, the risk of misclassification is reduced, enabling meaningful comparisons among pedometer brands (De Cocker et al., 2012; Schneider et al., 2004; Tudor-Locke & Bassett, 2004). XL-18 had a mean percent error of 6.5%. We suggest that the XL-18 is an acceptable tool for monitoring step count in free-living conditions. However, it is important to note that in certain populations (e.g. elderly or individuals with mobility constraints), a 10% increase in number of steps may be a significant and meaningful change. Future studies are warranted to validate the use of XL-18 in these population groups.

The discrepancy between the LX-18 and the Yamax SW-200 pedometers may be attributed to the different internal mechanisms of the devices (Schneider et al., 2004). Pedometer devices that are more sensitive to detecting steps at slower speeds than criterion pedometers are prone to overestimating steps. The Yamax pedometer is spring-gauged, and studies have shown that it is sensitive at speeds faster than 4.5 km/h (Colley et al., 2013), while the XL-18 is sensitive at a slower speed than 4.5km. However, it is also possible that the increased sensitivity of the XL-18 pedometer may capture non-ambulatory activity such as fidgeting, twisting, bending and mechanical vibrations from motor vehicle travel (Le Masurier & Tudor-Locke, 2003; Schneider et al., 2004). Future studies need to use more robust criterion measures such as an accelerometer, which would strengthen the free-living condition test.

Intra-instrument reliability was high when the XL-18 pedometer was worn in the pant pockets during the six-minute walk test. In a previous study, the HJ-720 piezoelectric pedometer reported that having it placed in the pants pocket produced poor accuracy compared to having it worn around the neck (De Cocker et al., 2012). While a direct comparison of different wearing positions was not conducted in this study, we did find that the XL-18 pedometer produced low
absolute percent error when worn in pants. Future studies should examine the influence of the pedometer’s position (such as around the neck, in a backpack or shirt pockets) on accuracy.

4.5 Conclusion

Validity (criterion and construct) and intra-instrument reliability of XL-18 pedometer were tested in the controlled and free-living conditions. This study demonstrated that the Lifesource XL-18 pedometer is a suitable tool to measure steps under controlled and free-living conditions in adults. Similar to other brands of piezoelectric pedometers, the accuracy of the pedometer is not influenced by BMI or waist size. However, the XL-18 pedometer may underestimate steps at slow speeds (3-3.9km/h) and overestimate steps compared to Yamax under the free-living condition.
Chapter 5.  Effectiveness of User and Expert Driven Internet-based Lifestyle Interventions on Hypertension Control: a Randomized Controlled Trial

Abstract

**Background:** The effectiveness of self-guided Internet-based lifestyle counselling (e-counselling) varies depending on treatment protocol. Evidence to support choices of e-counselling protocol is lacking. Two dominant procedures for delivery in e-counselling are “Expert-driven” and “User-driven”. The influence of these e-counselling procedures on blood pressure control and health behaviour change remains unclear.

**Purpose:** The primary objective was to assess whether systolic blood pressure (SBP) improved with Expert-driven or User-driven e-counselling over usual care in patients with hypertension over a 4-month period. Secondary outcomes included diastolic blood pressure (DBP), pulse pressure (PP), cholesterol, 10-year Framingham Cardiovascular Risk (CVD risk), daily steps and dietary habits measured by validated food frequency questionnaire.

**Methods:** 129 participants between 35-74 years of age with stage 1 or 2 hypertension were randomly assigned to Control, Expert or User-driven e-Counselling groups. Controls received a weekly general e-message on BP management. The Expert-driven group was prescribed a weekly exercise and a diet plan. The User-driven group received weekly e-messages, which allowed them to choose their intervention goals. Study outcomes were measured during clinical visits at baseline and 4 months.
**Results:** User and Expert-driven groups showed a greater SBP decrease than Controls at follow-up (User-driven vs. Control: -5.7 mmHg [95%CI, -10.1 to -0.6], p=.02; Expert-driven vs. Control: -8.7 mmHg [95% CI, -13.8 to -3.7], p<.001). SBP reduction did not significantly differ between User- and Expert-driven. No significant DBP change was found across groups. However, only Expert-driven compared with Controls showed a significant improvement in PP (-5.1 mmHg [95%CI, -8.9,-1.3], p=0.005), cholesterol (-0.67 mmol/L [95%CI, -1.04,-0.29], p<0.001) and CVD risk (-3.0% [95%CI, -4.7,-1.3], p=0.005). The Expert-driven intervention was more effective than both User-driven and Control groups in increasing daily steps (Expert vs. Control: 2187 steps/day [95%CI, 837, 3538], p<0.001; Expert vs. User: 1671 steps/day [95%CI, 307, 3035], p=0.011) and daily fruit intake (Expert vs. Control: 1.4 servings/day [95%CI, 0.1, 2.7], p<0.001; Expert vs. User: 1.7 steps/day [95%CI, 0.4, 3.1], p=0.011).

**Conclusions:** Expert- and User-driven e-counselling were both effective in reducing SBP. However, the Expert-driven approach was more favourable than the User-driven e-counselling in improving daily steps and vegetable intake in a 4 month intervention. It may be advisable to incorporate an Expert-driven protocol to a self-guided, automated Internet-based intervention in order to accommodate participants with greater motivation to change their lifestyle behaviours.
5.1 Introduction

Hypertension is a leading risk factor for cardiovascular disease and mortality. Lifestyle counselling is recommended as a first line therapy for reducing blood pressure (BP) and risk for cardiovascular events (James et al., 2014; Liakos, Grassos, & Babalis, 2014). Numerous studies suggest that automated, self-guided Internet-based lifestyle counselling (e-counselling) programs can evoke meaningful improvements in daily physical activity (King, Bickmore, et al., 2013; Nolan et al., 2012), dietary behaviours (Nolan et al., 2012; Wangberg, 2008) and resting BP (Green et al., 2008; Liu et al., 2013). These e-counselling programs can offer a promising means of delivering health promotion programs that can reach more individuals at a potentially lower cost than conventional face-to-face programs (Bennett & Glasgow, 2009). However, the effectiveness of e-counselling varies due to treatment protocol (Liu et al., 2013; Neubeck et al., 2009). Certain features of treatment protocol for Internet-based interventions have been found to improve intervention efficacy such as proactively (vs. reactively) contacting the participant with health-related messages or incorporating self-monitoring behaviour techniques (Liu et al, 2013; Webb et al 2010). No studies have evaluated the effects of different types of clinical methods used in Internet-based interventions to help manage hypertension. Clinical methods are the styles or counselling approaches used to deliver a health behaviour intervention, which can influence the way a person feels both cognitively and physically, and consequently may influence intervention efficacy (Miller & Rollnick, 2009).

Based on the broader clinical counselling literature, the two dominant clinical methods for lifestyle e-counselling programs are Expert-driven (protocol-driven, prescriptive) and User-driven (self-guided, collaborative) (Miller & Rollnick, 2009; Liu et al., 2013). Expert-driven programs prescribe specific changes for lifestyle behaviour, which are intended to facilitate adherence to behaviour change. An Expert-driven approach can be advantageous in situations when individuals do not have the necessary experience or knowledge about blood pressure control using lifestyle change. However, based on the trans-theoretical model, this type of approach presumes sufficient motivation in the participant to adhere to e-counselling directives to progress towards behaviour goals (Miller & Rollnick, 2009). In contrast, User-driven e-counselling actively involves the participant in goal-setting and/or the selection of the
intervention used to reach the behavioural goal. This type of approach enables the participant to be more actively focused on intrinsic motivation for change and engage in their self-care. Currently, both clinical methods to promote lifestyle change are used indiscriminately in e-counselling programs (Liu et al., 2013). As a result, there is inadequate data to determine the efficacy of self-guided and automated Internet-based programs that are Expert-driven versus User-driven in reducing BP while modifying lifestyle behaviour. Research in this area is needed to better understand the strengths and limitations of Expert versus User-driven e-counselling programs so that these clinical methods can be most effectively used to reduce blood pressure in patients with hypertension.

The primary objective was to assess whether systolic blood pressure (SBP) improved with Expert-driven or User-driven e-counselling over usual care in patients with hypertension over a 4-month period. Secondary outcomes included diastolic blood pressure (DBP), pulse pressure (PP), proportion of individuals with BP control (SBP < 130mmHg, DBP < 85mmHg), total cholesterol, 10 year Framingham cardiovascular risk, daily physical activity as measured by 4-day step count, and diet as measured by validated food frequency questionnaire. Exploratory analyses also evaluated the relationship between readiness for behaviour change at baseline and the effectiveness of the clinical method protocol. We hypothesized that both Expert- and User-driven e-counselling groups would have a greater improvement than Controls in SBP, DBP, PP, proportion of BP control, cholesterol, 10-year CVD risk and adherence to daily exercise and diet. Additionally, based on the Tran-theoretical model, we hypothesized that the Expert-driven e-counselling protocol would be more effective than User-driven in individuals with higher levels of readiness for change.

5.2 Methods

Design

This study used a 3-parallel group, double blind randomized controlled design: 3 (Groups: Control, Expert-driven, and User-driven e-Counselling) by 2 (Assessments: baseline, 4-month). Participants who had been diagnosed with hypertension were randomly assigned to one
of the three intervention groups. E-counselling emails were sent to the participants weekly during the 4 month period. Ethics approval was obtained from the research ethics board at the University Health Network, Toronto, Canada.

This study was a sub-study of a larger, multi-centered double-blind randomized controlled trial in e-counselling: Reducing risk with e-based support for adherence to lifestyle change in hypertension (Nolan et al., 2013). Randomization was conducted by a computer program (Randomize.net) using randomly permuted blocks. The randomization code was only known to the research coordinator, but not to investigators and the research assistants who administered the assessments. Blinding was maintained during baseline and 4-month follow-up.

**Inclusion/exclusion Criteria**

Participants diagnosed with stage 1 or 2 hypertension (SBP, 140–180mm Hg; DBP 90–110mm Hg) and between the ages of 35-74 years old were recruited. Hypertension diagnoses were confirmed with the participant’s family doctor at baseline if they were not prescribed anti-hypertensive medication. All participants were required to have an unchanged prescription for antihypertensive medication at least 2 months before enrolment. Participants prescribed antihypertensive medication were also required to have SBP ≥130 mmHg and/or DBP ≥85 mmHg, in order to prevent “floor effects”. Exclusion criteria included: diagnosis of kidney disease, major psychiatric illness (e.g. psychosis), alcohol or drug dependence in the previous year, pregnancy, sleep apnea, institutional residence or an inability to comprehend English.

**Recruitment and Assessment Protocol**

Participants were informed about the study through the Heart and Stroke Foundation heart disease risk assessment website as well as posters at the University Health Network facilities. Eligible participants then underwent clinical assessments at the Peter Munk Cardiac Center, Toronto General Hospital, University Health Network. Recruitment took place between June 2012 and June 2014.
Baseline and 4-month follow-up assessments were scheduled between 8:00 am and 12:00 pm to minimize diurnal BP variability. All participants fasted for 12 hours prior to their assessment in order to obtain accurate samples of lipoprotein cholesterol. Participants were also instructed to avoid smoking for at least 4 hours, caffeine for 12 hours and strenuous exercise for 24 hours prior to their assessment. Anthropometric characteristics, medical history, medication information, resting BP, daily physical activity level, dietary behaviour and participants’ readiness for lifestyle behaviour changes were collected during the baseline and 4 month follow-up assessment. Participants’ cardiovascular risk calculated by the Framingham 10-year absolute risk was provided to the participants at the end of each assessment. Participants were also asked for program feedback during follow-up assessments.

Blood pressure was measured by a validated protocol for automated BP assessments with the BpTRU device (Rabi et al., 2011). Participants were seated for at least 5 minutes prior to activation of the BpTRU device. The BP cuff was applied to participants’ left arms by a trained research assistant. Following the initial BP measurement, the research assistant exited the room while the BpTRU device completed an automated series of 5 BP recordings with 1-minute intervals separating each of these recordings. The recorded blood pressure (SBP, DBP) at each assessment interval was the mean of these five BpTRU measurements. PP was determined by the difference between SBP and DBP readings. Adherence to recommended guidelines for daily intake of fruits, vegetables, dairy and total dietary fat was evaluated by the NIH/NCI Diet History Questionnaire (DHQ) (Thompson et al., 2002). Daily physical activity was defined as the mean 4-day steps (3 week day, 1 weekend day) recorded on a pedometer (LifeSource /A&D XL-18CN Activity Monitor) which has been previously validated in this population (Liu, Brooks, Thomas, Eysenbach, & Nolan, 2014). All participants were given the XL-18CN pedometer to use as part of this program.

Readiness for exercise and dietary change were measured using a questionnaire from our previous trial and the stages of change were defined as the following: Pre-contemplation (not ready to adhere to the target behaviour in the next 6 months), Contemplation (ready to adhere to the target behaviour in the next 6 months), Preparation (ready to adhere to the target behaviour in the next 4 weeks), Action (adherence to the behaviour but for less than 6 months), Maintenance (adherence to the behaviour for 6 months or more) (Nolan et al. 2012). Participants were asked to
complete a program feedback questionnaire about the email schedule and program content (Scale 1-5, 1 = not helpful at all, 5 = extremely helpful) as well as written feedback. See Appendix 1 for the detailed assessment package for readiness to change, diet history questionnaire, and program feedback questionnaire.

**Intervention Descriptions**

**User-driven**

The User-driven e-counselling group received weekly e-mails that enabled participants to select their areas of lifestyle change using text and video web links embedded in the email. The transtheoretical model was used to inform the design of the User-driven program. Specifically, the web links contained information about the following: constructing exercise and diet plans (e.g. fruit and vegetable and sodium consumption) based on the Canadian Physical Activity Guidelines (Tremblay et al., 2011), Canada’s Food Guide (Canada's Food Guide, 2014) and Canadian Hypertension Education Program (Dasgupta et al., 2014), setting behavioural goals based on their readiness, resolving ambivalence for change, increasing efficacy for initiating change, and reviewing social and cognitive behaviour skills for relapse prevention to maintain adherence.

