DEVELOPING THE LIVE 5-2-1-0 MOBILE APP USING HUMAN-CENTERED DESIGN AND CO-CREATION TO PROMOTE HEALTHY BEHAVIOURS IN CHILDREN

by

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Abstract

Background: Live 5-2-1-0 is a community-based childhood obesity prevention initiative that promotes the message: 5+ vegetables/fruits; < 2 hours of screen time; 1+ hour of active play; and 0 sugary drinks, every day. A Live 5-2-1-0 Toolkit for healthcare providers (HCPs) was previously developed and piloted in two BC Children's Hospital clinics.

Objective: To co-create, in partnership with children, parents, and HCPs, a Live 5-2-1-0 mobile app that supports healthy behaviour change.

Methods: Leveraging a systematic review of the literature on interventions utilizing mobile applications to promote healthy behaviour changes in children, a series of three focus groups (FG) were conducted using human-centered design and a participatory approach. FG #1 consisted of separate children and joint parents-HCPs sessions that focused on app conceptualization. Researchers and app developers participated in an ideation session to analyze qualitative data from FG #1. Key themes that emerged were presented in separate family and HCP FG #2 (co-creation) sessions to identify desired app features. Families tested a prototype in FG #3 and provided feedback on usability and content via questionnaires.

Results: Fourteen children, 12 parents, and 18 HCPs participated; most participated in two or more FGs. Parents wanted an app that empowers children to adopt healthy behaviours using internal motivation and accountability; children described challenge-oriented goals and family-based activities as appealing. Families identified gamification, goal setting, daily steps, family-based rewards and daily notifications as desired features; HCPs wanted a baseline

behaviour assessment and to see users' behaviour change progress. After testing the prototype, families reported ease in completing tasks, with a median [Q1,Q3] score of 7 [6,7] on a 7-point Likert scale (1=very difficult, 7=very easy). Children liked most suggested rewards (28/37), and found 76/96 suggested daily steps realistic to achieve.

Conclusion: Co-creating an ehealth app with children, parents, and HCPs was feasible. Stakeholders desired for an app that facilitated shared decision making with children as active agents in behaviour change. Future research will involve a quasi-experimental trial to assess the usability and effectiveness of the Live 5-2-1-0 App in achieving healthy behaviour change when used to support health behaviour counselling in a clinical setting.

Lay Summary

Increasingly, Canadian children are becoming overweight and obese due to unhealthy behaviours, such as being less active and eating fewer fruits and vegetables. They are more likely to be obese as an adult and to develop conditions including heart disease and type 2 diabetes. To address this problem, the Live 5-2-1-0 initiative was created by working with community leaders to create environments that support families in achieving the 5-2-1-0 goals: "have at least *five* fruits and vegetables, less than *two* hours of screen time, at least *one* hour of active play, and *zero* sugary drinks, per day." To support families to make healthy behaviour changes, a mobile app was created together with children, parents, and healthcare providers. After gathering their ideas in focus groups, the Live 5-2-1-0 App, which included features like goal-setting, daily challenges, family-based rewards, and notifications, was developed and is currently being tested in two pilot studies.

Preface

This thesis is an original, unpublished, and independent intellectual product of the author. The research work presented in Chapters 3 and 4 obtained ethics approval from the Children's and Women's Research Ethics Board (certificate number: H18-00700; PI: Shazhan Amed; date of approval: August 16, 2018) under the project title "The Live 5-2-1-0 eHealth App." The study procedures outlined in Chapter 3 were designed by Dr. Shazhan Amed, the Principal Investigator, and carried out by the author under the supervision of Dr. Shazhan Amed and co-supervisor Dr. Tricia Tang. The contents of chapters 3 and 4 have been summarized and presented by the author at institutional and national conferences as abstracts and posters. The author performed majority of the data collection and data analysis. Ms. Susan Pinkney provided guidance and performed the thematic analysis of the qualitative analysis alongside the author to identify the key themes that emerged. Ms. Angela Kalia was involved in the data extraction process for the systematic literature review presented in chapter 2; Ms. Annie Kim served as a second assessor to identify the risk of bias of studies reported in the systematic literature review.

Table of Contents

Abstract ..... **iii**

Lay Summary ..... **v**

Preface ..... **vi**

Table of Contents ..... **vii**

List of Tables ..... **xii**

List of Figures ..... **xiii**

List of Symbols and Abbreviations ..... **xiv**

Chapter 1: Introduction **1**

1.1: Childhood Obesity 1

1.2: Mobile Health 4

1.3: Fogg's Behaviour Model 4

1.4: Human-centered Design 5

1.5: The Live 5-2-1-0 Initiative 6

1.6: Rationale 7

Chapter 2: Systematic Literature Review of Interventions Utilising Mobile Applications to Promote Healthy Behaviour Changes in Children **9**

2.1: Introduction 9

2.2: Aim 9

2.3: Methods 10

2.3.1: Literature Search 10

2.3.2: Eligibility Criteria 11

2.3.3: Study Selection 11

2.3.4: Data Extraction 12

2.3.5: Quality Assessment 12
2.4: Results 13
2.4.1: Study Selection 13
2.4.2: Study Characteristics 15
2.4.3: Risk of Bias Assessment 21
2.4.4: Study Design 24
2.4.5: Intervention Design 24
2.4.6: Behaviour Change Theory 25
2.4.7: Outcome Measures 27
2.4.8: App Design Features 31
2.5: Discussion 31
2.6: Strengths and Limitations 37
2.7: Conclusion 38
Chapter 3: Live 5-2-1-0 App Development Methodology 39
3.1: Study Design 39
3.2: Participants 40
3.3: Data Collection 40
3.4: Data Analysis 41
3.4.1: Quantitative Data Analysis 41
3.4.2: Qualitative Data Analysis 42
3.5: Focus Groups, Ideation Session, and Agile Development 42
3.5.1: Focus Group 1 (App Conceptualization) 44
3.5.2: Ideation Session 45
3.5.3: Focus Group 2A (Co-creation – family session) and 2B (HCP session) 46
3.5.4: Agile Development 47
3.5.5: Focus Group 3 (User Testing) 48
Chapter 4: Live 5-2-1-0 App Development Results 50
4.1: Demographics 50

4.2: Focus Group 1A (App Conceptualization - Adult Session) 52
4.2.1: Life Logistics as a Barrier to Healthy Behaviour Practice 52
4.2.2: Environmental Factors Promote Sedentary Behaviour and Impede Physical Activity 54
4.2.3: Communication Facilitates Shared Decision Making 55
4.2.4: Social Connectivity as a Key Motivator for Children and Families 57
4.2.5: Parents as Role Models for Healthy Behaviours 60
4.2.6: Education and Awareness are Key to Making Healthy Behaviour Changes 62
4.2.7: Peer Interactions Influence Children's Decision Making 64
4.2.8: Intrinsic Rewards Lead to Development of Healthy Habits 66
4.2.9: Behaviour Tracking Changes Child Behaviour and Supports Health Care Providers 67
4.2.10: Data Sharing and Security Concerns 69
4.3: Focus Group (App Conceptualization) 1B – Children Session 70
4.3.1: Influencers and Role Models Matter 70
4.3.2: Factors that Discourage Screen Time 71
4.3.3: Social Connection and Competition as Fun Elements 73
4.3.4: Incorporation of Gamification Elements To Increase Appeal 73
4.4: Ideation Session 74
4.4.1: Collaborative Decision Making Between Families and Health Care Providers 74
4.4.2: Family Involvement Encourages Healthy Habit Adoption 75
4.4.3: Need for Adaptive and Customizable Goals 76
4.4.4: Design Elements for Gamification 77
4.5: Pilot Journey Map and Screen Wireframes 78
4.6: Focus Group 2A (Co-creation – Family Session) 78
4.6.1: Introduction and Onboarding to App 79
4.6.2: Parental Involvement via Family Challenges 81
4.6.3: Novelty and Progression Promote User Retention 81
4.6.4: Customization of Reward Features Enhances User Experience 83
4.6.5: In-App Rewards as a Record of Achievement 86