A sample of the User-driven program is listed below:

**Week 1** ...from the heart health clinic to your e-home...

*We hope that you will use this program to guide your self-help efforts to control your blood pressure as you think about heart healthy lifestyle change.....*

*We appreciate that you’re the expert on you! The REACH program will provide you with well-researched information and self-help tools for heart healthy living. We encourage you to tailor this counselling to your personal priorities by clicking on the e-links below.*

[Click here]–I want to feel more ready and confident to change my lifestyle

[Click here]–I want self-help tips for exercise
Expert-driven

Participants in the Expert-driven group received the same hypertension management recommendations for lifestyle change as the User-driven group; however, the weekly e-mails consisted of pre-determined exercise and dietary goals (e.g. increase daily steps by 1000 steps, consuming 2-3 servings of fruit and vegetables per day). Specifically, the exercise program was based on the Canadian Physical Activity Guidelines and the Canadian Hypertension Education Program (Tremblay et al., 2011), which consisted of aerobic exercises five times per week, 30 minutes per session at moderate intensity (100 steps/ minute). A lower exercise intensity and shorter duration was recommended in the initial 3 weeks to allow for adaptation. Participants were also recommended to follow Canada’s Food Guide (Canada's Food Guide, 2014) and reduce their sodium intake. The recommended sodium consumption was no more than 2000 mg/day (Canada's Food Guide, 2014; Hackam et al., 2013). The Expert-driven intervention aimed to build participant’s self-efficacy by setting achievable behaviour change goals, providing video and text instructions to help participants model their behaviour, and reviewing behaviour skills to maintain adherence to behaviour change.

A sample of the Expert-driven program is listed below:

**Week 2 Getting Active**

*Welcome to your second week. Congratulations on your ongoing participation in this program for lifestyle change!*
Your physical activity goals this week are:

- Increase your step count by 1000 per day in addition to your baseline steps.
  1000 steps is equal to about 750 meters.
  - Click here for more information

Combining a healthy diet with regular exercise will allow you to receive the maximum amount of health benefits.

Your Nutrition goals this week are:

Add 1-2 servings of vegetables and 1-2 servings of fruit if you have not reached the recommended daily intake by the Canada’s Food Guide.

To accomplish this goal, you can find out more about:

[Click here]– Tips to choose and prepare vegetables.

[Click here]– Shopping tips

[Click here]– Vegetable Recipes

Control

The Control group received weekly e-mails provided by the Heart and Stroke Foundation e-Health program that contained a brief newsletter article regarding BP management through lifestyle changes. The Control group was distinct from the intervention groups as the e-mails were limited to general information on blood pressure management.
**Week 2 Understand why it is important to manage your blood pressure.**

Just because you have high blood pressure doesn’t mean you will develop heart disease or have a stroke. However, it does significantly increase the risk of developing these diseases: High blood pressure is the number one controllable risk factor for stroke, increasing the risk by three or four ..... 

.... By taking your medication as prescribed and making some lifestyle changes, you can bring your blood pressure down to a healthy range and reduce your risk of developing heart disease, stroke and kidney disease.....

**Statistical Analysis**

Differences in baseline characteristics were evaluated by Pearson’s chi-squared test for categorical variables and F-test for continuous variables. For our primary outcome (SBP), the difference among groups was evaluated using multivariate linear regression adjusted for baseline outcome measures (e.g. SBP at baseline) and baseline characteristic that were significantly related to either the outcome of interest or the intervention groups. Post-hoc comparisons among the 3 treatment groups were performed only if the overall F test was significant. To protect against type 1 error, the Bonferonni adjustment was used. Secondary outcomes (DBP, blood pressure control, PP, total cholesterol, 10 year Framingham CVD risk, daily steps, daily fruit and vegetable consumption) followed a similar statistical approach as the primary outcome analysis.

Blood pressure control was defined as whether SBP and DBP was less than 135mmHg and 85 mmHg, respectively. Logistic regression model was used to assess whether individuals achieved blood pressure control among the groups adjusted for baseline outcomes measures. A univariable linear regression model was used to evaluate the relationship between levels of readiness for behaviour change and the effectiveness of User- and Expert-driven e-counselling.
The study was powered to detect clinical meaningful differences in SBP of 5 mmHg with an SD of 8 mmHg between Control and User-driven or Expert-driven groups (Park et al., 2009). This sample size estimated that a total of 114 participants were required for the 3 groups with 80% power to detect difference in SBP and a 5% type 1 error rate. We anticipated 20% attrition rate prior to the beginning of our recruitment. However, the actual attrition rate was only 10% throughout the trial. Therefore, a total of 129 participants were recruited. Missing at random assumption was made since there was no significant difference of baseline value for participants with missing outcome data versus completers (Table 5.1). Final analyses were performed on those participants with complete follow-up. A sensitivity analysis was performed using the last-observation-carried-forward assumption. Statistical significance was defined by a 2-tailed test with a p value <0.05. All analyses were performed using SPSS 19.0 (SPSS Inc.).

5.3 Results

The flow of the participants through the study is displayed in Figure 5.1. Recruitment emails were sent to 1745 participants who expressed interest in the study. Of those contacted by telephone and answering the telephone screening questions, 305 of 847 (36%) were ineligible because they were not diagnosed with hypertension. Of those remaining eligible after the telephone screening interview, 226 of 847 (27%) agreed to a clinic screening appointment. Of the participants who showed up for the appointment, 63 of 192 (33%) did not meet our blood pressure requirement. A total of 129 participants were randomized for the study and 116 (90%) completed the 4 month follow-up visit. Demographic characteristics of the study groups were similar at baseline (p >0.10; Table 5.1). Withdrawal rates (Control = 4, 9%; User = 5, 12%; Expert=4, 9%; p=0.79) and baseline characteristics did not differ significantly between those who completed the follow-up versus those who did not (Table 5.2).

The prevalence of racial minorities (28%) in this study underrepresented the distribution in the Greater Toronto Area but this is similar to the census survey in the surrounding southern Ontario area (Canada, 2011). There were 52% (n=67) female participants and the mean age (±SE) for the full sample was 56.87 ±0.83 years. Baseline SBP, DBP, PP, Cholesterol and 10-year Framingham CVD risk were similar across all three groups. Antihypertensive medication was
prescribed to 88% (n=109) of participants. There was a low prevalence of change in antihypertensive medication from baseline to 4 month follow-up (5%; n=7). Daily steps, and fruit and vegetable consumption were similar between the groups at baseline. The number of participants who achieved more than 10 000 steps per day at baseline (17%, n=23) was less than the Canadian norm (33%)(Colley et al., 2010). However, the number of participants who reported consumption of 5 or more servings of daily fruit and vegetable (71%, n=92) at baseline was higher than the Canadian norm (40%)(Canada, 2012).
847 Participants completed telephone screening interview

226 Patients assessed for baseline visit

Excluded: 621
305 did not meet inclusion criteria
178 refused to participate
138 travel distance

Excluded: 97
63- BP controlled
34 - no show

129 Randomized

43 Randomized to receive Expert-driven treatment
Study Completion: 39

43 Randomized to receive Control treatment
Study Completion: 39

43 Randomized to receive User-driven treatment
Study Completion: 38

**Figure 5.1:** Flow of participants through recruitment, intervention and follow-up assessment.
### Table 5.1: Baseline Characteristics

<table>
<thead>
<tr>
<th>Variables</th>
<th>Total (n=129)</th>
<th>Control (n=43)</th>
<th>User-driven (n=43)</th>
<th>Expert-Driven (n=43)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>56.87±0.83</td>
<td>55.30±1.38</td>
<td>57.74±1.47</td>
<td>57.56±1.48</td>
<td>0.42</td>
</tr>
<tr>
<td>Female sex</td>
<td>67 (52%)</td>
<td>24 (56%)</td>
<td>21 (49%)</td>
<td>22 (52%)</td>
<td>0.81</td>
</tr>
<tr>
<td>Household Income (CAD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤$29,999</td>
<td>16 (12.4%)</td>
<td>7 (5.4%)</td>
<td>6 (4.7%)</td>
<td>3 (2.4%)</td>
<td></td>
</tr>
<tr>
<td>$30,000-59,999</td>
<td>23 (24.0%)</td>
<td>12 (9.3%)</td>
<td>8 (6.2%)</td>
<td>19 (14.7%)</td>
<td>0.63</td>
</tr>
<tr>
<td>$60,000-89,999</td>
<td>30 (23.3%)</td>
<td>11 (8.5%)</td>
<td>10 (7.8%)</td>
<td>9 (7.0%)</td>
<td></td>
</tr>
<tr>
<td>≥$90,000</td>
<td>52 (40.3%)</td>
<td>13 (10.1%)</td>
<td>19 (14.7%)</td>
<td>20 (15.5%)</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤12 y Or High School</td>
<td>26 (20.2%)</td>
<td>9 (7.0%)</td>
<td>13 (10.1%)</td>
<td>4 (3.1%)</td>
<td></td>
</tr>
<tr>
<td>College/University</td>
<td>72 (55.8%)</td>
<td>26 (20.2%)</td>
<td>18 (14.0%)</td>
<td>28 (21.7%)</td>
<td>0.10</td>
</tr>
<tr>
<td>Graduate School</td>
<td>31 (24.0%)</td>
<td>8 (6.2%)</td>
<td>12 (9.3%)</td>
<td>11 (8.5%)</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>94 (72.9%)</td>
<td>30 (69.8%)</td>
<td>33 (76.7%)</td>
<td>31 (72.1%)</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>8 (6.2%)</td>
<td>4 (3.1%)</td>
<td>2 (1.6%)</td>
<td>2 (1.6%)</td>
<td></td>
</tr>
<tr>
<td>South Asian</td>
<td>10 (7.8%)</td>
<td>4 (9.3%)</td>
<td>2 (4.7%)</td>
<td>4 (9.3%)</td>
<td>0.62</td>
</tr>
<tr>
<td>Asian</td>
<td>6 (4.7%)</td>
<td>1 (0.8%)</td>
<td>1 (0.8%)</td>
<td>4 (9.3%)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>11 (8.5%)</td>
<td>4 (9.3%)</td>
<td>5 (11.6%)</td>
<td>2 (1.7%)</td>
<td></td>
</tr>
<tr>
<td>Current Smoker</td>
<td>6 (4.7%)</td>
<td>2 (1.6%)</td>
<td>3 (2.3%)</td>
<td>1 (0.8%)</td>
<td>0.86</td>
</tr>
<tr>
<td>≥1 antihypertensive Medications</td>
<td>109 (85%)</td>
<td>36 (84%)</td>
<td>37 (86%)</td>
<td>36 (84%)</td>
<td>0.94</td>
</tr>
<tr>
<td>Beta- Blockers</td>
<td>14 (10.9%)</td>
<td>3 (7.0%)</td>
<td>7 (16%)</td>
<td>4 (9.3%)</td>
<td>0.35</td>
</tr>
<tr>
<td>Calcium Channel Blocker</td>
<td>24 (18.6%)</td>
<td>9 (20.9%)</td>
<td>8 (18.6%)</td>
<td>7 (16.3%)</td>
<td>0.86</td>
</tr>
<tr>
<td>Angiotensin-converting enzyme</td>
<td>48 (37.2%)</td>
<td>14 (32.6%)</td>
<td>18 (41.9%)</td>
<td>16 (37.2%)</td>
<td>0.67</td>
</tr>
<tr>
<td>inhibitor</td>
<td>39 (30.2%)</td>
<td>12 (27.9%)</td>
<td>15 (34.9%)</td>
<td>12 (27.9%)</td>
<td>0.72</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>********</td>
<td>********</td>
<td>********</td>
<td>********</td>
<td>********</td>
</tr>
<tr>
<td>Angiotensin II receptor blocker</td>
<td>32 (24.8%)</td>
<td>13 (30.2%)</td>
<td>8 (18.6%)</td>
<td>11 (25.6%)</td>
<td>0.45</td>
</tr>
<tr>
<td>Diuretic</td>
<td>20 (15.5%)</td>
<td>7 (16.3%)</td>
<td>8 (18.6%)</td>
<td>5 (11.6%)</td>
<td>0.65</td>
</tr>
<tr>
<td>Lipid-Lowering Medications</td>
<td>30.64 ±0.51</td>
<td>29.94 ±0.87</td>
<td>30.90 ±0.83</td>
<td>31.10 ±0.94</td>
<td>0.61</td>
</tr>
<tr>
<td>Body Mass Index (kg/m2)</td>
<td>139.4±1.1</td>
<td>140.3±2.01</td>
<td>137.5±1.67</td>
<td>140.2±2.05</td>
<td>0.50</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>88.8 ±0.85</td>
<td>87.40±1.34</td>
<td>87.93±1.48</td>
<td>89.40±1.61</td>
<td>0.61</td>
</tr>
<tr>
<td>Diastolic Blood pressure (mmHg)</td>
<td>51.1±0.98</td>
<td>52.90±1.86</td>
<td>49.58±1.63</td>
<td>50.88±1.57</td>
<td>0.38</td>
</tr>
<tr>
<td>Pulse Pressure (mmHg)</td>
<td>5.02±0.09</td>
<td>5.03±0.17</td>
<td>5.04±0.14</td>
<td>5.01±0.13</td>
<td>0.99</td>
</tr>
<tr>
<td>Cholesterol (mmol/L)^a</td>
<td>14.7 ±0.65</td>
<td>13.4±1.04</td>
<td>15.5±1.12</td>
<td>15.5±1.23</td>
<td>0.31</td>
</tr>
<tr>
<td>10 year Framingham CVD Risk (%)^a</td>
<td>7431±21</td>
<td>7911±533</td>
<td>7105±448</td>
<td>7270±422</td>
<td>0.43</td>
</tr>
<tr>
<td>Daily Steps (Steps/day)</td>
<td>4.30±0.23</td>
<td>4.29±0.40</td>
<td>3.95±0.39</td>
<td>4.6±0.40</td>
<td>0.44</td>
</tr>
<tr>
<td>Daily Fruit Intake(servings/day)^b</td>
<td>3.45±0.19</td>
<td>3.50±0.35</td>
<td>3.24±0.37</td>
<td>3.61±0.29</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Data are presented as mean ±SE or number of participants (percentage)

^a Missing data from 1 participant in User-driven group

^b Missing data from 2 participants in the Control group
Table 5.2: Baseline characteristics between completers vs. non-completers (Mean ±SE)