4.7: Focus Group (Co-creation) 2B – HCPs....87
4.7.1: Supporting Patient-Centered Care and Shared Decision Making....87
4.7.2: Readiness to Change Enables Healthy Behaviour Adoption....89
4.7.3: Prompts and Novelty Trigger Behaviour Change....90
4.7.4: External Support and Education Complements App Intervention....91
4.8: Focus Group 3 (User Testing)....94
4.9: Final Product of the App Development Process....100
4.9.1: Onboarding....101
4.9.2: Goal Setting and Rewards Selection....101
4.9.3: Completing Daily Challenges and Achieving Goals....102
4.9.4: Assessment Dashboard and App Menu....103
Chapter 5: Discussion....108
5.1: Co-creation and Participatory Approaches Allow for Efficient Development of Apps Meaningful to Users....110
5.2: Shared Decision Making Supports Children in Making Health Behaviour Changes 112
5.2.1: Shared Decision Making Enhances Patient-centered Care and Promotes Behaviour Change....112
5.2.2: Children Are Active Agents of Behaviour Change....113
5.3: Intrinsic Goals and Extrinsic Rewards as Motivators for Progressive Behaviour Change....114
5.4: Integration of Family Connectivity and Connection with Healthcare Providers Encourages the Adoption of Healthy Behaviours....116
5.5: Strengths and Limitations....118
5.6: Future Directions....121
5.7: Conclusions....121
References....123
Appendices....130

Appendix A: Systematic literature Review Search and Data Extraction 130

Appendix B: Healthy Habits Questionnaire 141

Appendix C: Focus Group 1 (App Conceptualization) Materials 142

Appendix D: Ideation Session Materials 145

Appendix E: Focus Group 2 (Co-creation) Materials 146

Appendix F: Focus Group 3 (User Testing) Materials 152

List of Tables

Table 1. Characteristics of the app-based intervention studies included 16

Table 2. Risk of bias assessment scores 23

Table 3. Study design and intervention type of studies included 26

Table 4. Measured outcomes of included studies 30

Table 5. Demographics and Live 5-2-1-0 behaviours of focus group children participants ...50

Table 6. Demographics of parent participants 51

Table 7. Median scores for prototype testing during focus group 3 (user testing) 96

Table 8. Rating of reward ideas during focus group 3 (user testing) 97

Table 9. Additional reward ideas from focus group 3 (user testing) 100

List of Figures

Figure 1. PRISMA flow diagram summarizing the study selection process.....14

Figure 2. Schematic of research activities for Live 5-2-1-0 App development 43

Figure 3. Screenshots of the onboarding process 104

Figure 4. Screenshots of goal setting and reward selection screens.....105

Figure 5. Screenshots of tiny step selection and goal achievement 106

Figure 6. Screenshots of assessment dashboard and tiny steps record.....107

Figure 7. Pathway from initiation of App use to achievement of healthy behavioural changes and BMI measures.....108

List of Symbols and Abbreviations

BC	British Columbia
BCCH	BC Children's Hospital
CINAHL	Cumulative Index of Nursing and Allied Health Literature
EMBASE	Excerpta Medica database
ERIC	Education Resources Information Center
FBM	Fogg's Behavioural Model
HCD	Human-centered design
HCP	Healthcare provider
HHQ	Healthy Habits Questionnaire
HMW	How Might We
IQR	Interquartile range
MEDLINE	Medical Literature Analysis and Retrieval System Online
MeSH	Medical subject headings
MET	Metabolic equivalent of task
MVPA	Moderate to vigorous physical activity
PRISMA	Preferred Reporting Items for System Review and Meta-Analyses
PsycINFO	Psychological Information Database
RCT	Randomized controlled trial
RoB 2	Risk of Bias 2
ROBINS-I	Risk of Bias in Non-randomized Studies of Interventions
UBC	University of British Columbia
WHO	World Health Organization
zBMI	BMI z-score
$\%BMI_{p50}$	percent over-BMI relative to the 50^{th} percentile
$\%BMI_{p95}$	percent over-BMI relative to the 95^{th} percentile

Chapter 1: Introduction

1.1: Childhood Obesity

Rates of childhood obesity have increased dramatically around the world since the 1970s. It has been estimated that a total of 150 million children worldwide currently live with obesity, with numbers projected to increase to 206 million by 2025 and further to 254 million by 2030 (1). Such alarming increases have led to the emergence of childhood obesity as one of the most pressing public health challenges of the 21st century. Childhood obesity is associated with increased risk of developing chronic conditions, such as type 2 diabetes, hypertension, and cardiovascular disease (2), as well as psychosocial consequences, such as depression and anxiety (3). Obesity in childhood tends to persist throughout adulthood along with its associated physical and psychosocial consequences (4).

Similar to global trends, childhood obesity has also emerged as a significant public health problem in Canada, with more children becoming overweight and obese due to decreasing levels of physical activity and unhealthy nutrition (5). In fact, childhood obesity rates in Canada have tripled since 1979 (6). Results from the 2015 Canadian Community Health Survey indicated that an estimated 1.5 million Canadian children (30.9%) were classified as overweight and obese, with one in eight children (580,800 children) reported as obese (7). It is estimated that close to 60% of children today will be obese at the age of 35, with approximately 50% becoming obese during childhood (8). In the long run, increasing childhood obesity rates may add to the economic burden related to obesity-related healthcare costs, including medications, hospitalization and physician costs. Healthcare costs are

estimated to increase to $9 billion in 2021 from current estimates of between $5 billion and $7 billion, excluding the consideration of productivity loss and reductions in tax revenues (9).

With rates of childhood obesity rising continuously over the past decades, health agencies around the world have increasingly implemented various policies to address this critical challenge. Healthy lifestyle behaviours such as diet, physical activity, and sedentary behaviour are commonly considered to be key modifiable risk factors related to obesity (10). In 2004, member states of the World Health Organization (WHO) endorsed the Global Strategy on Diet, Physical Activity, and Health to encourage governmental health institutes at local, national and global levels to adopt policies and implement interventions that promote healthy diet and increased physical activity levels to combat obesity and its associated consequences for all populations (11). In 2014, due to slow and inconsistent progress in decreasing obesity rates, the "Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013-2020" included stopping rising global obesity rates as one of nine global non-communicable disease targets, with a specific goal to halt further increases to childhood obesity rates by 2025 (11). In addition, the Commission for Ending Childhood Obesity was established to identify gaps in current initiatives and areas for action (12).

In Canada, a multitude of efforts have been led by childhood obesity advocates to address the epidemic at all stages of the care continuum, which consists of prevention, identification, early intervention, weight management, and specialized treatment (13). Due to the tendency for obesity to have its onset in the early stages of life, obesity prevention advocates have highlighted the importance of early population-based prevention initiatives in order to halt or

minimize childhood obesity rates and address the global epidemic more effectively (14). In 2012, the Ontario government declared the reduction of childhood obesity rates as a key focus area for healthcare and established an expert panel to advise the Ministry of Health and Long-term Care on an action plan to reduce childhood obesity rates via strategies involving various jurisdictions and public health units (15). Similarly, in 2015, the BC Ministry of Health, along with the Childhood Obesity Foundation and Child Health BC, identified the need for better communication of childhood obesity prevention and treatment strategies across the province and published a report summarizing existing interventions and programs to address the continuous increase in obesity rates among children in the province (13).

Childhood is a key time to intervene with the promotion of healthy behaviours, but progress in reducing childhood obesity rates has been slow. Between ages of 8-12 years, children experience significant physical and developmental changes, including early signs of puberty, and formation of their own identity, including their own values and practices (16). Consequently, childhood obesity interventions should target this age group such that children are able to adopt healthy behaviour changes that will continue throughout their lives. Given that the prevention of childhood obesity is often associated with reduction in long-term complications, interventions for this prepubertal age group should focus on the prevention of excessive adiposity, regular monitoring of height and weight data, and healthy living counselling and education on nutrition and physical activity (14).