<table>
<thead>
<tr>
<th></th>
<th>Completers (n=116)</th>
<th>Non-completers (n=13)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>57 ±0.90</td>
<td>54±1.8</td>
<td>0.20</td>
</tr>
<tr>
<td>Sex (Female)</td>
<td>57 (50%)</td>
<td>10(67%)</td>
<td>0.28</td>
</tr>
<tr>
<td>Household Income (1&lt;20k, 10≥100K)</td>
<td>7.5±0.27</td>
<td>7.5±0.63</td>
<td>0.97</td>
</tr>
<tr>
<td>Education (&lt;12 Completed high school, &gt;16 completed undergraduate university)</td>
<td>16.3±0.26</td>
<td>15.0±0.73</td>
<td>0.10</td>
</tr>
<tr>
<td>Body Mass Index (kg/m2)</td>
<td>30.4±0.54</td>
<td>32.4±1.2</td>
<td>0.19</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>139±1.2</td>
<td>141±2.3</td>
<td>0.56</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>88±9.7</td>
<td>89±9.7</td>
<td>0.81</td>
</tr>
<tr>
<td>10 year CVD risk (%)</td>
<td>15.2±0.85</td>
<td>13.7±1.6</td>
<td>0.41</td>
</tr>
<tr>
<td>Daily step count (steps/day)</td>
<td>7546±288</td>
<td>6563±779</td>
<td>0.25</td>
</tr>
<tr>
<td>Daily Fruit and Vegetable (servings/day)</td>
<td>7.8±0.39</td>
<td>7.7±0.85</td>
<td>0.87</td>
</tr>
<tr>
<td>Mean Readiness for regular exercise and physical activity</td>
<td>4.0±0.75</td>
<td>3.9±0.84</td>
<td>0.71</td>
</tr>
<tr>
<td>Mean Readiness for a healthy diet</td>
<td>3.9±0.07</td>
<td>3.9±0.15</td>
<td>0.89</td>
</tr>
</tbody>
</table>
Blood Pressure and Cardiovascular outcomes

Blood pressure outcomes at 4 months are displayed in Table 5.3. Both User- and Expert-driven groups demonstrated a greater SBP reduction than Controls (mean difference between User-drive vs. Control: -5.7 mmHg [95% CI, -10.1 to -0.6], p=0.02; Expert-driven vs. Control: -8.7 mmHg [95% CI, -13.8 to –3.7], p<0.001). The magnitude of SBP reduction did not significantly differ between User- and Expert-driven (P>0.05). DBP reduction was not significantly different across groups. Expert- and User-driven groups were 4.0 and 5.1 times more likely to achieve BP control (defined as SBP<130mmHg and DBP<85mmHg) relative to control. Sensitivity analysis using baseline BP values for those who did not complete follow-up showed similar results (Table 5.4). The differences among groups were slightly attenuated.

Only the Expert-driven group demonstrated a significant reduction compared with Controls in PP (-5.1 mmHg [95%CI, -8.9,-1.3], p=0.005), cholesterol (-0.67 mmol/L [95%CI, -1.04,-0.29], p<0.001), 10 year Framingham cardiovascular disease risk (-3.0% [95%CI, -4.7,-1.3], p=0.005) (Table 5.3).

Lifestyle Behaviour Outcomes

Changes in daily steps and fruit and vegetable consumptions were displayed in Table 4.5. The Expert-driven group showed a significantly greater improvement than both Controls and the User-driven group in daily steps (Expert vs. Control: 2187 steps/day [95%CI, 837, 3538], p<0.001; Expert vs. User: 1671 steps/day [95%CI, 307, 3035], p=0.01) and servings of fruit consumption (Expert vs. Control: 1.4 servings/day [95%CI, 0.1, 2.7], p<0.001; Expert vs. User: 1.7 steps/day [95%CI, 0.4, 3.1], p=0.01).
Table 5.3: Cardiovascular Outcomes at 4 months for all participants completing clinic follow-up

<table>
<thead>
<tr>
<th></th>
<th>Control (n=39)</th>
<th>User-driven (n=38)</th>
<th>Expert (n=39)</th>
<th>Overall p-value</th>
<th>Control vs. User</th>
<th>Control vs. Expert</th>
<th>Expert vs. User</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP (mmHg)</td>
<td>136.5(132.0,140.9)</td>
<td>128.8(125.7,132.0)</td>
<td>127.8(124.2,131.4)</td>
<td>.002</td>
<td>.014</td>
<td>.004</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted mean</td>
<td>-3.1(-6.0,-0.3)</td>
<td>-8.8(-11.7,-5.9)</td>
<td>-11.9(-14.9,-8.9)</td>
<td>&lt;.001</td>
<td>.023</td>
<td>&lt;0.001</td>
<td>.45</td>
</tr>
<tr>
<td>change&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>84.4(81.1,87.8)</td>
<td>83.0(80.5,85.5)</td>
<td>81.3(78.3,84.2)</td>
<td>.303</td>
<td>1.0</td>
<td>.71</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted mean</td>
<td>-4.7(-7.3,-2.1)</td>
<td>-5.2(-7.8,-2.7)</td>
<td>-6.9(-9.1,-4.4)</td>
<td>.10</td>
<td>.23</td>
<td>.11</td>
<td>.22</td>
</tr>
<tr>
<td>change&lt;sup&gt;a&lt;/sup&gt;</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PP (mmHg)</td>
<td>51.7(47.7,55.6)</td>
<td>45.8(43.2,48.5)</td>
<td>46.5(43.4,48.6)</td>
<td>.023</td>
<td>.04</td>
<td>.06</td>
<td>1.0</td>
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<tr>
<td></td>
<td>Adjusted mean</td>
<td>Proportion of controlled BP</td>
<td>Cholesterol</td>
<td>10 year CVD risk</td>
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<td></td>
<td>change&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>Unadjusted mean</td>
<td>0.20(-3.0,3.4)</td>
<td>-3.5(-5.7,-1.2)</td>
<td>5.4(5.0,5.8)</td>
<td>13.2(11.1,15.4)</td>
<td></td>
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<tr>
<td>Adjusted mean</td>
<td>0.29(0.07,0.50)</td>
<td>-0.04(-0.26,1.76)</td>
<td>5.0(4.6,5.3)</td>
<td>13.4(11.1,15.8)</td>
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<tr>
<td>change&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td>-0.38 (-0.59,-0.16)</td>
<td>4.7(5.4,5.0)</td>
<td>12.2(10.3,14.2)</td>
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<td></td>
<td></td>
<td>&lt;0.001</td>
<td>0.71</td>
<td>0.71</td>
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<td></td>
<td></td>
<td></td>
<td>0.40</td>
<td>&gt;1.0</td>
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<td></td>
<td></td>
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<td>0.02</td>
<td>&gt;1.0</td>
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<td></td>
<td></td>
<td>0.69</td>
<td>&gt;1.0</td>
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<td>0.27</td>
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<td>0.02</td>
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<td>&lt;0.001</td>
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<td>0.08</td>
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<td></td>
<td></td>
<td>&lt;0.001</td>
<td>0.18</td>
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</tbody>
</table>

<sup>a</sup>Adjusted for Baseline outcome, age, Sex, medication

<sup>b</sup>Defined as systolic and diastolic BP lower than 130 and 85 mmHg, respectively.

<sup>c</sup>Missing Data from 1 participant from control and User-driven and 2 participants from Expert-driven groups
Table 5.4: Sensitivity Analysis for primary outcome

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>User-driven</th>
<th>Expert</th>
<th>Overall p-value</th>
<th>Control vs. user</th>
<th>Expert vs. User</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP</td>
<td>-2.8 (-5.6,-0.11)</td>
<td>-7.7 (-10.5,-4.9)</td>
<td>-10.7 (-13.4,-7.9)</td>
<td>&lt;0.001</td>
<td>0.05</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DBP</td>
<td>-3.1 (-5.0,-1.2)</td>
<td>-4.9 (-6.7,2.9)</td>
<td>-6.0 (-7.9,4.1)</td>
<td>0.11</td>
<td>0.60</td>
<td>0.11</td>
</tr>
<tr>
<td>Proportion of controlled BP</td>
<td>1 [reference]</td>
<td>3.6 (1.3,10)</td>
<td>5.0 (1.7,14.9)</td>
<td>0.009</td>
<td>0.02</td>
<td>0.003</td>
</tr>
</tbody>
</table>
Table 5.5: Behavioural Outcome at 4 months for all participants completing clinic follow-up

<table>
<thead>
<tr>
<th></th>
<th>Control (n=38)</th>
<th>User-driven (n=37)</th>
<th>Expert (n=37)</th>
<th>Overall p-value</th>
<th>Control vs. User</th>
<th>Control vs. Expert</th>
<th>Expert vs. User</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Daily Steps</strong></td>
<td></td>
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<tr>
<td>Unadjusted mean</td>
<td>7854(6697,9011)</td>
<td>7432(6331,8533)</td>
<td>9919(8739,11099)</td>
<td>.006</td>
<td>1.0</td>
<td>0.03</td>
<td>.007</td>
</tr>
<tr>
<td>Adjusted mean</td>
<td>-95 (-854,633)</td>
<td>420(-350,1192)</td>
<td>2092(1307,2876)</td>
<td>&lt;0.001</td>
<td>1.0</td>
<td>&lt;0.001</td>
<td>.011</td>
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<tr>
<td>Change\textsuperscript{a}</td>
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<tr>
<td><strong>Daily Fruit intake\textsuperscript{b}</strong></td>
<td></td>
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<tr>
<td>Unadjusted mean</td>
<td>4.2 (3.2,5.2)</td>
<td>3.7(3.2,4.3)</td>
<td>5.7(4.9,6.6)</td>
<td>.002</td>
<td>1.0</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>Adjusted mean</td>
<td>0.82 (-0.1, 1.6)</td>
<td>0.48(-0.3,1.3)</td>
<td>2.2(1.4,3.0)</td>
<td>0.005</td>
<td>1.0</td>
<td>0.037</td>
<td>.006</td>
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<td>Change\textsuperscript{a}</td>
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<tr>
<td><strong>Daily Vegetable intake\textsuperscript{b}</strong></td>
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<tr>
<td>Unadjusted mean</td>
<td>4.6(3.6,5.6)</td>
<td>4.9(3.8,5.9)</td>
<td>4.4(3.9,4.9)</td>
<td>.77</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Adjusted mean</td>
<td>0.51 (-0.1,1.2)</td>
<td>1.1 (0.37,17)</td>
<td>0.34 (-0.33,1.0)</td>
<td>.31</td>
<td>.80</td>
<td>1.0</td>
<td>.42</td>
</tr>
<tr>
<td>Change\textsuperscript{a}</td>
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\textsuperscript{a}Adjusted for Baseline outcome, age, sex, motivation (mean readiness for exercise or diet)

\textsuperscript{b}Missing Data from 2 participants from Control and 1 participant from User-driven groups
Readiness for Behavioural Change

All participants recruited were highly motivated at baseline for adopting a healthy lifestyle (Figure 5.2 a, b). The percentage of participants that were already in the action stages (action or maintenance) of readiness for exercise and diet were 67% (n=86) and 54% (n=70), respectively. Only 3% (n=4) and 8% (n=10) of participants were in the pre-contemplation and contemplation stages of readiness at baseline for exercise and diet, respectively.

The distribution of readiness for change at 4 month follow-up was similar among the groups Figure 5.2 c, d. Overall, the number of participants who stayed in or who moved towards action stages (action, maintenance stages of readiness for change) at 4 months for exercise and diet were 82% (n=92) and 74% (n=82), respectively (Figure 5.3).

We did not find that the levels of readiness at baseline influenced the effectiveness of User-or Expert-driven protocol in reducing SBP, DBP, PP, 10 year CVD risks, daily steps and daily servings of fruit and vegetable intake. Due to the limited number of individuals in early stages of readiness for change, this may have limited our ability to detect statistical difference. However, the mean readiness for regular physical activity at baseline was significantly correlated with reduction in SBP (r=-0.24, p=0.01), and increase in daily steps at 4 months (r=0.42, p<0.001). The mean baseline readiness to change a healthy diet was significantly correlated to total fruit (r=0.22, p=0.03) and vegetable (r=0.37, p<0.001) consumption at 4 months.
**Figure 5.2:** Distribution of readiness for exercise and diet at baseline and 4 month; PC/c, pre-contemplation/contemplation; P, Preparation; A, Action; M, Maintenance;

**Figure B** Baseline distribution of readiness for exercise (number of participants (percentage):

Control: PC/C=3 (7%) P= 11 (26%) A=18 (42%) M= 11(25%); User-driven: PC/C=1 (2%) P= 19 (44%) A=14 (33%) M= 9(21%); Expert-driven: PC=0 (0%) P= 9 (21%) A=21 (49%) M= 13(30%); $\chi^2(6, N = 129) = 9.9, p = .13$.

**Figure B** Baseline distribution of readiness for diet (number of participants (percentage):

Control: PC/C=3 (7%) P= 18 (41%) A=17 (40%) M= 5(12%); User-driven: PC/C =4 (9%) P= 17 (40%) A=19 (44%) M= 3(7%); Expert-driven: PC/C =3 (7%) P= 14 (33%) A=14 (33%) M= 12(27%); $\chi^2(6, N = 129) = 8.2, p = .22$. 
**Figure C** 4-month distribution of readiness for exercise (number of participants (percentage):

Control: PC/C =1 (3%) P=6 (15%) A=17 (45%) M= 14(37%); User-driven: PC/C =3 (8%) P= 5 (13%) A=21 (57%) M=8(22%); Expert-driven: PC/C =0 (0%) P=5 (13%) A=16 (43%) M= 16(43%); $\chi^2(6, N = 112) = 7.2., p = .31.$

**Figure D** 4-month distribution of readiness for diet (number of participants (percentage):

Control: PC/C =4 (10%) P= 5 (13%) A=20 (53%) M= 9(24%); User-driven: PC/C =3 (8%) P= 10 (27%) A=16 (43%) M= 8(21%); Expert-driven: PC/C =4 (11%) P= 4 (11%) A=19 (51%) M= 10(27%); $\chi^2(6, N = 112) = 4.1, p = .66.$
Figure 5.3: Change in readiness for exercise (a) and diet (b) following the e-counselling intervention

Figure A) Change in readiness for exercise (number of participants (percentage):

Moved to Pre-action from Action: Control: 3(8%)User-Driven:2(5%)Expert-Driven:2(5%); Stayed in Pre-action: Control:4(10%)User-Driven:6(17%)Expert-Driven: 3(8%); Stayed in action or moved into action: Control:31(82%)User-Driven:29(78%)Expert-Driven:32(87%); $\chi^2(4, N = 112) = 1.5, p = .83$. 