1.2: Mobile Health

At the same time that childhood obesity rates increase, this past decade has also witnessed a tremendous rise in digital technology, in particular, the adoption of mobile devices, such as smartphones and tablets in common households (17), and the usage of applications (apps) on these devices (18). Mobile devices, such as smartphones and tablets, are being used by nearly all age groups, with 85% of British Columbians reporting to have easy access to a mobile device (19). Recent years have also witnessed a significant surge in the number of health and fitness apps, with the global mobile health market expected to increase five-fold from 21 billion US dollars in 2016 to approximately 100 billion US dollars in 2021 (20). The increasing popularity of health and fitness apps is associated with its ability to reach large numbers of people at once, accessibility for individuals living in remote/rural areas, ability to collect real-time data in an efficient manner, and being cost effective (21). Previous interventions that used mobile health with children have reported high levels of interest by participants, low attrition rates, and significant improvements in readiness levels and healthy behaviour changes (22). However, as many mobile health apps are not evidence-based and did not involve medical professionals in the design and development processes, the reliability and accuracy of the apps raise concerns as they may undermine patient safety (23). In addition, since many apps have been developed commercially and did not involve end users in the design and implementation, many encounter low usage and user retention rates (21).

1.3: Fogg's Behaviour Model

Health interventions are often created based on behavioural change theories in order to increase their effectiveness and improve patient quality of care. One of these theories is Fogg's

behaviour model (FBM), which posits that motivation, ability, and triggers must all be present in order to influence an individual to perform a target behaviour (24); in the case of health interventions this is to influence a patient to adopt healthy behaviour changes. FBM includes three core motivators (pleasure/pain, hope/fear, and social acceptance/rejection), six interrelated ability elements (time, money, physical effort, brain cycles, social deviance, and non-routine) and three trigger types (spark, facilitator, and signal).

Fogg further explains that the presence of high motivation and high ability does not necessarily lead to the occurrence of the target behaviour unless an appropriate trigger is present. With triggers becoming increasingly prevalent in our everyday lives in the form of mobile device notifications that allow for a strong association between trigger (e.g. app push prompt) and behaviour (e.g. opening an app), Fogg suggests that those involved in persuasive technology should use FBM to think systematically about how motivation, ability, and triggers should be optimized in order to increase the efficiency in producing target behaviours.

1.4: Human-centered Design

The human-centered design (HCD) framework is a type of participatory action research method that engages relevant stakeholders throughout all phases of the development process of a project (25). HCD can be used to directly collaborate with end-users throughout the entire development process to generate creative and feasible solutions that reflect the desires and needs of end-users. The HCD process begins with the inspiration phase, which involves establishing a multifaceted understanding of the needs of the target audience by immersing the researcher/observer into the lives of the audience via methods such as conducting focus groups

and interviews. Next is the ideation phase, where knowledge generated from the inspiration phase is used to brainstorm product ideas, identify potential designs, and create a prototype for testing by working collaboratively with stakeholders in a co-creation manner. The last stage is implementation, where the solution is brought to life and evaluated for further refinement.

1.5: The Live 5-2-1-0 Initiative

The Live 5-2-1-0 initiative is rooted in the principles of community-based participatory research and works with community partners to create healthy environments for children. To achieve this goal, the initiative builds capacity among community stakeholders across multiple sectors, such as health, community services, recreation centres, and schools, to share and support the Live 5-2-1-0 message: having at least five vegetables and fruits, less than two hours of screen time, at least one hour of active play, and zero sugary drinks, per day (26). Over 40 resources and tools have been co-created with community partners to provide a framework for stakeholders in various sectors to implement changes to policies and environments, and to advocate for the use of the Live 5-2-1-0 message to support children and families in adopting healthy behaviour changes. In 2019, a total of 2,434 resources were downloaded by 350 unique multi-sectoral partners, including HCPs, schoolteachers, parents, and municipal employees, from 63 communities across BC, Canada (27). Currently, the Live 5-2-1-0 initiative has 12 partner communities and a total of 74 Live 5-2-1-0 Playboxes filled with play equipment and active game ideas installed in 31 communities across the province.

A sub-project of the Live 5-2-1-0 initiative has been the development of the Live 5-2-1-0 Family Practitioner Toolkit, a paper-based toolkit containing resources such as goal trackers,

the Healthy Habits Questionnaire (HHQ), and informational handouts, which enhance the ability of family practitioners to integrate health living counselling into their interactions with children. A total of 14 family practitioners who participated in a pilot study of the Family Practitioner Toolkit reported positive changes in their practice in which they addressed nutrition, screen time, and sugary drink consumption more frequently with their pediatric patients; and displayed an increase in knowledge related to motivational interviewing and patient-centered behavioural goal setting. The participating family practitioners identified the Live 5-2-1-0 message and the Toolkit resources as key in facilitating these changes in their practice (28). This pilot led to the development of a similar Healthcare Provider (HCP) Toolkit that was designed to provide *pediatric* clinicians with the knowledge, skills, and resources to integrate the promotion of healthy behaviours in their clinical practice. The Live 5-2-1-0 HCP Toolkit was previously piloted in two sub-specialty clinics (renal transplant and long-term oncology clinic) at BC Children's Hospital (BCCH). HCPs found the Toolkit to be useful in providing healthy lifestyle counselling. 80% of HCP participants rated resources on sleep and health, screen time, and the HHQ as useful or very useful; all HCPs rated resources on encouraging healthy eating habits as useful or very useful. The introduction of the Toolkit also resulted in increasing frequency of lifestyle assessments and counselling performed by HCPs, with the exception of physical activity and sleep counselling in healthy patients (29).

1.6: Rationale

Given that the HCP Toolkit is used by clinicians only during patient encounters, it is currently difficult for clinical providers to determine whether patients are making progress in achieving their healthy living goals *in-between* clinic visits. While children and their families are often sent home with paper-based resources to support them in making healthy behaviour changes,

a digital tool such as a mobile app may be complementary to in-person counselling by continuously engaging and guiding families towards achieving healthy behaviour changes between patient visits. A mobile app may allow for HCPs to monitor children's goal progress and provide guidance remotely. Therefore, the aim of this study was to use the HCD framework to co-create, in partnership with children, parents, and HCPs, the Live 5-2-1-0 mobile app (hereinafter referred to "the App") that could be used to support HCPs in delivering healthy behaviour counselling, and to motivate healthy behaviour change in children.

Chapter 2: Systematic Literature Review of Interventions Utilising Mobile Applications to Promote Healthy Behaviour Changes in Children

2.1: Introduction

With the usage of mobile apps becoming increasingly popular among pediatric populations, many health and fitness apps have been developed and used as either a standalone intervention (30–35) or as part of a multi-component intervention (36–39). However, results from these studies have generally been mixed, and the efficacy (performance of an intervention under ideal circumstances) and effectiveness (performance of an intervention in real life conditions) of mobile apps in delivering health promotion interventions to address childhood obesity remain unclear. While a few systematic reviews have focussed on mobile health interventions that address diet, physical activity, and sedentary behaviour among children, most did not focus on traditional mobile app use (user directly interacts with the app via user interface) exclusively, but rather, adopted a broader definition and included exergames (digital games that involve physical movements for active gameplay experience), video games, websites, and text messaging that were performed on a mobile device (40–43). Of those that focused solely on mobile apps, most targeted adolescents (43,44) or a mix of pediatric and adult populations (45). There is therefore a knowledge gap related to mobile app interventions for the promotion of healthy behaviours specifically in children ages 8-12 years, a critical period of time for habit and behaviour establishment.

2.2: Aim

The aim of this study was to conduct a systematic review to examine the effectiveness of mobile health technologies that promote healthy behavior change in diet, physical activity, or

sedentary behavior in children ages 8-12 years, a critical period for children to establish good habits and behaviours as they form their own identity, and to identify mobile application feature characteristics of successful ehealth interventions.