![Graph showing change in readiness for exercise and diet following the e-counselling intervention.](image-url)
**Figure B** Change in readiness for diet (number of participants (percentage)):

Moved to Pre-action from Action: Control: 2(5%) User-Driven:0(0%) Expert-Driven:2(5%);
Stayed in Pre-action: Control:7(18%) User-Driven:13(35%) Expert-Driven:6(17%);
Stayed in action or moved into action: Control:29(77%) User-Driven:24(65%) Expert-Driven:29(78%);

$\chi^2(4, N = 112) = 5.9, p = .20$. 

![Bar chart showing change in readiness for diet](chart.png)
Program Feedback

Program feedback was completed by 75% (n=87) of the participants. The overall satisfaction was defined as the degree to which the e-counselling program helped participants to feel more confident to begin or maintain their lifestyle change. The participants’ ratings (Scale 1-5, 1=not helpful at all, 5=extremely helpful) for the email schedule and the program content were positive and similar across groups (Mean ±SE; Email Schedule: Control: 3.2 ±0.18, User: 3.1 ±0.23, Expert: 3.3 ±1.14, p=0.62; Program content: Control 3.1 ±0.19, User: 2.9 ±1.1, Expert: 3.2 ±0.8, p=0.44). Additional written feedback on the specific components of the program was provided by 38% (n=33) of the participants. Qualitative content analysis showed that some participants (n=10) in the Control group found the behaviour change content useful but it was too generic and basic. A common trend among participants (n=7) in the Control group found that it was the schedule of the weekly email reminders (not the content) that helped them change or maintain their lifestyle. In the User-driven group, the most prevalent feedback was that participants would have liked to see more specific strategies on behaviour change (n=5). In the Expert-driven group, several participants (n=16) said that the weekly incremental changes in exercise and dietary goals were helpful; however, some participants (n=5) found the weekly behaviour goals either too challenging or too easy.
5.4 Discussion

We evaluated the effectiveness of Expert and User-driven e-counselling methods on improving blood pressure and lifestyle behaviours for individuals with hypertension. The results of this study showed that both Expert-driven and User-driven programs were effective in reducing SBP (primary outcome) relative to Controls at the 4-month follow-up. However, only the Expert-driven group showed a significant difference compared to Controls in improving PP, cholesterol and 10-year CVD risk. Additionally, the Expert-driven intervention was more effective than both User-driven and Control groups in improving behavioural outcome of daily steps and fruit consumption.

Our study findings support previous research that self-guided Internet-based interventions can improve blood pressure control and promote healthy lifestyle change (Morgan et al., 2009; Nolan et al., 2012; Park et al., 2009; Pressler et al., 2010). This study demonstrated that the clinical method (Expert- and User-driven protocol) used to deliver e-counselling can influence the effectiveness of the Internet-based intervention. Our findings indicate that an Expert-driven Internet-based program was overall more favourable than User-driven during a 4-month period among participants with increased motivation for change. The magnitudes of blood pressure reduction for both Expert and User-driven groups were comparable to interventions of similar length and procedure. Park et al., (2009) reported that a 2-month Expert-driven Internet-based lifestyle program significantly reduced SBP by 9.1 mmHg. Meanwhile, Nolan et al., (2012) reported a reduction in SBP of 8.9 mmHg in a 4-month User-driven lifestyle program. There may be several factors that contributed to the success of the Expert-driven group.

First, it is worth noting that the majority of the participants (~73%) who joined the study were already in preparation and action stages. Based on the trans-theoretical model of change, individuals in these stages are ideal candidates receiving directed interventions for behaviour change (Expert-driven) (Prochaska & Velicer, 1997). Guiding the participant based on their motivation for change and associated change goals (user-driven approach) may be more important for those in the pre-contemplation or contemplation stages of readiness. Due to the limited number of participants in the earlier stages of readiness for healthy lifestyle change, our ability was limited in finding the influence of baseline readiness on the effectiveness of User-or Expert-driven protocols. The distribution of readiness for exercise and diet observed in this study does not represent the typical distribution in the general public which ranged between 15-30% in pre-
contemplation, 9-19% in contemplation, 10-20% preparation, 4-10% in action and 40-50% in maintenance (Laforge, Velicer, Richmond, & Owen, 1999). The elevated number of motivated participants in our sample may have resulted from our self-referral recruitment process (as opposed to referral from health care providers) (Ganguli, Lytle, Reynolds, & Dodge, 1998). In order to implement Internet-based interventions on a population level, future studies need to examine the effects of User- and Expert-driven methods of e-counselling on individuals with lower levels of readiness.

Second, the User-driven lifestyle approach may not have reached its full potential in creating a collaborative support environment by using automated email messages and video links alone. A recent meta-analysis by our team found that significant incremental SBP reduction was observed when the e-counselling program incorporated: educational feedback that clarified how behaviour influenced the person’s health status; self-monitoring of a targeted behaviour; instructions on how to perform behaviour change; and performance-based behavioural feedback. The User-driven e-counselling in this study contained these features, however, providing performance-based feedback and reinforcing user-selected behaviours that are linked to goals identified for change was lacking in our current program due to technical limitations. The User-driven e-counselling program allowed the participants to choose the areas that they would like to focus on but the program was not able to introduce relevant feedback or new health content once the participants reviewed all the material. In contrast, in the Expert-driven program, participants were prescribed pre-determined exercise and dietary weekly goals that built on the previous week’s goals. In retrospect, this may have acted as a degree of performance-based feedback, which was lacking in the User-driven group. Based on the scientific statement on preventive counselling by the American Heart Association, providing performance-based feedback can help tailor the intervention to the participant is one of the key components for counselling that are derived from the well-established models of cognitive-behavioural therapy and motivational interviewing (Artinian et al., 2010). A recent meta-analysis reported that dynamically tailored computer-based interventions were more effective than static interventions in promoting physical activity and a healthy diet (Krebs, Prochaska, 2010). A potential area of future research in Internet-based interventions is to investigate the effectiveness of incorporating performance-based feedback into a User-driven protocol. In addition, recent studies have shown that using animated characters tailored to participants’ cultures may be required to further enhance the effectiveness of User-driven programs (King, Bickmore, et al., 2013).
Third, multiple targets of behaviour change (e.g. exercise intensity, duration and frequency, types of food to consume) are required for effective hypertension management (Rabi et al., 2011). A meta-analysis has shown that targeting both exercise and diet behaviours simultaneously is more effective in lowering cardiovascular risk than targeting exercise or diet alone (Sweet & Fortier, 2010). An Expert-driven approach may be more effective by simplifying weekly behaviour change goals for both exercise and diet right from the beginning of the program. Participants in the User-driven group would be required to construct their own exercise and dietary plans after learning about current guidelines. Consequently, the participants may not have constructed a program that benefits from the weekly progressive exercise and dietary goals similar to the Expert-driven protocol. However, despite the success of the Expert-driven protocol, some participants did find the program difficult to follow due to differences in behaviour skills and rate of progression. An optimal Internet-based intervention may require a hybrid of Expert- and User-driven protocols in order to overcome this challenge. An Expert-driven protocol may be recommended to individuals who are motivated, while User-driven features such as enabling the participants to choose the degree of progression for weekly exercise or dietary goals may be necessary. Future studies are warranted in examining the effects of a combined Expert and User-driven program.

A limitation of the present study was that the majority of participants recruited were motivated for healthy lifestyle change. Therefore, our findings may be limited to participants who are motivated for healthy lifestyle change. Another limitation was that our follow-up period was limited to 4 months. It may be possible that expert- and user-driven protocols may be most beneficial at various time periods of the behaviour change process. Thus, future studies should assess the long-term intervention (12-month) effects of User- and Expert-driven protocols. Furthermore, this study only assessed servings of fruit and vegetable consumption at baseline and follow-up. A more comprehensive dietary assessment could have also provided information about sodium intake and other food groups such as grain, dairy and meat consumption. Finally, objective longitudinal engagement data was not examined in this study. The influence of Expert and User-driven protocols on user-engagement with the Internet-based program remains unclear. Our aim in future studies is to address the pattern of engagement overtime with User- and Expert-driven protocols.
5.5 Conclusion

Since self-guided Internet-based interventions do not involve in-person contact, they have the potential to be delivered on a population level. In this study, Expert- and User-driven e-counselling were both effective in reducing systolic blood pressure. However, the Expert-driven approach was more favourable than User-driven e-counselling in improving daily steps and vegetable intake in a 4-month intervention. It may be advisable to incorporate an Expert-driven protocol to a self-guided Internet-based intervention in order to accommodate participants with greater motivation to change their lifestyle behaviours. It is important to note that the participants recruited in this study were motivated to adopt a healthier lifestyle. Thus, in order to implement Internet-based interventions on a population level, future studies need to examine the influence of clinical methods used in individuals with various levels of motivation.
A healthy lifestyle is a critical part in managing hypertension (Liakos et al., 2014). The rapid growth and adoption of the Internet presents an incredible opportunity for delivering these lifestyle interventions aimed at hypertension management without overtaxing health care resources (Bennett & Glasgow, 2009). The overall aims of this thesis were to identify and evaluate intervention protocol design strategies to enhance the effectiveness of a self-guided Internet-based hypertension management program. Specifically, three research studies were conducted which included: 1) a meta-analysis examining the effectiveness of BP reduction using Internet-based Interventions (Chapter 3), 2) validation of a physical activity monitor (XL-18 Lifesource) used in an Internet-based health intervention (chapter 5) for patients with hypertension and 3) a randomized controlled trial examining the effectiveness of Expert vs. User-driven Internet-based interventions in managing hypertension (Chapter 5).

The meta-analysis conducted in Chapter 3, to our knowledge, is the first that examined the effectiveness of Internet-based interventions in reducing SBP and DBP in individuals with elevated resting BP. The results add to the current body of literature demonstrating the effectiveness of Internet-based interventions, which includes treating a range of health-related problems such as anxiety (Botella et al., 2004), depression (Clarke et al., 2005), body image (Celio et al., 2002), insomnia (Celio et al., 2002), back pain (Buhrman et al., 2004) and diabetes (Barrera et al., 2002).

Our meta-analysis showed that self-guided Internet-based lifestyle modification programs could significantly reduce resting SBP and DBP relative to control, and the magnitude of BP reduction was comparable to previous meta-analyses of face-to-face lifestyle counselling programs. However, a challenge for Internet-based interventions aimed at BP control was that the effectiveness varied depending on intervention protocol design. As mentioned in the literature review, the various components of the intervention protocol that could influence intervention efficacy included: intervention duration (< 6 months or ≥6 months), method of delivery (proactive vs. reactive), supplemental components (e.g. in-person, text-message, telephone), behaviour targets (exercise or diet), behaviour theories and techniques and clinical methods (Expert-, User-driven protocol) (Ritterband et al., 2009).
Results from this thesis suggest that there were several intervention protocol components that were associated with increased effectiveness for Internet-based health programs aimed at BP reduction. First, Internet-based interventions that lasted longer in duration (≥6months) were associated with greater BP reduction. This finding was in agreement with our hypothesis. We believe that the influence of lifestyle intervention on BP may require a period of time in order to learn the behaviour change skills to evoke a therapeutic change (Glanz et al., 2008). However, more studies are required to confirm our finding.

Second, SBP reduction was significantly augmented when the e-counselling protocol was designed to be proactive (vs. reactive) in contacting participants with health-related messages and when interventions were longer in duration. The proactive method of delivery may have enhanced the degree to which the Internet-based program was perceived as providing sufficient support for health behaviour change.

Third, significant incremental reductions in SBP were observed when the e-counselling protocols presented a repertoire of at least five techniques to modify diet or exercise. Techniques that were utilized in over 50% of successful trials for SBP reduction included the following: providing information on consequences of behaviour in general, incorporating feedback on performance, prompting self-monitoring of behaviours, and instructions or modeling how to perform the targeted behaviour. Even though many of the studies in the meta-analysis did not report specific behavioural theories used, many of the techniques used are associated with well-established constructs within behaviour theories. For example, based on the TPB, educating participants about the consequences of the undesirable behaviour can help improve their attitude toward the desirable behaviour in order to enhance behaviour intention. It may also shift a patient’s decisional balance (perceived pros vs. cons of a behaviour change) in favour of change, which would be consistent with TTM. Meanwhile, behaviour techniques such as incorporating feedback on performance, prompting self-monitoring of behaviours, giving instructions and modeling on how to perform the targeted change in behaviour can help improve self-efficacy which is an important construct for many behaviour theories (e.g. TTM, SCT, and TPB). The behavioural techniques found in Internet-based interventions aimed at BP control (Chapter 3) were similar to those mentioned in the recent scientific statement on preventive counseling proposed by the American Heart Association (Artinian et al., 2010). However, the distinct behaviour technique identified by the American Heart
Association which should be considered for future Internet-based intervention includes the use of incentives (e.g. monetary rewards) to support behaviour change and exposure to significant others who model adaptive behaviour change. Currently, the combination of behaviour techniques that enhances the efficacy of Internet-based interventions for individuals with various characteristics is an area that warrants future research.

Finally, in chapter 5 our results suggest that clinical methods (User- and Expert-driven procedure) used in an Internet-based intervention can influence the effectiveness of the intervention. Clinical methods are the styles of counselling approaches used to deliver an eHealth behaviour intervention. It is the clinical method that applies the behaviour theory or technique and puts it into practice that enables behaviour change to occur. The clinical method used can influence the way a person feels both cognitively and physically and can affect the efficacy of the intervention (Miller & Rollnick, 2009).

The results from the randomized controlled trial in chapter 5 indicated that both Expert- and User-driven programs were effective in reducing SBP relative to Controls at the 4-month follow-up. However, the Expert-driven Internet-based program was more favourable than User-driven in improving PP, cholesterol, daily physical activity and fruit consumption during a 4-month period. The effectiveness of an Expert-driven program may be enhanced by the participant’s readiness for behaviour change. We hypothesized that individuals in earlier stages of readiness for change (pre-contemplation and contemplation) who are ambivalent about adopting a new lifestyle may benefit more from a User-driven approach. The User-driven approach enabled the participant to reflect on the pros and cons of behavioural change and to change a behaviour that they perceive as salient. Meanwhile, individuals who are more motivated for behavioural change (preparation, action) may benefit from an Expert-driven approach as they are ready to take action. However, there were a limited number of participants in the earlier stages of readiness for healthy lifestyle change. As a result, this limited our ability to detect interaction effects between Expert and User-driven e-counselling procedures and baseline readiness for change in our primary and secondary outcomes. Nevertheless, the qualitative analysis revealed that there were both strengths and weaknesses to the User and Expert-driven approaches. In the User-driven group, the most prevalent feedback was that participants would have liked to see more specific strategies on behaviour change (n=5). In the Expert-driven group, several participants (n=17) said that the weekly incremental changes in
exercise and dietary goals were helpful, while others (n=5) found the weekly behaviour goals hard to follow. Therefore, a hybrid of Expert- and User-driven may be optimal, but future studies are warranted.

The results from this thesis did not uncover evidence to support the hypotheses that BP reduction is augmented with e-counselling programs that target multiple lifestyle behaviours or that provide supplementary components such as text messaging, in-person visits, and telephone support. The majority of the studies included in the meta-analysis targeted exercise and diet, as well as incorporated supplemental components. Therefore, the relatively small sample size may have limited our ability to detect statistical difference. Future research is warranted to confirm our finding.

In sum, results from this thesis support the continued development of Internet-based interventions aimed at BP control. Additionally, understanding the influence of these intervention protocol components on the effectiveness of Internet-based interventions is the first step to creating ways to tailor interventions to the individual and further improve efficacy.

A unique ability of Internet-based programs is that they enable participants to interact and collect longitudinal data at a much greater frequency than traditional face-to-face interventions. As wearable technology continues to be integrated with Internet-based programs, more comprehensive and objective data can be collected. These data provide the potential to deliver health behaviour interventions tailored to the person’s baseline characteristics as well as the user’s frequently changing behaviour, psychological state and environmental context (Collins, Murphy, & Bierman, 2004; Riley et al., 2011). Consequently, both the content of the intervention and the timing of the intervention delivery can be dynamically tailored to an individual over time based on their prior data input. For example, following a prompt to exercise, an Internet-based program could be designed to wait for a certain amount of time before reminding again. Currently, most Internet-based trials, including the study conducted in this thesis, provided a standardized content and/or timing of the self-guided Internet-based health intervention delivery across all participants and were not dynamically tailored at the individual level (Krebs, Prochaska, & Rossi, 2010; Riley et al., 2011).
The behaviour change model for Internet-based intervention described in the literature review as well as existing behaviour theories (e.g. TPB, SCT, TTM) have helped guide intervention design. These models and theories are useful in informing the ways that interventions can be tailored to the individual’s baseline status. However, some have argued that current behaviour theories are limited in answering intervention development questions likely to arise as interventions better leverage the longitudinal data collected as part of the Internet-based intervention (Riley et al., 2011). Dunton et al., (2009) have noted that the increasing availability of time-intensive information (e.g. longitudinal data of step count, readiness for change) allows for the intra-individual tailoring (e.g. tailoring the content and timing of the intervention delivery) but that current between-person theories (e.g. TPB, SCT, TTM) do not account for such tailoring (Dunton & Atienza, 2009). For example, based on TTM, the content of the intervention can be tailored based on the person’s motivation level but the model does not address questions such as: how should the timing and content of the follow-up prompt be tailored based on the prior pattern of response to prompt? Consequently, these theories have been used with considerable success to tailor health behaviour interventions based on pre-intervention factors, but have not been used to adapt the intervention to individuals over the course of the intervention (Riley et al., 2011). In order to reach the full potential of Internet-based interventions and utilizing the longitudinal data, a more comprehensive behaviour change model or theory is required to tailor the intervention to the individual over the course of the intervention.

Despite the limitations associated with these current behaviour change models and theories, this does not mean that they are irrelevant to Internet-based intervention design. In fact, there are some constructs within behaviour theories that highlighted the importance of dynamic tailoring; for example, the stage of change in the TTM as well as the reciprocal determinism in SCT. Behaviour theories should be used to guide Internet-based health behaviour interventions, but it is also important to build on these theories, as well as other components of Internet-based intervention (e.g. target behaviour, clinical method, usable design) to better address dynamic tailoring.

Control system engineering may provide a framework to transform current behaviour change theories and models into dynamic tailored models for Internet-based interventions (Collins et al., 2004; Riley et al., 2011; Rivera, Pew, & Collins, 2007). Control system engineering studies the influence of dynamic systems to achieve a desired outcome. The use of control theories have been
commonly used in human physiology to describe feedback regulatory processes such as the baroreceptor feedback loop in regulating resting BP. The application of control theories may have the potential to offer new ways of designing Internet-based interventions as well as improve our understanding of human behaviour in order to build on our existing behaviour theories.

The majority of the Internet-based interventions developed in the past decade are “fixed” in nature, which means that the same dosage or content is applied to all program participants. A dynamically tailored Internet-based intervention can adapt the intervention to each individual’s changing needs throughout the course of the intervention (Collins et al., 2004; Rivera et al., 2007). In order to transform a “fixed” Internet-based intervention into a dynamically tailored one, there are 3 additional factors that need to be considered in addition to the behaviour change model for Internet-based interventions described in the literature review. These include choice of tailoring variables, measurement of the tailoring variables and the decision rules linking tailoring variables. All these factors are interdependent; for example, tailored variables will not be effective unless they have been shown to be important for individual tailoring (Collins et al., 2004).

The following section will describe an example of a dynamic tailored Internet-based BP management program that incorporates the results found in this thesis and as well as control theories from system engineering. Specific design considerations that are discussed are 1) choice of tailoring variables, 2) measurement of the tailoring variables, and 3) the decision rules linking tailoring variables. The overall goal of the program proposed below (Figure 6.1) is to help individuals lower their BP through lifestyle changes. The program is designed to proactively engage the participants to access the Internet-based intervention. For the purpose of this illustration, the intervention focused on improving exercise behaviour.
Figure 6.1 A block diagram illustration of an adaptive Internet-based intervention aimed at BP control.

Input:
BP

Tailor Timing:
- IF BP “very poor” THEN deliver 2 emails per week
- IF BP is “poor” THEN deliver weekly emails
- IF BP is at threshold THEN biweekly emails

Review Interval (monthly)

Output:
BP

Physical activity level (Daily steps)

Tailor content (behaviour target):
- IF “low” daily steps THEN “beginner” exercise program
- IF “moderate” daily steps THEN “intermediate” program
- IF “high” daily steps THEN recommend “advanced” program

Internet-based BP management program

Disturbances:
- E.g. Stress, job loss, environmental constraints

Tailor content (Clinical Method)
- IF “low” readiness for daily exercise, THEN deliver content that are more User-driven, and aimed to build readiness for change.
- IF “high” readiness for daily exercise, THEN deliver more expert driven content and aim to teach behaviour change skills to improve and maintain daily exercise activity

Readiness for Behaviour Change
Identifying the adaptive components and tailoring variables

Tailoring variables refer to the components of the intervention that are adapted to the individual. The adaptive components are variables expected to moderate the effect of the treatment (Collins et al., 2004). This can include variables such as intervention dosage, target behaviour or clinical method. There can be an endless number of tailoring variables. Therefore, determining relevant tailoring variables is important in avoiding unnecessary complications to the development of an Internet-based intervention. The use of behaviour theories and involvement of skilled clinicians can be helpful in identifying these variables. Alternatively, studies that compare the various components of an Internet-based intervention, such as the study in Chapter 5, are also critical.

Figure 6.1, describes the adaptive intervention as an engineering control loop. The tailoring variables chosen are the intervention dose, target behaviour and clinical method. Individuals who have a higher resting BP are given a more intensive intervention (e.g. more frequent proactive email messages), whereas a less vigorous intervention will be sufficient for those with a controlled BP. Similarly, the content delivered to the individual can also be tailored by the user’s current exercise behaviour as well as the readiness for change. Tailoring the content based on a person’s readiness level is supported by the TTM (Prochaska & Velicer, 1997). Furthermore, results from this thesis suggest that incorporating an Expert-driven approach may be beneficial for individuals with higher levels of readiness. Therefore, these variables are chosen to be tailoring variables in the BP control program depicted in Figure 6.1.

In Figure 6.1, the effectiveness of the tailored Internet-based intervention can be negatively influenced by disturbances such as exercise barriers (e.g. limited amount of time, neighbourhood walkability), stress from jobs or socioeconomic status as well as the amount of benefit that each individual will receive from an intervention (Dunton & Atienza, 2009; Riley et al., 2011). The review interval for the tailored variable is set at monthly in this sample. However, the frequency of the review interval can also be tailored depending on a specific variable.

Measurement of the tailoring variables

Every tailored variable decision made (e.g. type of exercise program) in a personalized Internet-based intervention is based on the measurement of that variable (e.g. step count). Therefore, it is critical that the measurement of tailoring variables is reliable and valid. Reliability is the amount of
variance in the instrument that is not due to random error. Validity is the extent to which the measurement instrument is unbiased (Collins et al., 2004). Unreliable and invalid measurement of tailoring variables in an adaptive intervention can systematically point to an inappropriate tailoring. Thus, validation studies of measurement instruments, similar to the study conducted in Chapter 4, is critical for designing effective Internet-based interventions.

The activity monitor that we have chosen to examine in chapter 4 was a pedometer with a tri-axial accelerometer sensor which can detect motion between vertical and horizontal planes. As a result, these pedometers, as compared with traditional spring-gauge pedometers, do not need to be worn upright at the hip in order to detect motion. Thus, this type of pedometer may be more convenient to wear and increase overall usability. Although physical activity level can be monitored using self-reported physical activity journals, it is often associated with large differences when compared with direct/objective physical activity measures (e.g. pedometer) (Prince et al., 2008).

In chapter 4, we found that the Lifesource XL-18 pedometer was suitable in measuring steps in both controlled and free-living environments in a hypertensive population. The specific advantages of this pedometer were 1) ease of use 2) long storage capacity (14 days), and 3) percent error of the pedometer was not influenced by wearing positions, waist size or BMI. A larger waist size and BMI is often seen in individuals with elevated BP; thus, this feature of the XL-18 pedometer was particularly important.

The XL-18 pedometer is an example of a personal wearable technology that is able to track a person’s daily steps and provide self-monitoring for the participants to their awareness of physical cues and/or behaviours (Salah, MacIntosh, & Rajakulendran, 2014). As the wearable technology advances, the ability to objectively measure, track and analyze expand beyond daily steps to outcomes that include physiological (e.g. BP, heart rate) and psychophysiological (e.g. galvanic skin response) data. Some of the latest wearable technology including Fitbit or Apple Watch, which have the ability to measure daily physical activity level, sleep patterns and heart rate. The data collected from these new wearables can then be automatically uploaded to sync with an Internet-based intervention. Ultimately, these measurements can be used to 1) inform the participants about their progress, 2) enable the e-counselling program to better tailor the intervention to the participant, and 3) allow researchers to access these longitudinal data to build more effective interventions.
The wearable technology industry is expected to grow by 9-fold in the next 4 years (Salah et al., 2014). It is important for researchers to validate the use of these commercially available wearable technologies for clinical populations.

**The decision rules linking tailoring variables**

The decision rules determine the appropriate timing and content assigned to each participant. Effective decision rules can help tailor the intervention based on the person’s needs. A good decision rule needs to be based on an accurate model of the relation among tailoring variables and outcome, and must clearly define the value on the measure of the tailoring. Decision rules should also be comprehensive, covering anticipated situations that can occur in practice (Collins et al., 2004).

Behaviour theories can be particularly helpful in providing a framework for the decision rules. For example, in the TTM, type of content delivered should be tailored to the person’s readiness for change. However, as mentioned earlier, current behaviour theories may not be fully adequate to address a certain type of Internet-based intervention. The study such as the one conducted in Chapter 5 may be especially valuable in articulating these decision rules. In some cases, incorporating clinical judgment may also be important to consider.

In the example described in Figure 6.1, the decision rules for the program are based on 3 tailoring variables: Resting BP, Behaviour target and readiness for change. One of the methods is the “IF-THEN” decision rule.

The decision rule for determining intervention dosage is listed below:

- IF BP is “very poor” >140/90 mmHg THEN deliver 2 emails per week
- IF BP is “poor” 130-140/85-90 mmHg THEN deliver weekly emails
- IF BP is “at threshold” <130/85 mmHg THEN deliver biweekly emails
The decision rules for determining exercise content is listed below

- IF “sedentary” level of daily activate (steps <4000 steps per day) THEN recommend “beginner” exercise program
- IF “low” level of daily activate (steps 4000-8000) THEN recommend “intermediate” exercise program
- IF “optimal” level of daily activate (>8000 steps per day) THEN recommend “advanced” exercise program

The decision rules for determining the method of delivering exercise content.

- IF “low” readiness for daily exercise (pre-contemplation, contemplation stages of change), THEN deliver content that are more User-driven, and the content is aimed at building readiness for change.
- IF “high” readiness for daily exercise (preparation stages of change and beyond), THEN deliver content that are Expert driven (e.g. samples of pre-constructed exercise plan and workouts) and are aimed at teaching behaviour skills that the participant can use to initiate and maintain an active lifestyle.

The “IF-THEN” decision assigns the various dosage and content based on the most recent measurement of the tailoring variable. This type of decision rule is relatively simple to design and execute. However, a potential challenge of this type of decision rule is that it can dramatically overshoot or undershoot a set-point while seeking stability. For example, individuals can start at a beginner exercise program, but during the next assessment, the individual may be assigned an advanced exercise program due to their high level of daily steps based on the If-Then” decision rule. In this case, the progression of the exercise program may be too quick and thus it has the potential to “overshoot” the behavioural goal. A potential solution is to apply the Proportional-Integral-Derivative (PID) algorithms in the decision rule. The PID family of controllers is among the most commonly applied control algorithms in industry practice. The PID can assign the closest level of exercise progression levels (beginner, intermediate, advance) based on user history, rather than the most recent measurement of tailoring variables such as the “IF-THEN” decision rule (Riley
et al., 2011; Rivera et al., 2007). In order to design intelligent decision rules for Internet-based intervention, it is useful to incorporate control engineering methodologies.

The potential of Internet-based interventions to collect intensive longitudinal data is important for building a dynamic system model such as the BP reduction program illustrated above. Using the longitudinal data collected, the tailored variable and decision rules can fine-tune the model to be adaptive in deciding on the timing and content of the intervention components. In turn, by fine-tuning the decision rules, it can also inform us of the ways to build on current behaviour change theories and models. Overall, the Internet-based intervention is an exciting and rapidly growing field. The application of system engineering can help develop dynamic behaviour change models for Internet-based health interventions.