2.3: Methods

2.3.1: Literature Search

This systematic literature review was conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (46). A literature search strategy was created with guidance from a research librarian. Briefly, Medical Subject Heading (MeSH) terms and free-text keywords related to mobile app development, obesity prevention and healthy behaviours, and mixed methods research interventions were identified. The search strategy was designed such that results must contain at least one search term from each of the three categories. Using this strategy, a systematic literature search of electronic databases MEDLINE (Medical Literature Analysis and Retrieval System Online), EMBASE (Excerpta Medica database), PsycINFO (Psychological Information Database), CINAHL (Cumulative Index of Nursing and Allied Health Literature), and ERIC (Education Resources Information Center) limited to literature published between 2008 and September 7th, 2018 was performed. Search filters to retrieve pediatrics articles were used for MEDLINE (47), EMBASE (48) and CINAHL (49). Age groups and education level limiters were used for PsycINFO and ERIC respectively to retrieve pediatrics articles. The complete search strategy is presented in Appendix A. In addition, grey literature was searched by screening reference lists of included articles, research studies listed in the U.S. National Library of Medicine clinical trials database (using search terms “Obesity”, Childhood,” and “Mobile health”), the

first 100 results from a search of keywords “childhood obesity” and “mobile health” on Google Scholar, and results from title and abstract search of ProQuest Dissertations and Theses Global with search terms “childhood obesity” and “mobile.”

2.3.2: Eligibility Criteria

Eligibility criteria for articles included: a) children aged 8 to 12 years as participants; b) the direct use of an application on a mobile device by children and/or their immediate caregivers; and c) targeted behaviour change in at least one of the following domains: diet, physical activity, and sedentary behaviour. In order to provide a broad overview of the current published literature, both experimental and observational studies were included. Non-English and non-peer-reviewed primary studies (e.g. conference proceedings, commentaries, reviews) were excluded. Articles that described the use of web, email, or text message-based interventions were also excluded.

2.3.3: Study Selection

After duplicates were removed from the database and grey literature search, a single author (KY) performed initial screening based on title and abstract to identify full text articles for assessment for eligibility. Any uncertainty that arose from this process was discussed with another author (SA) and decisions were made by consensus. Articles that could not be excluded based on the information provided in the title and abstract were included in the full-text review. Two authors (KY and AK) then reviewed the full-text articles independently, after which they compared their decisions on eligibility, discussed and resolved any discrepancies by consensus, and finalized the list of articles to be included in this review.

2.3.4: Data Extraction

The following information was extracted from each intervention study: study design, inclusion criteria, sample size, sociodemographic characteristics of participants, study details (e.g. behaviour change theory, study length), description of the mobile app, and outcome measures (quantitative and qualitative). Two authors (KY and AK) performed data extraction independently, following a pre-determined data extraction template (refer to Appendix A). Discussions between KY, AK, and SA (when needed) occurred regularly to reach a consensus in cases of disagreement.

2.3.5: Quality Assessment

To evaluate the quality of the intervention studies included in this review, two authors (KY and AK) independently assessed the risk of bias of randomized controlled trials (RCTs) and non-randomized studies using the Cochrane Risk of Bias 2 (RoB 2) tool for randomized trials (50) and the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) tool (51), respectively. The RoB 2 assesses bias arising from five domains: randomization process, deviations from the intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. The ROBINS-I assesses seven domains through which bias may be introduced into a non-randomized study: confounding, selection of participants into the study, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of reported results. Any discrepancies in ratings were resolved via discussion between the authors until a consensus was reached.

2.4: Results

2.4.1: Study Selection

A flowchart summarizing the study selection process is presented in Figure 1. The systematic literature search initially identified 2,893 publications. Three additional publications were added from a grey literature search in Google Scholar. After removal of duplicates, the title and abstract of 2,051 publications were screened and 42 full text articles were considered to be potentially eligible. Upon review, 32 full text articles were excluded due to: a) reporting on a text message-based (*n*=5) or computer-based (*n*=1) intervention; b) being a study protocol (*n*=6) or non-peer reviewed primary study (*n*=2); c) target population (*n*=10) or target behaviour (*n*=2) not meeting eligibility criteria; and d) describing only the app development process (*n*=6). In the end, 10 articles were deemed eligible to be included in this review. Two studies that used the same mobile app but in different settings were included (36,37).

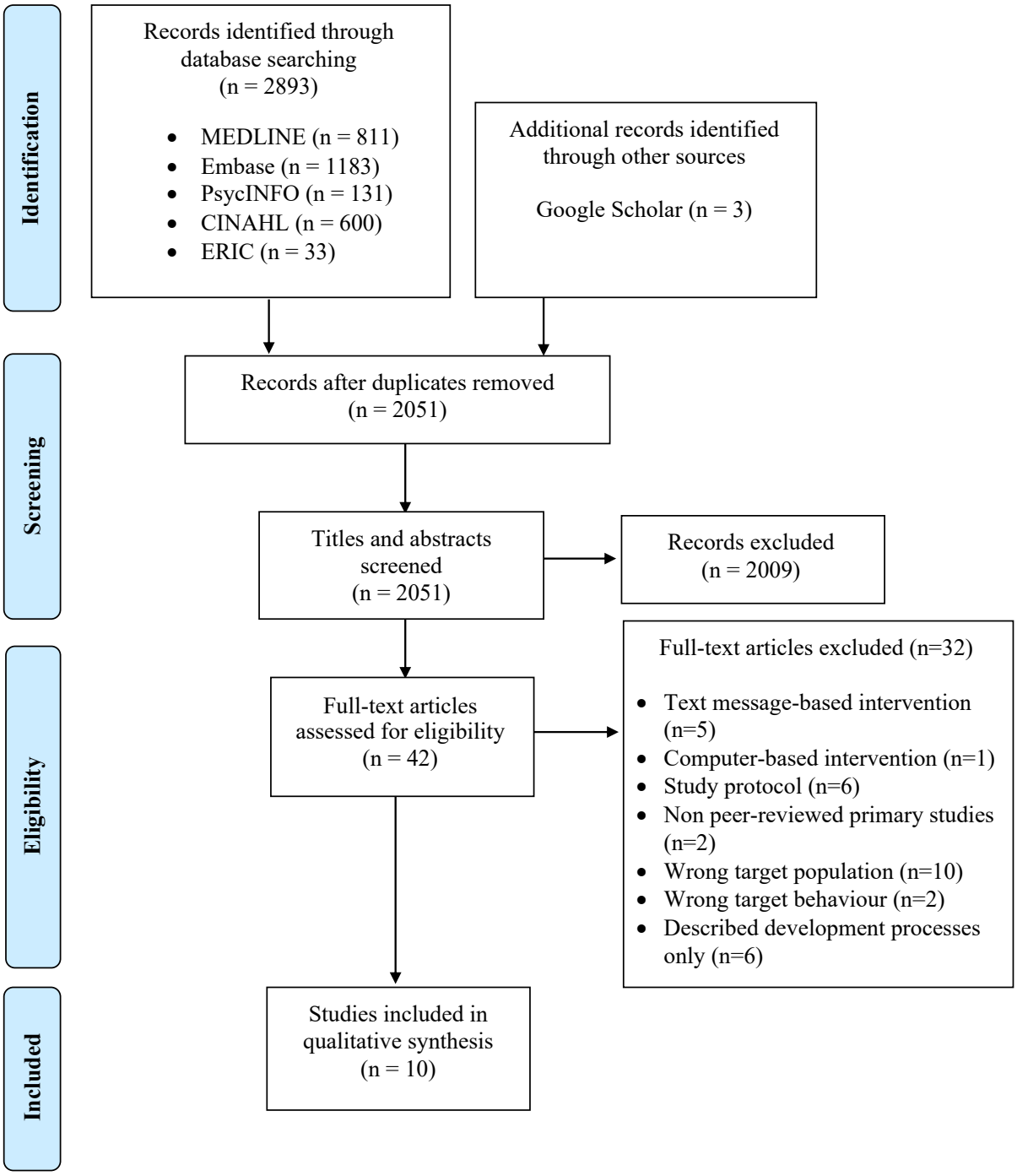


Figure 1. PRISMA flow diagram summarizing the study selection process

2.4.2: Study Characteristics

Of the 10 articles included in this review (Table 1), seven studies were from the United States (32–38) and the remaining three studies were from Australia (39), Canada (30), and the Netherlands (31). Despite limiting the search to publications from 2008-2018, the articles selected were all published between 2011 and 2018. The number of participants per study ranged from 18 to 2,477, with two studies including only male (39) or only female (33) participants. The age of participants ranged from 4 to 21 years, with four studies involving only adolescents (greater than 10 years of age) (31,34,37,39). Across the studies, there was diverse representation from various racial or ethnic minority groups, including African (39), African American (32,33,37,38), American Indian/Alaska native (33), Asian (32,39), Hispanic (32,37,39), Pacific Islander (33), and Middle Eastern (39). In four studies, more than half of the total study participants were from racial or ethnic minority populations (32,33,35,37). Targeted recruitment for participants from low socioeconomic backgrounds was performed in four studies (33,35,38,39). Two studies only included participants who were deemed at risk for developing obesity as determined by various measures, including failure to meet international physical activity or screen-time guidelines (39) and positive results on a food addiction scale (37).

Table 1. Characteristics of the app-based intervention studies included

Author	Year	Country	Title	Sample (age reported as mean ± SD) (M = male; F = female) (SES = socioeconomic status)
Blackman e*t al*. (35)	2015	United States	Examining the feasibility of smartphone game applications for physical activity promotion in middle school students	*N* = 27 Age: 12.3 years Sex: 56% (M); 44% (F) Ethnicity: African American (30%); White (59%); Biracial (7%); Hispanic (4%) SES: low-SES neighbourhood
Byrne *et al.* (34)	2012	United States	Caring for mobile phone-based virtual pets can influence youth eating behaviors	*N* = 39 Age: 13.1 ± 0.70 years (12-14 years) Sex: 56.4% (M); 43.6% (F) Ethnicity: Caucasian (84%); biracial/mixed race (16%) SES: community with median household income of $44,808

Author	Year	Country	Title	Sample (age reported as mean ± SD) (M = male; F = female) (SES = socioeconomic status)
Dunton *et al.* (32)	2011	United States	Investigating children's physical activity and sedentary behavior using ecological momentary assessment with mobile phones	*N* = 121 Age: (9-13 years) Sex: 51% (M); 49% (F) Ethnicity: African American (10.0%); Asian (12.5%); Hispanic/Latino (32.5%); White (23.3%); Biracial/mixed (15.8%); Other (5.8%) SES: annual household income < $45,000 (25.0%)
Nollen *et al*. (33)	2014	United States	Mobile technology for obesity prevention: a randomized pilot study in racial-and ethnic-minority girls	*N* = 51 Age: 11.3 ± 1.6 years (9-14 years) Sex: 100% (F) Ethnicity: African American (83.7%); bi- or multi-racial (8.2%); American Indian/Alaska Native (6.1%); Asian/Pacific Islander (2.0%) SES: economically disadvantaged neighborhoods; 32.4% of children living in poverty

Author	Year	Country	Title	Sample (age reported as mean ± SD) (M = male; F = female) (SES = socioeconomic status)
Patten *et al*. (30)	2017	Canada	A pilot study of children's physical activity levels during imagination-based mobile games	*N* = 20 Age: 7 ± 1.75 years (4-11 years) Sex: 45% (M); 55% (F) Ethnicity: N/A SES: N/A
Pretlow *et al.* (36)	2015	United States	Treatment of child/adolescent obesity using the addiction model: a smartphone app pilot study	*N* = 43 Age: 16.0 ± 0.43 (10-21 years) Sex: 35% (M): 65% (F) Ethnicity: Caucasian (83.7%); Black (9.3%); Latino (4.7%); Asian (2.3%) SES: low (44.0%); middle/high (56.0%)

Author	Year	Country	Title	Sample (age reported as mean ± SD) (M = male; F = female) (SES = socioeconomic status)
Smith *et al*. (39)	2014	Australia	Smart-phone obesity prevention trial for adolescent boys in low-income communities: the ATLAS RCT	*N* = 361 Age: 12.7 ± 0.5 years (12-14 years) Sex: 100% (M) Ethnicity: Australian (77.2%); European (14.8%); African (0.6%); Asian (1.7%); Middle Eastern (1.1%); Other (2.8%) SES: low-income communities
Struempler *et al.* (38)	2014	United States	Changes in fruit and vegetable consumption of third-grade students in body quest: food of the warrior, a 17-class childhood obesity prevention program	*N* = 2,477 Age: 8-9 years Sex: 51% (M); 49% (F) Ethnicity: Black (46%); non-Black (54%) SES: recruited from schools with > 50% of students receiving free or reduced-price lunch

Author	Year	Country	Title	Sample (age reported as mean ± SD) (M = male; F = female) (SES = socioeconomic status)
Vidmar *et al.* (37)	2018	United States	An addiction model-based mobile health weight loss intervention in adolescents with obesity	*N* = 18 Age: 14.44 ± 1.65 years (12-18 years) Sex: 27.78% (M); 72.22% (F) Ethnicity: Hispanic (61.11%); non-Hispanic (38.89%) SES: N/A
Van Woudenberg *et al.* (31)	2018	Netherlands	A randomized controlled trial testing a social network intervention to promote physical activity among adolescents	*N* = 190 Age: 12.17 ± 0.50 years (11-14 years) Sex: 46.32% (M); 53.68% (F) Ethnicity: N/A SES: N/A

2.4.3: Risk of Bias Assessment

The results of the risk of bias assessment for the 10 articles included in this review can be found in Table 2. Of the four articles that reported on studies that utilised a RCT design, one was judged as having low risk of bias (39) and three with some concerns (31,33,34). A potential major source of bias was from the randomization process itself. Three studies did not elaborate on randomization methods other than providing a statement that the study was randomized. Due to the nature of the interventions, blinding of participants and those delivering the intervention from group allocation was impossible for all studies. One study attempted to blind assessors from treatment allocations but were only successful at baseline but not at follow-up (39). Three studies reported incomplete outcome data due to participant absence on day of data collection (31,39), loss to follow-up (33,39), withdrawal from the study (39), and malfunctioning of measuring devices (31). Two studies reported objective measures as the primary outcome (31,39) and all studies scored a low risk of bias in outcome measurement. The pre-specified intentions for data analysis was only available for two studies, with both analysing the data in accordance with the pre-specified analysis plan as outlined in a trial register (31) and a published protocol (39).

Of the six non-randomized intervention studies, three were assessed as having a moderate risk of bias (30,36,38) and three as having a serious risk of bias (32,35,37). Baseline confounding was found to be serious risk of bias for three studies, with two studies measuring but not controlling for potential confounding factors (35,37) and one study neglecting to consider previous exposure to intervention as a potential confounder for a small subset of participants in a retrial (32). All studies scored low or moderate risk for bias in classification of

interventions, missing data, measurement of outcomes, and selection of the reported result. A pre-specified analysis plan was only available for one study (37) in the form of a trial register.

Table 2. Risk of bias assessment scores

Randomized Trials

Study	Randomization process	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall Bias
Byrne et *al*. (34)	Some concerns	Low	Low	Low	Some concerns	Some concerns
Nollen *et al.* (33)	Some concerns	Low	Some concerns	Low	Some concerns	Some concerns
Smith *et al.* (39)	Low	Low	Low	Low	Low	Low
van Woudenberg *et al.* (31)	Some concerns	Low	Low	Low	Low	Some concerns

Non-randomized Trials

Study	Confounding	Selection of participants	Intervention classification	Deviations from intended intervention	Missing data	Measurement of outcomes	Selection of reported result	Overall Bias
Blackman *et al.* (35)	Serious	Low	Low	Low	Moderate	Low	Moderate	Serious
Dunton *et al.* (32)	Serious	Low	Low	Low	Low	Low	Moderate	Serious
Patten *et al.* (30)	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Pretlow *et al.* (36)	Moderate	Low	Low	Low	Low	Moderate	Moderate	Moderate
Struempler *et al.* (38)	Moderate	Low	Low	Low	Moderate	Moderate	Moderate	Moderate
Vidmar *et al.* (37)	Serious	Low	Moderate	Low	Low	Low	Low	Serious

2.4.4: Study Design

Quasi-experimental study designs (Table 3) were the most prevalent among the studies (*n*=6) and included within subject design (30), one-group post-test-only design (32), and one-group pre-test-post-test design (35–38). The remaining four interventions studies were cluster RCTs (31,39) or RCTs (33,34). The intervention duration ranged from one hour to six months, with four studies being less than one month (30–32,34), two studies between one month and three months (33,35) and four studies more than three months (36–39). Only one study included a long-term follow-up assessment to determine the sustainability of changes after the end of the intervention (39).