6.1 Study limitations

There were several limitations that need to be addressed in future studies. First, in our meta-analysis (Chapter 2), the ability to generalize our findings to the wider population with high BP is limited by the small number of clinical trials (N=13). Nevertheless, the components of e-counselling identified to be important to its efficacy correspond well with the key features of preventive counselling noted by the American Heart Association. Both Internet-based and conventional counselling methods include patient education, self-monitoring of symptoms or behaviour, tailored feedback and scheduling of regular contacts. In a recent study, components found to be unique to e-counselling included tailoring the intervention to the settings or environmental resources of the patient. This may include information about neighbourhood stores or walking paths where participants would engage in the healthy behaviour. The ability to share e-messages among patients or with healthcare providers is also unique to the e-counselling protocol. Future studies need to examine whether certain e-counselling components work better for individuals with specific characteristics. For example, there may be some components (e.g. e-forums, trackers) that are particularly important to certain individuals to enhance a sense of support to achieve healthy lifestyle change.

A limitation in our randomized controlled trial was that our findings may only apply to participants who are motivated for health behaviour change. Our sample consisted of few participants that were
in pre-contemplation or contemplation stage of change for exercise and diet. This limited our ability
to detect potential interaction effects between clinical methods and baseline readiness for change in
BP or adherence to exercise or diet. Our follow-up period was 4 months long and thus, the long-
term intervention (12-month) effects remain unclear.

The activity monitor that we used in the Expert vs. User-driven e-counselling study was validated.
However, the accuracy of the activity monitor decreases with slower walking speed. Furthermore,
the activity monitor did not capture the intensity of the exercise which is another important
component in quantifying daily activity level. However, participants in the treatment arms (Expert
and User-driven) were taught about monitoring the intensity of their exercise by monitoring the
number of steps taken during 10-30 minute intervals. This enabled the user to exercise at intensity
where they would receive optimal cardiovascular benefits.

The current study did not examine the longitudinal data for engagement with the e-counselling
program over the 4-month period. Longitudinal data can be particularly important in identifying the
time period when users are disengaged from the program so that additional features (e.g. rewards,
proactive emails) can be built into the system. Preliminary results from a heart failure pilot study
conducted in our lab over a 16-week period indicated that there were three clusters of patient
engagement patterns: active engagement, diminishing engagement and intermittent engagement.
Participants in the active engagement group accessed the program regularly each week. Participants
in the diminishing engagement decreased adherence with the program over time. Finally, in the
intermittent group accessed the program sporadically and are characterized by “chunking” the
amount of the content. Future studies need to examine longitudinal data over critical time-points in
order to gain insight into tailoring e-counselling protocols to the needs of the patients and increase
the efficacy of the program.

Finally, an area that was not explored in depth in this thesis was usability and user experience of the
Internet-based intervention. Guidelines for a usable website were followed in designing our
Internet-based intervention. However, specific usability testing was not conducted. Future Internet-
based intervention trials should consider usability testing to ensure that the intervention is user-
friendly.
6.2 Future Directions

The self-guided Internet-based lifestyle intervention holds great potential in managing high BP as well as in health promotion for primary and secondary prevention. This thesis has demonstrated that a self-guided e-counselling program can be effective; however, determining the specific components that make an e-platform effective is only the beginning. There are several areas related to e-counselling that need to be developed in order to actualize the full potential of e-counselling.

Determining the reach of e-Counselling Intervention

The number of individuals who have access to the Internet has steadily increased over the past decade. Currently, 85% of the population has access to the Internet, however, real-world studies estimating the actual reach for Internet health interventions are lacking. Most of the studies in this area used convenience sampling or recruited participants offline. The reach of the Internet programs varies across studies. Glasgow et al., (2007) reported that an invitation to participate in an Internet-based weight-loss program attracted 1.8% of well members (n=1402 out of 79378) and 4.8% (n=909/18779) of those with coronary artery disease or with diabetes. In another study, Graham, Cobb, Raymond, Sill, & Young, (2007) reported in a corporate wellness program that among the 8688 smokers identified, 19.7% of the smokers (1713) chose to use an Internet-based smoking cessation program. Current studies suggest that although the overall participation rate for Internet health interventions was not high, the large size of the respective population demonstrates the potential for a broad reach. Glasgow et al. (2010) reported that among individuals who received an invitation to participate, patients with known cardiovascular disease or diabetes were more likely to participate than patients without a known illness (4.8% vs. 1.8%).

In one of our recent studies, we have shown that the use of external rewards can be one of the ways to increase the potential reach of Internet-based programs. Individuals given a single exposure of loyalty rewards (equivalent to about $2.00 CAD) were 28 times more likely to enroll in an Internet heart health program (Liu et al. 2010). An alternative strategy to increase the reach of Internet programs is to offer it through various family health clinics, public health units or hospitals. In a recent meta-analysis, Goldfarb et al., (2015) reported that studies employing a recruitment strategy in which the family member was contacted by healthcare professionals reported a pooled participation rate of 88%. 
It will become particularly important for future public health promotion programs to establish partnerships with industry organizations (e.g. loyalty one, Aero plan) and social media companies (e.g. Facebook) to extend the reach of Internet-based interventions. One of the recent examples is the partnership between Facebook and The National Suicide Prevention Lifeline in order to accelerate the action needed to prevent suicide in Canada and the U.S. Individuals who use Facebook (151 million in U.S. and 15 million in Canada) can report and receive support related to suicide (Facebook, 2015). Population-based health promotion and prevention programs delivered using Internet-based programs can have the potential to reach many individuals, especially through establishing key partnerships.

**Integrating human support**

Several systematic reviews and meta-analyses reported that Internet-based programs can be as effective as in-person coaching interventions in improving health outcomes (King et al., 2007; King et al., 2014; Wantland et al., 2004). However, not all individuals may be suited for Internet-based programs. There may be instances where human intervention is required. Some participants may have several co-morbidities or medical conditions that may be outside the scope of the Internet health intervention. In our trial, a few participants mentioned that they were lactose intolerant, however the e-counselling platform built was not able to take that into consideration. In other complex chronic disease management cases, such as heart failure, sudden change of body weight can be an indication of worsening heart function. Therefore, a health professional may be required. It is important to ensure that the enhanced communication of Internet-based intervention between patient and health care providers do not lead to increased workload for the health care provider. Future studies in this area are warranted.

Technical related support also needs to be taken into consideration for Internet-based health programs. In our trial, there were several participants that had trouble receiving our intervention emails due to their spam filter setting and required human support. Individuals with lower computer literacy level may also find the Internet-based program challenging to navigate. However, there are several readability and design guidelines published by the U.S. Department of Health and Human Services (Leavitt & Shneiderman, 2015) that aim to improve user experience. There are computer programs that utilize a “virtual advisor” to interact with and deliver the health program. This unique automated computer program provides interactive, personalized health behaviour counselling that
breaks down barriers typically faced by other e-health programs including health literacy, language, culture, and computer knowledge. Individuals can interact with the virtual advisors via speech and a touch screen.

Despite the advances made in addressing computer health literacy level, there are only a few studies that have attempted to determine who responds better to a computer vs. human-delivered health intervention. Hekler et al., (2013) reported in a 12-month physical activity intervention that participants who had high motivation for physical activity and low levels of private self-consciousness (e.g. more inwardly focused) responded better to an automated computer program compared with human advisors. This preliminary evidence helps generate hypotheses about potential pathways for supporting later clinical decision-making with regards to the use of either human or computer-delivered physical activity programs. However, future research in this area is warranted to determine when it is an optimal time for human vs. a self-guided Internet-based support.

**Dynamic Tailoring**

Computer programs that dynamically tailor the intervention were found to have increased efficacy over time as compared with tailored intervention based on one assessment only (Kreuter et al, 1999; Collins et al., 2004). These types of programs can assess individuals and select communication content using data-driven decision rules that produce feedback automatically from a content database. Future Internet-based programs need to strive towards providing dynamic tailoring. In the example illustrated earlier, the tailoring variables included intervention dosage, exercise behaviour, baseline readiness and clinical method (Expert- and User-driven protocol). However, there are several other tailoring variables that also need to be considered.

First, tailoring can be based on participants’ physiological, behavioural or psychometric measures. As wearable technology advances, it is becoming easier to track physical activity level (duration, intensity, type of activity), sleep patterns, weight, BP and dietary habits. Psychometric measures such as overall mood, motivation or energy level can be tracked using simple questionnaires on mobile apps. These physiological, behavioural and psychometric data are important in informing the participants about their progress and can act as a positive reinforcement. Ultimately, this bio and psychometric information can be used to tailor a participant’s health program. For example,
participants can be introduced to new recipes that are tailored to their exercise habits recorded by their activity tracker (e.g. Fitbit). Diet recipes may contain higher protein content when participants are engaged in frequent resistance training. Meanwhile, participants may be introduced to a higher carbohydrate diet if they are engaged in endurance training.

The second method of tailoring is to adapt the Internet health program to the participants’ environments. Currently, the majority of research in this field has focused on adapting e-health interventions to personal factors (e.g. culture, motivations, health literacy), and fails to evaluate the impact of the built environment. Many studies have shown that the built environment can influence a person’s lifestyle. Areas that have poor walkability features (poor side-walk, high vehicle traffic) or low access to healthy grocery stores can result in lower physical activity and poor dietary choices. The impact of the environment is also a major component in the ecological model of health. Thus, future Internet health interventions should take into consideration environmental features (e.g. walking path, exercise facilities) that enable participants to carry out healthy behaviours.

Third, Internet-based programs can also be tailored based on participants’ engagement levels with the Internet program. Preliminary results from a heart failure pilot study conducted in our lab over a 16-week period indicate that there were three clusters of patient engagement patterns: active engagement, diminishing engagement and intermittent engagement. Future Internet-based programs need to identify participants with diminishing engagement and proactively engage them with email reminders, incentives, or alternative methods.

Dynamic tailoring is a critical component to constructing an effective self-guided Internet-based program. Future research in this area is needed in order to construct algorithms with evidence-based decision rules to provide effective feedback.

**Improving the Development, Evaluation and Dissemination Process of Internet-based Intervention**

The final area for future research involves process improvement for the way Internet-based health interventions are developed, evaluated and disseminated. There are several challenges that became clear as result of the research projects carried out in this thesis.
One of the challenges facing eHealth researchers is the amount of resources that it takes to develop Internet-based Interventions. Since few health researchers and clinicians have computer programming skills, the development often gets outsourced. Consequently, this can be costly ($20 000-$100 000) and take several months to develop. Furthermore, the ability to easily share and build on the Internet-based interventions created by researchers and clinicians is lacking. As a result, the interventions often need to be re-created each time and this can add additional develop time and resources. Evaluating the effectiveness of an Internet-based program (e.g. a randomized controlled trial) also requires a lot of effort and time recruiting and following-up with participants to collect required data. Finally, most researchers will publish their results in academic journals, and these Internet-based interventions often fail to become available for public use after the clinical trial ends. Researchers wanting to make their intervention publically available are likely to be faced with scalability challenges. Most of the Internet interventions tested in research studies experience a relatively low volume of traffic, ranging between 50 to 1000 users. Once the user-base increases (e.g. up to 100000 users), upgrades to platform architecture (e.g. multiple servers, web-security, redundant storage) is required to match the demand. Overall, these challenges hinder the “process” for which Internet-based health interventions are developed, evaluated and disseminated. Therefore, it is important to overcome these challenges in order to actualize the full potential of Internet-based interventions.

A solution to these challenges is to develop an open-access web platform that will enable researchers and clinicians to develop interactive Internet-based interventions using “drag and drop” web tools instead of coding. This web-platform can also be a central hub for the general public to contribute to the evaluation of Internet-based interventions and/or participate in a health intervention that has already been evaluated through research studies. There is the potential for such an open access web-platform to address the challenges mentioned above and enhance the innovation for Internet-based health interventions. Specifically, the open source platform can significantly decrease the cost and resources for intervention development. Clinicians and researchers can focus on content development and understanding the best way to design an Internet-based intervention, rather than worrying about computer programming and technical abilities. Sustainability of open-access web-platform has been proven to be possible using a freemium model as it is used by companies such as Word press, Linux and Wix.
In addition, this web-platform also enables researchers to collaborate and build on each other’s Internet-based health interventions. For example, if there is already an intervention that has been shown to be effective in improving physical activity level, it is much more efficient for other researchers to build on that program rather than creating it anew. The ability to share and build on existing Internet-based interventions can potentially decrease development time and promote collaboration.

Finally, data collection and evaluation of the Internet-based intervention can also become more efficient through this platform. In some cases, researchers can allow their participants to collect relevant research data via manual user-input (e.g. surveys, diary) or integrate with third party applications (e.g. wearables, mobile apps). Using this method of data collection, researchers could recruit participants in various geographic locations and reach their desired sample size faster.

In conclusion, this web-platform can have a significant impact on the field of Internet-based health intervention by 1) decreasing the barriers for researchers and clinicians to create Internet-based interventions 2) promoting cross-discipline collaboration and 3) providing the public with evidence-based Internet interventions.
Chapter 7: Conclusion

Internet-based lifestyle interventions aimed at hypertension management hold great potential to reach a large number of individuals without overtaxing health care results. Results from studies in this thesis suggest that i) self-guided Internet-based lifestyle counselling (e-counselling) programs can be effective in reducing BP and promoting adherence to a healthy lifestyle in patients with hypertension, and ii) certain design strategies for intervention protocol may enhance intervention efficacy. Specifically, the meta-analysis showed that Internet-based interventions may be more efficacious when the program was 6 months or longer, delivered proactively, and provided at least five behavioural techniques. The randomized controlled trial demonstrated that it may be advisable to integrate an Expert-driven e-counselling procedure into future Internet-based interventions in order to accommodate participants with greater levels of motivation for behaviour change. Overall, these findings have significant implications in designing the next generation of health interventions delivered using Internet communication technology.
References


Canadian Institute for Health Information. (2006). *How Healthy Are Rural Canadians? An Assessment of Their Health Status and Health Determinants*. Ottawa, Canada: Canadian Institute for Health Information.


CDC. (2010). *National Chronic Kidney Disease Fact Sheet*: CDC.


Appendices

Appendix 1: Assessment package for Readiness

Please read each question and select the one statement that best describes your stage of change for each lifestyle behaviour. Please be as honest and accurate as possible when you answer. No wishful thinking.