2.4.5: Intervention Design

Two studies were overweight or obesity treatment interventions (36,37) and eight were obesity prevention interventions (30–35,38,39) (Table 3). The targeted healthy behaviours included physical activity (30–32,35,39), screen time/sedentary behaviour (32,35,39), and nutritional intake (33,34,36–39). Most studies targeted only one healthy behaviour. One study targeted two behaviours – nutritional intake and screen time/sedentary behaviour (33). Another study targeted all three healthy behaviours (39). Four studies (36–39) consisted of multicomponent interventions that involved the use of one or more apps alongside other activities, such as physical activity sessions, mentoring sessions, websites, parental education, and researcher-led seminars (39); educator-led lessons, fruit and vegetable tastings, and printed materials (38); as well as text messages (36,37), phone calls (36,37), and group sessions (36). Rather than using commercially available apps, all studies included apps that were developed solely for the purpose of the intervention. Most studies included the use of one app only. One study used

a collection of four apps (35), while another used a collection of seven apps (38) as part of the intervention.

2.4.6: Behaviour Change Theory

All but two studies (30,32) reported on behaviour change theories that served as the basis for app and intervention design to promote healthy behaviour change among participants (Table 3). A total of eight different behaviour change theories were reported, with seven studies reporting one behaviour change theory (31,33–38) and one study reporting two behaviour change theories (39). Two interventions (34,39) used social cognitive theory (52), which suggests that learning and acquiring certain behaviours occur through reciprocal interactions between an individual and his or her environment. Another two studies (36,37) that used the same app adopted the addiction treatment model (53), which is based on the three principles of divide-and-conquer, staged withdrawal/abstinence, and body focused repetitive behavioural intervention methods. Other behaviour change theories that were used include self-determination theory (31,39), behavioural weight control principles (33), Fogg's behaviour model (35), and experiential learning theory (38).

Table 3. Study design and intervention type of studies included

Study	Study Design					Intervention Type			Multi-component	Duration	Behaviour Change Theory
	Quasi-experimental			RCT	Cluster RCT						
	Within Subject	One-group Posttest-only	One-group Pretest-posttest			Healthy Behaviour Promotion	Obesity Prevention	Obesity Treatment			
Blackman *et al.* (35)			✓			✓				6 weeks	Fogg's behaviour model
Byrne *et al.* (34)				✓		✓				9 days	Social cognitive theory
Dunton *et al.* (32)		✓				✓				4 days	N/A
Nollen *et al.* (33)				✓			✓			12 weeks	Behavioural weight control principles
Patten *et al.* (30)	✓					✓				1 hour	N/A
Pretlow *et al.* (36)			✓					✓	✓	20 weeks	Addiction treatment model
Smith *et al.* (39)					✓		✓		✓	20 weeks	Social cognitive theory; self-determination theory
Struempler *et al.* (38)			✓				✓		✓	17 week	Experiential learning theory
Vidmar *et al.* (37)			✓					✓	✓	6 months	Addiction treatment model
Van Woudenberg *et al.* (31)					✓	✓				7 days	Self-determination theory

2.4.7: Outcome Measures

A summary of reported outcome measures are presented in Table 4. Overall, six of 10 studies reported significant improvement in at least one of the healthy behaviours. Measures of physical activity were the most commonly reported outcomes among the intervention studies and included moderate to vigorous physical activity (MVPA) via estimation from heart rate (30) and accelerometry (32,39), number of steps (31,32,39), and metabolic equivalents (METs) as determined by accelerometry (35). Of the five articles that reported on physical activity, four studies that focussed solely on physical activity as an outcome found a statistically significant increase in physical activity levels upon app use (30,32,35,39). Two studies utilised mobile apps to guide participants to participate in physical activity in their own environments without encouraging excessive screen time. For example, Biba Games (30) is a suite of mobile apps aimed at encouraging imagination-based outdoor play to promote MVPA via playful directives from a mobile phone. Compared to regular playground gameplay, participants who used Biba Games displayed greater amounts of MVPA as demonstrated by a significant increase in measured heart rate. In another study (35), participants at an after school program were asked to play a series of four smartphone physical activity games resembling popular childhood games (e.g. tag, scavenger hunt) that were designed to be used either individually or as a group. Compared to baseline, participants displayed significantly higher METs, a measure estimated based on the number of step counts recorded by accelerometers.

Dietary outcomes were also reported in four intervention studies and included fruit and vegetable intake (33,38), sugar-sweetened beverage intake (33,39), and likelihood of eating breakfast (34). Body Quest: Food of the Warrior (38) is a multicomponent elementary school-

based childhood obesity prevention program that aimed to increase fruit and vegetable consumption, increase physical activity, and promote family involvement via a mix of traditional curriculum teaching, iPad app education, weekly fruit and vegetable tastings, and weekly take-home activities. Intervention participants demonstrated significant increases in fruits and vegetable consumption over the course of the program, and at the end of the program, consumed significantly more servings of fruits and vegetables compared to the control group. In Smith *et al.*'s (39) cluster RCT, participants demonstrated a significant intervention effect for sugar-sweetened beverage consumption as measured by number of glasses per day after completing a 20-week multicomponent school-based intervention that involved the use of a smartphone app as a complement to other intervention components, such as in-school sport sessions, researcher-led seminars, and teacher professional development workshops. On the other hand, use of a mobile app as a standalone, minimal-contact childhood obesity prevention tool resulted in a mix of non-significant and significant intervention effects. In Nollen *et al*.'s pilot RCT (33), intervention participants tested a mobile app that facilitated goal setting, self-monitoring, and positive reinforcement to promote healthy behaviours. However, a 24-hour dietary recall failed to detect any significant healthy behaviour changes, but revealed a trend towards increased fruit and vegetable consumption and decreased sugar-sweetened beverage consumption. However, participants who tested a virtual pet mobile game app aimed at improving eating behaviours demonstrated a significant increase in their likeliness to consume breakfast (34).

BMI or BMI-derived measures were reported among four of the intervention studies and included BMI (33,39), BMI z-score (zBMI) (37), and percent over-BMI relative to the 95th

percentile (%BMI_{p95}) (37) and 50th percentile (%BMI_{p50}) (36). Two studies that reported on the same weight loss intervention but different settings - healthcare (37) and community (36), measured various BMI-derived measures from baseline to program completion. The intervention was a multicomponent program based on an addiction treatment model that involved the use of an app, as well as weekly phone meetings and group meetings to guide participants into staged, incremental food withdrawal to address problem foods, snacking, and meal size reduction. In the community setting, participants demonstrated a significant decrease in %BMI_{p50} from baseline to end of intervention ($p < 0.01$). In addition to a significant decrease in %BMI_{p50}, intervention participants in the healthcare setting (37) also experienced a significant decrease in zBMI and %BMI_{p95}, which are more stringent measures, upon program completion compared to age-matched controls, with both measures achieving $p \leq 0.001$. Two other studies that reported BMI only (33,39) found no significant differences upon intervention completion despite comparable intervention duration (between 12-20 weeks).

Other reported measures included waist circumference (39), body fat percent (39), strength measurements (39), recreational screen time (33,39), importance of eating healthily (34), and process evaluation outcomes, such as retention rates and program satisfaction (33,35–37). In a virtual pet intervention aimed at promoting youth eating behaviours, participants who received positive feedback only from their virtual pets reported viewing healthy eating as less important than those who received both positive and negative feedback ($p<0.01$), illustrating the motivational value of negative feedback (34). Significant intervention effects were found for screen time ($p=0.03$) and physical strength ($p=0.04$) in a 20-week multicomponent obesity prevention intervention using smartphone technology (39).

Table 4. Measured outcomes of included studies (* represents $p < 0.05$ significance)

Study	Anthropometry						Physical Activity				Dietary			Screen Time	Process Evaluation
	BMI	BMI z-score	%BMI p95	%BMI p50	Waist Circum-ference	Body Fat %	MVPA	Step Count	Metabolic Equivalents	Physical Strength	Fruit and Vegetable	Sugar-sweetened Beverages	Breakfast Likeliness		
Blackman *et al.* (35)									✓*						✓
Byrne *et al.* (34)													✓*		✓
Dunton *et al.* (32)							✓*	✓*							
Nollen *et al.* (33)	✓										✓	✓		✓	
Patten *et al.* (30)							✓*								
Pretlow *et al.* (36)				✓*											✓
Smith *et al.* (39)	✓				✓	✓	✓	✓		✓*		✓*		✓*	✓
Struempler *et al.* (38)											✓*				
Vidmar *et al.* (37)		✓*	✓*												✓
Van Woudenberg *et al.* (31)								✓							

2.4.8: App Design Features

Intervention studies used apps that had a variety of design features. The most common design feature was behavioural monitoring, either automatically upon app use or inputted manually by the user (*n*=5). This included using the app as a tool for self-report questionnaire administration (31,32,36,37), as well as collection of information from accelerometers (31,39), food scales (36,37) and body weight scales (36,37). Goal setting to adopt healthy behaviour changes was also a feature that was included (*n*=4). This included goal setting for physical activity (39), screen-time (33,39), fruits and vegetables (33), sugar-sweetened beverages (33), and reduction in food amounts, problem foods, and snacking (36,37). Four studies adopted a gamification approach in app design (30,33–35) by incorporating features such as song-based rewards (33), virtual pets (34), and on-screen instructions for individual and small group play (30,35). Two studies delivered educational (33) and training (31) materials via the app. Push notifications (31,39), text messages (36,37), and emails (34) were used to deliver tailored motivational messages. In one app, when a participant experienced too much weight loss, an in-app feature would automatically send an email to the research team as an alert (36,37). Four studies representing three apps incorporated social support features including peer assessments (39), peer nominations (31), app bulletin boards (36,37), and in-app chat groups (36,37). Two apps (34,36,37) allowed users to take photos of their meals in the app and to submit their photos to a research server for scoring and review.

2.5: Discussion

Based on the results of the studies included in this systematic review, interventions that utilised mobile heath applications and included participants between the ages of 8-12 were generally

effective in improving the healthy behaviours of diet, physical activity, and sedentary behavior. Quasi-experimental study designs were the most common approach among the interventions described in this review. The one-group pre-post-test design, which allows for the determination of the effect of the intervention on a given sample by directly comparing outcomes before and after an intervention is implemented (54), was the most popular quasi-experimental design (35–38). Advantages of this study design include the elimination of randomization and control groups, which are often seen regarded as unethical practices, as well as requiring less resources compared to study designs that have a control group, particularly when it is used for pilot studies (55). However, it has often been criticized for its weak internal validity due to confounding, and weak external validity due to the inclusion of non-random samples (55).

The majority of included studies describe healthy behaviour promotion interventions, which is indicative of the gradual shift in focus from treatment to preventative health and health maintenance within the scientific community. All but two studies (30,32) designed its intervention around principles from at least one previously validated behavioural change theory. All but one study (31) reported significant effects for at least one anthropometric (e.g. BMI, waist circumference) or healthy behaviour outcome, with diet (33,34,38,39) and physical activity (30,32,35) measures emerging as the most common healthy behaviour outcomes reported to obtain significant improvements post-intervention. Data collection and goal setting were the two most commonly reported features in the mobile app interventions. Interestingly, the risk of bias for studies that utilised RCT designs were similar to non-randomized designs, with studies being assessed as either having a moderate or high risk of bias.

The prevalence of quasi-experimental designs among studies included in this review could be explained by the proof-of-concept nature of the studies. Of the six quasi-experimental studies, one was described as a feasibility study (35) and three were described as a pilot study (30,36,37). With a multitude of study design types available (e.g. interrupted time series, designs with/without control groups), quasi-experimental designs are able to address the versatility in study design that interventions may require due to factors such as limited resources. While RCTs are known as the gold-standard in study design for its methodology rigour, they often require a large sample size, which leads to the need for greater amounts of resources such as monetary funds, research personnel, and the appropriate infrastructure (56). In addition, researchers may have considered the unethical nature of performing randomization among populations at risk. While a stepped-wedge study design that involves a waitlist control group, where participants wait to receive an intervention after the treatment group, could address this concern, the delay in treatment, especially in situations where participants are deprived of their usual care during the waiting period, may jeopardize the wellbeing of participants (57). Given these limitations with RCTs, many researchers often turn to quasi-experimental designs. In fact, quasi-experimental experiments can provide insight into correlation due to its design flexibility in the inclusion of retrospective control groups, multiple measures over time, and cross-overs. Thus, quasi-experimental experiments can often generate preliminary results that can dictate whether it is worthwhile for researchers to conduct a RCT afterwards to confirm causation (58).

While only two of four studies reported significant improvements in adiposity measures, seven of ten studies reported significant improvements in at least one of the healthy behaviour outcomes. This trend of the absence of significant improvements in adiposity measures but the presence of improvements in behavioural measures has been previously reported (40). A possible explanation for this observation is the limited duration of the reported interventions, which at most lasted six months. The short duration of studies could be due to the fact that most studies included in this review were considered proof-of-concept studies and hence may have had limited resources (i.e. funding, personnel, infrastructure) to conduct interventions that were longer in duration. For instance, participants of *Patten et al.*'s pilot study (30) investigating the effects of an imagination-based mobile game on MVPA engaged in two separate 20 minute play sessions (with and without the use of the mobile app) separated by a 10-15 minute break in between, resulting in a total study duration of approximately one hour. Given the pilot nature of the study, the authors discussed limited budget and scope as potential limitations of the study and further acknowledged that the results may be insufficient to support the existence of an important interaction and be generalizable to the population of interest. In fact, even interventions that were conducted for nine months (59) and up to two years (60) identified follow-up duration as a potential limitation in accurately assessing adiposity in children. Results from interventions that last four to six months, a duration that an increasing number of childhood obesity interventions are adopting, should be evaluated with a short-term perspective in mind (59). However, long term interventions are not without its drawbacks. Long-term studies tend to result in lower retention rates compared to short-term studies. The average retention rate of childhood obesity interventions that last more than a year has been reported to be 74.0%; this value increases to 87.2% for studies that last less than a year (61).

In addition, using solely adiposity measures such as BMI and other BMI-derived measures (e.g. zBMI, $\%BMI_{p95}$, $\%BMI_{p50}$) have been found to be insufficient to evaluate the effects of interventions for childhood obesity (62). Results from a childhood obesity intervention study indicate that changes in zBMI were independent of changes in important health outcomes upon intervention completion (62). Regardless of changes in magnitude or direction of zBMI change, participants experienced positive improvements in health outcomes, such as increased physical activity levels and decreased sedentary behaviour.

Although one of the aims of this review was to determine the effectiveness of mobile apps in promoting healthy behaviours, with four of the ten studies being multicomponent interventions where the app is used alongside other intervention activities, it is difficult to gauge the unique variance in behaviour change associated with the app versus other intervention components. For example, Body Quest: Food of the Warrior's (38) aimed at promoting fruit and vegetable consumption via a multicomponent intervention that included a 17-week educator-led lesson curriculum, a collection of seven iPad apps, and weekly fruits and vegetable tastings. After the intervention, the treatment group consumed significantly greater amounts of fruits and vegetables compared to the control group. However, in another study where a mobile app was used as a standalone obesity prevention tool (33), results trended towards increased fruit and vegetable intake but were insignificant. Interestingly, all four multicomponent intervention studies reported at least one significant outcome, whereas only four of the six standalone intervention studies reported any significant outcome. This observation is consistent with the results of other systematic reviews of heathy behaviour change interventions (45,63) and suggests that the inclusion of an app in a multicomponent intervention may result in greater

effectiveness in achieving healthy behaviour change. A potential reason for this observation may be due to the tendency for multicomponent interventions to be longer in duration compared to standalone interventions. The multicomponent interventions in this review tended to be longer in duration (17 weeks to 6 months) compared to standalone interventions (1 hour to 12 weeks). Previous literature has also pointed out the correlation between longer follow-up time period for multicomponent interventions and its efficacy (63). Furthermore, given the difficulty in conducting intensive interventions (e.g. on a daily basis) due to resource and time constraints, the inclusion of a mobile app in a multicomponent intervention may potentially serve as a tool that continuously motivates healthy behaviour changes between intervention activities and study visits. The tendency for multicomponent interventions to be more efficient have been described previously (64), but to the best of our knowledge, few studies have directly investigated the effect of individual components of a multicomponent intervention. Therefore, the effects of the multicomponent interventions reported in this review cannot be directly attributed to solely the inclusion of the app(s). Other intervention components or combination of components, with or without the app, may have contributed to the intervention effects reported (65).