<table>
<thead>
<tr>
<th>Question</th>
<th>Y: Regularly for more than 6 months</th>
<th>E: Regularly within the past 6 months</th>
<th>N: But I am ready to do this in the next 4 weeks</th>
<th>N: But I am ready to do this in the next 6 months</th>
<th>O: I am not at all ready but I believe it IS IMPORTANT for my heart health</th>
<th>O: I am not at all ready and I believe it IS NOT IMPORTANT for my heart health</th>
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<td>I do a planned exercise for at least 20 minutes, 3-5 times a week (e.g. brisk walking, aerobics, jogging, swimming, skiing, etc.)</td>
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<td>I keep active in my daily habits 5-6 days a week (e.g. walking and climbing stairs at home and work, cutting grass, shoveling snow, washing floors).</td>
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I eat 3-5 servings of vegetables *each* day.  
(One half cup of raw or cooked vegetables is 1 serving).

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But I am ready to do this in the next 4 weeks

But I am ready to do this in the next 6 months

I am not at all ready but I believe it **IS** IMPORTANT for my heart health

I am not at all ready and I believe it **IS NOT** IMPORTANT for my heart health

I eat 2-4 servings of fruit *each* day. (1 piece of fruit, such as an apple, is 1 serving).

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But I am ready to do this in the next 4 weeks

But I am ready to do this in the next 6 months

I am not at all ready but I believe it **IS** IMPORTANT for my heart health

I am not at all ready and I believe it **IS NOT** IMPORTANT for my heart health

At *each* meal, I eat less than 30% of calories from fat by eating lean meat without the skin, avoiding fried foods, (e.g. French fries) and from high fat comfort foods such as potato chips.

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But I am ready to do this in the next 4 weeks

But I am ready to do this in the next 6 months

I am not at all ready but I believe it **IS** IMPORTANT for my heart health

I am not at all ready and I believe it **IS NOT** IMPORTANT for my heart health
At *each* meal, I avoid adding extra salt to my food, and I avoid eating salty foods such as chips, soy sauce, fast foods such as hamburgers, and prepared food mixes.

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But I am ready to do this in the next **4 weeks**

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I have a smoke-free lifestyle *every day*, which does not include even 1 puff of a cigarette.

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*Each* day, I do not have more than 2 drinks of alcohol. (1 drink = 1 bottle beer, 1 glass of wine, 1 shot of liquor).

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But I am ready to do this in the next **4 weeks**

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Appendix 2: Diet History Questionnaire
NATIONAL INSTITUTES OF HEALTH

Diet History Questionnaire II

GENERAL INSTRUCTIONS
• Answer each question as best you can. Estimate if you are not sure. A guess is better than leaving a blank.
1. Over the past month, how often did you drink *carrot juice*?

- [ ] NEVER (GO TO QUESTION 2)
- [ ] 1 time in past month
- [ ] 2–3 times in past month
- [ ] 1–2 times per week
- [ ] 3–4 times per week
- [ ] 5–6 times per week

   1a. Each time you drank *carrot juice*, how much did you usually drink?

- [ ] Less than ¾ cup (6 ounces)
- [ ] ¾ to 1¼ cups (6 to 10 ounces)
- [ ] More than 1¼ cups (10 ounces)

2. Over the past month, how often did you drink *tomato juice* or other vegetable juice? *(Please do not include carrot juice.)*

- [ ] NEVER (GO TO QUESTION 3)
- [ ] 1 time in past month
- [ ] 2–3 times in past month
- [ ] 1–2 times per week
- [ ] 3–4 times per week
- [ ] 5–6 times per week

   2a. Each time you drank *tomato juice* or other vegetable juice, how much did you usually drink?

- [ ] Less than ¾ cup (6 ounces)
- [ ] ¾ to 1¼ cups (6 to 10 ounces)
- [ ] More than 1¼ cups (10 ounces)

3. Over the past month, how often did you drink *orange juice* or grapefruit juice?

- [ ] NEVER (GO TO QUESTION 4)
- [ ] 1 time in past month
- [ ] 2–3 times in past month
- [ ] 1–2 times per week
- [ ] 3–4 times per week
- [ ] 5–6 times per week

   3a. Each time you drank *orange juice* or grapefruit juice, how much did you usually drink?

- [ ] Less than ¾ cup (6 ounces)
- [ ] ¾ to 1¼ cups (6 to 10 ounces)
- [ ] More than 1¼ cups (10 ounces)

   3b. How often was the orange juice or grapefruit juice you drank *calcium-fortified*?

- [ ] Almost never or never
- [ ] About ¼ of the time
- [ ] About ½ of the time
- [ ] About ¾ of the time
- [ ] Almost always or always
4. Over the past month, how often did you drink other 100% fruit juice or 100% fruit juice mixtures (such as apple, grape, pineapple, or others)?

☐ NEVER (GO TO QUESTION 5)
☐ 1 time in past month ☐ 1 time per day
☐ 2–3 times in past month ☐ 2–3 times per day
☐ 1–2 times per week ☐ 4–5 times per day
☐ 3–4 times per week ☐ 6 or more times per day
☐ 5–6 times per week

4a. Each time you drank other 100% fruit juice or 100% fruit juice mixtures, how much did you usually drink?

☐ Less than ¾ cup (6 ounces)
☐ ¾ to 1½ cups (6 to 12 ounces)
☐ More than 1½ cups (12 ounces)

4b. How often were the other 100% fruit juice or 100% fruit juice mixtures you drank calcium-fortified?

☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

5. How often did you eat applesauce?

☐ NEVER (GO TO QUESTION 6)
☐ 1 time in past month ☐ 3–4 times per week
☐ 2–3 times in past month ☐ 5–6 times per week
☐ 1 time per week ☐ 1 time per day
☐ 2 times per week ☐ 2 or more times per day

5a. Each time you ate applesauce, how much did you usually eat?

☐ Less than ½ cup
☐ ½ to 1 cup
☐ More than 1 cup

6. How often did you eat apples?

☐ NEVER (GO TO QUESTION 7)
☐ 1 time in past month ☐ 3–4 times per week
☐ 2–3 times in past month ☐ 5–6 times per week
☐ 1 time per week ☐ 1 time per day
☐ 2 times per week ☐ 2 or more times per day

6a. Each time you ate apples, how many did you usually eat?

☐ Less than 1 apple
☐ 1 apple
☐ More than 1 apple

7. How often did you eat pears (fresh, canned, or frozen)?

☐ NEVER (GO TO QUESTION 8)
☐ 1 time in past month ☐ 3–4 times per week
☐ 2–3 times in past month ☐ 5–6 times per week
Each time you ate **pears**, how many did you usually eat?

- Less than 1 pear
- 1 pear
- More than 1 pear

How often did you eat **bananas**?

- NEVER (GO TO QUESTION 9)
- 1 time in past month
- 2–3 times in past month
- 1 time per week
- 2 times per week

Over the past month...

Each time you ate **bananas**, how many did you usually eat?

- Less than 1 banana
- 1 banana
- More than 1 banana

How often did you eat **dried fruit** (such as prunes or raisins)? *(Please do not include dried apricots.)*

- NEVER (GO TO QUESTION 10)
- 1 time in past month
- 2–3 times in past month
- 1 time per week
- 2 times per week

Each time you ate **dried fruit**, how much did you usually eat?

- Less than 2 tablespoons
- 2 to 5 tablespoons
- More than 5 tablespoons

How often did you eat **peaches**, **nectarines**, or **plums**?

- NEVER (GO TO QUESTION 11)
- 1 time in past month
- 2–3 times in past month
- 1 time per week
- 2 times per week

Each time you ate **peaches**, **nectarines**, or **plums**, how much did you usually eat?

- Less than 1 fruit or less than ½ cup
- 1 to 2 fruits or ½ to ¾ cup
- More than 2 fruits or more than ¾ cup
11. How often did you eat **grapes**?

- □ NEVER (GO TO QUESTION 12)
- □ 1 time in past month
- □ 2–3 times in past month
- □ 1 time per week
- □ 2 times per week

11a. Each time you ate **grapes**, how much did you usually eat?

- □ Less than ½ cup or less than 10 grapes
- □ ½ to 1 cup or 10 to 30 grapes
- □ More than 1 cup or more than 30 grapes

12. How often did you eat **cantaloupe**?

- □ NEVER (GO TO QUESTION 13)
- □ 1 time in past month
- □ 2–3 times in past month
- □ 1 time per week
- □ 2 times per week

12a. Each time you ate **cantaloupe**, how much did you usually eat?

- □ Less than ¼ melon or less than ½ cup
- □ ¼ melon or ½ to 1 cup
- □ More than ¼ melon or more than 1 cup

13. How often did you eat **melon, other than cantaloupe** (such as watermelon or honeydew)?

- □ NEVER (GO TO QUESTION 14)
- □ 1 time in past month
- □ 2–3 times in past month
- □ 1 time per week
- □ 2 times per week

13a. Each time you ate **melon other than cantaloupe**, how much did you usually eat?

- □ Less than ½ cup or 1 small wedge
- □ ½ to 2 cups or 1 medium wedge
- □ More than 2 cups or 1 large wedge

**Over the past month...**

14. How often did you eat **strawberries**?

- □ NEVER (GO TO QUESTION 15)
- □ 1 time in past month
- □ 2–3 times in past month
- □ 1 time per week
- □ 2 times per week

14a. Each time you ate **strawberries**, how much did you usually eat?

- □ Less than ¼ cup or less than 3 berries
- □ ¼ to ¼ cup or 3 to 8 berries
15. How often did you eat **oranges, tangerines, or clementines**? 

[ ] NEVER (GO TO QUESTION 16)  

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<td>2 times per week</td>
<td>2 or more times per day</td>
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15a. Each time you ate **oranges, tangerines, or clementines**, how many did you usually eat?  

[ ] Less than 1 fruit  
[ ] 1 fruit  
[ ] More than 1 fruit

16. How often did you eat **grapefruit**? 

[ ] NEVER (GO TO QUESTION 17)  

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<td>2 times per week</td>
<td>2 or more times per day</td>
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16a. Each time you ate **grapefruit**, how much did you usually eat?  

[ ] Less than ½ grapefruit  
[ ] ½ grapefruit  
[ ] More than ½ grapefruit

17. How often did you eat **pineapple**? 

[ ] NEVER (GO TO QUESTION 18)  

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<td>2 times per week</td>
<td>2 or more times per day</td>
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17a. Each time you ate **pineapple**, how much did you usually eat?  

[ ] Less than ¼ cup or less than 1 medium slice  
[ ] ¼ to ¾ cup or 1 medium slice  
[ ] More than ¾ cup or more than 1 medium slice

18. How often did you eat **other kinds of fruit**? 

[ ] NEVER (GO TO QUESTION 19)  

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<td>2 or more times per day</td>
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18a. Each time you ate **other kinds of fruit**, how much did you usually eat?  

[ ] Less than ¼ cup  
[ ] ¼ to ¾ cup
176

19. How often did you eat **COOKED greens** (such as spinach, turnip, collard, mustard, chard, or kale)?

- NEVER (GO TO QUESTION 20)
- 1 time in past month
- 2–3 times in past month
- 1 time per week
- 2 times per week

19a. Each time you ate **COOKED greens**, how much did you usually eat?

- Less than ½ cup
- ½ to 1 cup
- More than 1 cup

20. How often did you eat **RAW greens** (such as spinach, turnip, collard, mustard, chard, or kale)? *(We will ask about lettuce later.)*

- NEVER (GO TO QUESTION 21)
- 1 time in past month
- 2–3 times in past month
- 1 time per week
- 2 times per week

Over the past month...

20a. Each time you ate **RAW greens**, how much did you usually eat?

- Less than ½ cup
- ½ to 1 cup
- More than 1 cup

21. How often did you eat **coleslaw**?

- NEVER (GO TO QUESTION 22)
- 1 time in past month
- 2–3 times in past month
- 1 time per week
- 2 times per week

21a. Each time you ate **coleslaw**, how much did you usually eat?

- Less than ¼ cup
- ¼ to ¾ cup
- More than ¾ cup

22. How often did you eat **sauerkraut** or **cabbage** (other than coleslaw)?

- NEVER (GO TO QUESTION 23)
- 1 time in past month
- 2–3 times in past month
- 1 time per week
- 2 times per week
22a. Each time you ate **sauerkraut** or **cabbage**, how much did you usually eat?

- [ ] Less than $\frac{1}{4}$ cup
- [ ] $\frac{1}{4}$ to 1 cup
- [ ] More than 1 cup

23. How often did you eat **carrots** (fresh, canned, or frozen)?

- [ ] NEVER (GO TO QUESTION24)
- [ ] 1 time in past month  
  - [ ] 3–4 times per week
- [ ] 2–3 times in past month  
  - [ ] 5–6 times per week
- [ ] 1 time per week  
  - [ ] 1 time per day
- [ ] 2 times per week  
  - [ ] 2 or more times per day

23a. Each time you ate **carrots**, how much did you usually eat?

- [ ] Less than $\frac{1}{4}$ cup or less than 2 baby carrots
- [ ] $\frac{1}{4}$ to $\frac{1}{2}$ cup or 2 to 5 baby carrots
- [ ] More than $\frac{1}{2}$ cup or more than 5 baby carrots

24. How often did you eat **string beans** or **green beans** (fresh, canned, or frozen)?

- [ ] NEVER (GO TO QUESTION25)
- [ ] 1 time in past month  
  - [ ] 3–4 times per week
- [ ] 2–3 times in past month  
  - [ ] 5–6 times per week
- [ ] 1 time per week  
  - [ ] 1 time per day
- [ ] 2 times per week  
  - [ ] 2 or more times per day

24a. Each time you ate **string beans** or **green beans**, how much did you usually eat?

- [ ] Less than $\frac{1}{4}$ cup
- [ ] $\frac{1}{2}$ to 1 cup
- [ ] More than 1 cup

25. How often did you eat **peas** (fresh, canned, or frozen)?

- [ ] NEVER (GO TO QUESTION26)
- [ ] 1 time in past month  
  - [ ] 3–4 times per week
- [ ] 2–3 times in past month  
  - [ ] 5–6 times per week
- [ ] 1 time per week  
  - [ ] 1 time per day
- [ ] 2 times per week  
  - [ ] 2 or more times per day

25a. Each time you ate **peas**, how much did you usually eat?

- [ ] Less than $\frac{1}{4}$ cup
- [ ] $\frac{1}{4}$ to $\frac{3}{4}$ cup
- [ ] More than $\frac{3}{4}$ cup

26. How often did you eat **corn**?

- [ ] NEVER (GO TO QUESTION 27)
- [ ] 1 time in past month  
  - [ ] 3–4 times per week
- [ ] 2–3 times in past month  
  - [ ] 5–6 times per week
26a. Each time you ate corn, how much did you usually eat?

- Less than 1 ear or less than ½ cup
- 1 ear or ½ to 1 cup
- More than 1 ear or more than 1 cup

Over the past month...

27. How often did you eat broccoli (fresh or frozen)?

- NEVER (GO TO QUESTION 28)
- 1 time in past month
- 2–3 times in past month
- 1 time per week
- 2 times per week
- 1 time per day
- 2 or more times per day

27a. Each time you ate broccoli, how much did you usually eat?

- Less than ¼ cup
- ¼ to 1 cup
- More than 1 cup

28. How often did you eat cauliflower or Brussels sprouts (fresh or frozen)?

- NEVER (GO TO QUESTION 29)
- 1 time in past month
- 2–3 times in past month
- 1 time per week
- 2 times per week
- 1 time per day
- 2 or more times per day

28a. Each time you ate cauliflower or Brussels sprouts, how much did you usually eat?

- Less than ¼ cup
- ¼ to ½ cup
- More than ½ cup

29. How often did you eat asparagus (fresh or frozen)?

- NEVER (GO TO QUESTION 30)
- 1 time in past month
- 2–3 times in past month
- 1 time per week
- 2 times per week
- 1 time per day
- 2 or more times per day

29a. Each time you ate asparagus, how much did you usually eat?

- Less than ½ cup or less than 4 spears
- ½ to ¾ cup or 4 to 7 spears
- More than ¾ cup or more than 7 spears

30. How often did you eat winter squash (such as pumpkin, butternut, or acorn)?
☐ NEVER (GO TO QUESTION 31)
☐ 1 time in past month  ☐ 3–4 times per week
☐ 2–3 times in past month  ☐ 5–6 times per week
☐ 1 time per week  ☐ 1 time per day
☐ 2 times per week  ☐ 2 or more times per day

30a. Each time you ate winter squash, how much did you usually eat?
☐ Less than ½ cup
☐ ½ to ¾ cup
☐ More than ¾ cup

31. How often did you eat mixed vegetables?
☐ NEVER (GO TO QUESTION 32)
☐ 1 time in past month  ☐ 3–4 times per week
☐ 2–3 times in past month  ☐ 5–6 times per week
☐ 1 time per week  ☐ 1 time per day
☐ 2 times per week  ☐ 2 or more times per day

31a. Each time you ate mixed vegetables, how much did you usually eat?
☐ Less than ½ cup
☐ ½ to 1 cup
☐ More than 1 cup

32. How often did you eat onions?
☐ NEVER (GO TO QUESTION 33)
☐ 1 time in past month  ☐ 3–4 times per week
☐ 2–3 times in past month  ☐ 5–6 times per week
☐ 1 time per week  ☐ 1 time per day
☐ 2 times per week  ☐ 2 or more times per day

32a. Each time you ate onions, how much did you usually eat?
☐ Less than 1 slice or less than 1 tablespoon
☐ 1 slice or 1 to 4 tablespoons
☐ More than 1 slice or more than 4 tablespoons

Over the past month...

33. Now think about all the cooked vegetables you ate in the past month and how they were prepared. How often were your vegetables COOKED WITH some sort of fat, including oil spray? *(Please do not include potatoes.)*

☐ NEVER (GO TO QUESTION 34)
☐ 1 time in past month  ☐ 3–4 times per week
☐ 2–3 times in past month  ☐ 5–6 times per week
☐ 1 time per week  ☐ 1 time per day
☐ 2 times per week  ☐ 2 or more times per day
33a. Which fats were usually added to your vegetables **DURING COOKING**? *(Please do not include potatoes. *Mark all that apply.*)

- [ ] Margarine (including low-fat)
- [ ] Corn oil
- [ ] Butter (including low-fat)
- [ ] Canola or rapeseed oil
- [ ] Lard, fatback, or bacon fat
- [ ] Oil spray, such as Pam or others
- [ ] Olive oil
- [ ] Other kinds of oils
- [ ] None of the above

34. Now, thinking again about all the **cooked vegetables** you ate in the past month, how often was some sort of fat, sauce, or dressing added **AFTER COOKING OR AT THE TABLE**? *(Please do not include potatoes.)*

- [ ] NEVER (GO TO QUESTION 35)
- [ ] 1 time in past month
- [ ] 2–3 times in past month
- [ ] 1–2 times per week
- [ ] 3–4 times per week
- [ ] 5–6 times per week
- [ ] 1 time per day
- [ ] 2 times per day
- [ ] 3 or more times per day

34a. Which fats, sauces, or dressings were usually added **AFTER COOKING OR AT THE TABLE**? *(Please do not include potatoes. *Mark all that apply.*)

- [ ] Margarine (including low-fat)
- [ ] Salad dressing
- [ ] Butter (including low-fat)
- [ ] Cheese sauce
- [ ] Lard, fatback, or bacon fat
- [ ] White sauce
- [ ] Other

34b. If margarine, butter, lard, fatback, or bacon fat was added to your cooked vegetables **AFTER COOKING OR AT THE TABLE**, how much did you usually add?

- [ ] Did not usually add these
- [ ] Less than 1 teaspoon
- [ ] 1 to 3 teaspoons
- [ ] More than 3 teaspoons

34c. If salad dressing, cheese sauce, or white sauce was added to your cooked vegetables **AFTER COOKING OR AT THE TABLE**, how much did you usually add?

- [ ] Did not usually add these
- [ ] Less than 1 tablespoon
- [ ] 1 to 3 tablespoons
- [ ] More than 3 tablespoons

35. How often did you eat **sweet peppers** (green, red, or yellow)?

- [ ] NEVER (GO TO QUESTION 36)
- [ ] 1 time in past month
- [ ] 2–3 times in past month
- [ ] 1 time per week
- [ ] 2 times per week
- [ ] 3–4 times per week
- [ ] 5–6 times per week
- [ ] 1 time per day
- [ ] 2 or more times per day

35a. Each time you ate **sweet peppers**, how much did you usually eat?

- [ ] Less than ¼ pepper
- [ ] ¼ to ½ pepper
More than ¼ pepper

Over the past month...

36. How often did you eat fresh tomatoes (including those in salads)?

□ NEVER (GO TO QUESTION 37)
□ 1 time in past month □ 3–4 times per week
□ 2–3 times in past month □ 5–6 times per week
□ 1 time per week □ 1 time per day
□ 2 times per week □ 2 or more times per day

36a. Each time you ate fresh tomatoes, how much did you usually eat?

□ Less than ¼ tomato
□ ¼ to ½ tomato
□ More than ½ tomato

37. How often did you eat lettuce salads (with or without other vegetables)?

□ NEVER (GO TO QUESTION 38)
□ 1 time in past month □ 3–4 times per week
□ 2–3 times in past month □ 5–6 times per week
□ 1 time per week □ 1 time per day
□ 2 times per week □ 2 or more times per day

37a. Each time you ate lettuce salads, how much did you usually eat?

□ Less than ¼ cup
□ ¼ to 1¼ cups
□ More than 1¼ cups

37b. How often did the lettuce salads you ate include dark green lettuce?

□ Almost never or never
□ About ¼ of the time
□ About ½ of the time
□ About ¾ of the time
□ Almost always or always

38. How often did you eat salad dressing (including low-fat) on salads?

□ NEVER (GO TO QUESTION 39)
□ 1 time in past month □ 3–4 times per week
□ 2–3 times in past month □ 5–6 times per week
□ 1 time per week □ 1 time per day
□ 2 times per week □ 2 or more times per day

38a. Each time you ate salad dressing on salads, how much did you usually eat?

□ Less than 2 tablespoons
□ 2 to 4 tablespoons
□ More than 4 tablespoons

39. How often did you eat sweet potatoes or yams?

□ NEVER (GO TO QUESTION 70)
□ 1 time in past month □ 3–4 times per week
□ 2–3 times in past month □ 5–6 times per week
39a. Each time you ate sweet potatoes or yams, how much did you usually eat?

☐ 1 small potato or less than ¼ cup
☐ 1 medium potato or ¼ to ½ cup
☐ 1 large potato or more than ½ cup

40. How often did you eat French fries, home fries, hash browned potatoes, or tater tots?

☐ NEVER (GO TO QUESTION 41)
☐ 1 time in past month ☐ 3–4 times per week
☐ 2–3 times in past month ☐ 5–6 times per week
☐ 1 time per week ☐ 1 time per day
☐ 2 times per week ☐ 2 or more times per day

40a. Each time you ate French fries, home fries, hash browned potatoes, or tater tots how much did you usually eat?

☐ Less than 10 fries or less than ½ cup
☐ 10 to 25 fries or ½ to 1 cup
☐ More than 25 fries or more than 1 cup

41. How often did you eat potato salad?

☐ NEVER (GO TO QUESTION 42)
☐ 1 time in past month ☐ 3–4 times per week
☐ 2–3 times in past month ☐ 5–6 times per week
☐ 1 time per week ☐ 1 time per day
☐ 2 times per week ☐ 2 or more times per day

41a. Each time you ate potato salad, how much did you usually eat?

☐ Less than ½ cup
☐ ½ to 1 cup
☐ More than 1 cup

42. How often did you eat baked, boiled, or mashed potatoes?

☐ NEVER (GO TO QUESTION 43)
☐ 1 time in past month ☐ 3–4 times per week
☐ 2–3 times in past month ☐ 5–6 times per week
☐ 1 time per week ☐ 1 time per day
☐ 2 times per week ☐ 2 or more times per day

Over the past month...

42a. Each time you ate baked, boiled, or mashed potatoes, how much did you usually eat?

☐ 1 small potato or less than ½ cup
☐ 1 medium potato or ½ to 1 cup
☐ 1 large potato or more than 1 cup
42b. How often was sour cream (including low-fat) added to your potatoes, EITHER IN COOKING OR AT THE TABLE?
- Almost never or never (GO TO QUESTION 42d)
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

42c. Each time sour cream was added to your potatoes, how much was usually added?
- Less than 1 tablespoon
- 1 to 3 tablespoons
- More than 3 tablespoons

42d. How often was margarine (including low-fat) added to your potatoes, EITHER IN COOKING OR AT THE TABLE?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

42e. How often was butter (including low-fat) added to your potatoes, EITHER IN COOKING OR AT THE TABLE?
- Almost never or never
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

42f. Each time margarine or butter was added to your potatoes, how much was usually added?
- Never added
- Less than 1 teaspoon
- 1 to 3 teaspoons
- More than 3 teaspoons

42g. How often was cheese or cheese sauce added to your potatoes, EITHER IN COOKING OR AT THE TABLE?
- Almost never or never (GO TO QUESTION 43)
- About ¼ of the time
- About ½ of the time
- About ¾ of the time
- Almost always or always

42h. Each time cheese or cheese sauce was added to your potatoes, how much was usually added?
- Less than 1 tablespoon
- 1 to 3 tablespoons
- More than 3 tablespoons

43. How often did you eat salsa?
- NEVER (GO TO QUESTION 44)
- 1 time in past month
- 2–3 times in past month
- 3–4 times per week
- 5–6 times per week
☐ 1 time per week  ☐ 1 time per day
☐ 2 times per week  ☐ 2 or more times per day

43a. Each time you ate salsa, how much did you usually eat?
☐ Less than 1 tablespoon
☐ 1 to 5 tablespoons
☐ More than 5 tablespoons

44. How often did you eat catsup?
☐ NEVER (GO TO QUESTION 45)
☐ 1 time in past month  ☐ 3–4 times per week
☐ 2–3 times in past month ☐ 5–6 times per week
☐ 1 time per week  ☐ 1 time per day
☐ 2 times per week  ☐ 2 or more times per day

44a. Each time you ate catsup, how much did you usually eat?
☐ Less than 1 teaspoon
☐ 1 to 6 teaspoons
☐ More than 6 teaspoons

45. How often did you eat cooked dried beans (such as baked beans, pintos, kidney, black-eyed peas, lima, lentils, soybeans, or refried beans)? (Please do not include bean soups or chili.)
☐ NEVER (GO TO QUESTION 46)
☐ 1 time in past month  ☐ 3–4 times per week
☐ 2–3 times in past month ☐ 5–6 times per week
☐ 1 time per week  ☐ 1 time per day
☐ 2 times per week  ☐ 2 or more times per day

45a. Each time you ate beans, how much did you usually eat?
☐ Less than ½ cup
☐ ½ to 1 cup
☐ More than 1 cup

45b. How often were the beans you ate refried beans, beans prepared with any type of fat, or with meat added?
☐ Almost never or never
☐ About ¼ of the time
☐ About ½ of the time
☐ About ¾ of the time
☐ Almost always or always

46 How often did you eat other kinds of vegetables?
☐ NEVER (skip question 46a)
☐ 1 time in past month  ☐ 3–4 times per week
☐ 2–3 times in past month ☐ 5–6 times per week
☐ 1 time per week  ☐ 1 time per day
☐ 2 times per week  ☐ 2 or more times per day

46a. Each time you ate other kinds of vegetables, how much did you usually eat?
☐ Less than ¼ cup
☐ ¼ to ½ cup
☐ More than ½ cup
Appendix 3: Program feedback questionnaire

**REACH Feedback Questionnaire**

For each question, please tell us how much the program helped you to feel more confident to begin or maintain your lifestyle changes?

1) The **schedule** of emails itself-just receiving a regular internet message from REACH:

   0  1  2  3  4
   No change at all  Extremely positive

2) The **content** of the email messages from REACH, including any e-links:

   0  1  2  3  4
   No change at all  Extremely positive

Which specific content(s) did you find most useful?

Which specific content(s) did you not find it useful? How would you like us to change or improve it?

4) Contact with REACH research staff during your assessments:

   0  1  2  3  4
5) Information about your cardiovascular risk factor:

0 1 2 3 4

No change at all  Extremely positive

6) Is there anything else that we can change in your emails to help you feel more confident to begin or maintain your lifestyle changes?

7) Did you participate in any other heart healthy programs (over the internet or in person) in the past 4 months in addition to the e-support offered through the REACH trial? Please check all the programs that apply to you.

- I DID NOT participate in any programs
- Exercise Programs
- Diet Programs
- Smoking free living

<table>
<thead>
<tr>
<th>Exercise Programs</th>
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<tbody>
<tr>
<td>Diet Programs</td>
<td></td>
</tr>
<tr>
<td>Smoking free living</td>
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</table>

If Yes, Please describe the program:

8) Did REACH play a role in motivating you to join the heart healthy program(s) mentioned above during the 4 month period?

- Yes
- No