While the role of apps in multicomponent interventions have been identified as an area that needs to be further examined, website-based interventions that incorporated mobile technology (e.g. text messaging, motivational messages) reported stronger behaviour change effects (66). The inclusion of certain features in an app may increase the effectiveness of interventions (67). The ability of an app to collect and record health data information automatically using wireless connected devices such as accelerometers and scales, may make it more convenient for users

to keep track of their progress, receive continuous feedback, and increase total amount of data collected. Of the seven studies that reported at least one significant outcome, three studies (36,37,39) incorporated the use of wireless technology that was able to deliver data from an external device directly to a mobile device. Other common features of effective interventions included motivational messaging, either in the form of in-app push notifications (39) or direct messages from mentors (36,37), social support in the form of app bulletin boards and in-app chats (36,37), and goal setting (36,37,39). Photography via the app using the mobile device's built-in camera and the ability to send these photos to a research server were also features that were included in three effective studies (34,36,37).

2.6: Strengths and Limitations

This review was conducted and reported following a systematic approach as outlined in the PRISMA guidelines (46). The literature search was conducted with guidance from a research librarian to ensure the integrity of search strategies and thoroughness of the search. Study screening, data extraction, and risk of bias assessments were performed by at least two independent reviewers and discussed until a consensus was reached. The narrow scope of this review will provide a thorough overview of the literature to those individuals who are interested in healthy behaviour promotion studies that focussed on mobile apps rather than other types of mobile health technologies such as SMS and web-based technologies, as well as studies that focused on pediatric populations.

However, there are a few limitations to this review as well. The majority of studies included in this review are quasi-experimental studies and as evident from the risk of bias assessment,

results from these studies are more likely to be biased. In addition, due to the exclusion of studies that were published in a language other than English, all the studies included in this review were conducted in Western countries, mostly in the US. Therefore, this review may not provide an accurate overview of all the interventions that have been conducted around the world and account for cultural differences in mobile app use practices. Lastly, our literature search strategy may not have captured all available literature that has been published to date as our search strategy included publications up to September 2018.

2.7: Conclusion

Results from this review suggest the potential of apps to increase the effectiveness of healthy behaviour promotion interventions among children ages 8-12. Dietary factors and physical activity measures emerged as the most common significant outcomes reported; wireless connection to external data collection devices, goal setting, and social support were common app features of interventions that reported significant outcomes. Further investigation is needed to determine the effectiveness of mobile apps as a standalone intervention. With most literature in this subject area consisting of quasi-experimental studies and lasting a relatively short duration, there is need for further research that utilises more rigorous study designs and spans a longer period of time in order to truly generate a comprehensive understanding of the efficacy of mobile apps in health behaviour promotion interventions for children.

Chapter 3: Live 5-2-1-0 App Development Methodology

3.1: Study Design

This study was approved by the UBC / Children's and Women's Health Centre of British Columbia Research Ethics Board (certificate number: H18-00700; PI: Shazhan Amed; date of approval: August 16, 2018) under the project title "The Live 5-2-1-0 eHealth App." Using a mixed-methods embedded research design, three sets of focus groups (app conceptualization, co-creation, and user testing) were conducted over a 4-month period between October 2018 and January 2019 in order to obtain perspectives of key stakeholder groups (children, parents, and HCPs) throughout the app development process. Details pertaining to the focus groups are detailed in the following sections. Briefly, each focus group was approximately one and a half to two hours in duration and was conducted at BCCH by facilitators from an external technology consulting firm (Striven; Vancouver, BC; https://www.strivenconsulting.com/) and/or our app developer partner (Tactica; Winnipeg, MB; https://tactica.ca/). Focus group guides were developed by members of the research team and consisted of open-ended questions that reflected Fogg's behaviour model (24). Focus group sessions incorporated various HCD techniques, such as the use of conversation starters and drawings, to organize ideas visually (25) and to stimulate creative thinking among participants. Upon completion of each focus group, child and parent participants received a $50 gift card for their time and to offset the costs of participating (e.g. parking); healthcare providers received a $5 Starbucks gift card as an honorarium for their time.

3.2: Participants

Children ages 8-12 and parents of children ages 8-12 were invited to participate in the study via a multitude of methods, including posters in clinics and other public areas at BCCH, advertisements in a patient family newsletter (Sunny Hill Connect), and posts on BCCH and Live 5-2-1-0 social media channels. Interested participants contacted a research assistant via phone or email to receive additional information about the study and to provide informed consent in order to participate. Eligibility criteria included: (i) able to read, speak and understand English; and (ii) able to attend at least one focus group session in person. A maximum of one child and one parent per family could participate in the study. Participants with severe intellectual difficulties or who were non-English speaking were excluded.

HCPs within the Department of Pediatrics at BCCH were invited to participate in the study via a department wide email containing information on the study and contact information of the research assistant. Representation of physicians and medical trainees, nursing staff, and allied health professionals was sought. To be eligible, HCPs were required to attend at least one focus group session in person.

3.3: Data Collection

Children and parents completed a self-report sociodemographic questionnaire, adapted from the Canadian Health Measures Survey and Canadian Community Health survey, that included age, gender, and cultural and racial background of both the child and parent, as well as marital status, educational level, and annual household income of the parent. Parents also completed an adapted version of the HHQ (refer to Appendix B), a previously validated tool used to assess

daily healthy behaviours, for their child (28). The adapted HHQ included questions related to the Live 5-2-1-0 healthy behaviours (daily fruit and vegetable intake, screen time, physical activity, and sugary drink intake), sleep habits, and eating behaviours (e.g. family meal frequency, eating out habits). Participants were offered the option of completing the questionnaires via an online link prior to attending a focus group or in person on the day of the focus group. Study data were collected and managed using REDCap electronic data capture tools hosted at BC Children's Hospital Research Institute (68,69). REDCap (Research Electronic Data Capture) is a secure web-based software platform designed to support data capture for research studies. User testing focus group participants were asked to complete surveys on the usability of the prototype and desired app content (e.g. ease in completing tasks on the App, rating rewards, and daily challenges).

3.4: Data Analysis

3.4.1: Quantitative Data Analysis

Descriptive statistics (means and standard deviation for continuous variables; counts and percentages for categorial variables; and medians and first/third quartiles for ordinal variables) were generated to describe the sociodemographic characteristics of study participants, ease in completing tasks using the prototype, and ratings of rewards and daily challenges. All quantitative data were analyzed using SPSS Statistics for Windows (Version 25.0; 2017; IBM Corp., Armonk, NY, USA).

3.4.2: Qualitative Data Analysis

All focus group sessions were audio-recorded and transcribed verbatim by one of the authors (KY) and reviewed by another research team member to ensure transcription accuracy. Two authors (KY and SP) independently conducted thematic analysis of all transcripts using NVivo (QSR International Pty Ltd., Melbourne, Australia). Following the immersion-crystallization framework (70), qualitative data generated from the focus groups were organized into coding categories that were continuously revised throughout the transcript reviewing process. This was followed by a discussion between the two authors to review the preliminary coding categories and reduce the data further using thematic coding and content analysis. Any discrepancies regarding the identified coding categories and interpretation of the data were discussed between the two authors until a consensus was reached.

3.5: Focus Groups, Ideation Session, and Agile Development

A schematic outlining the sequence of research activities described in this section can be found in Figure 2.

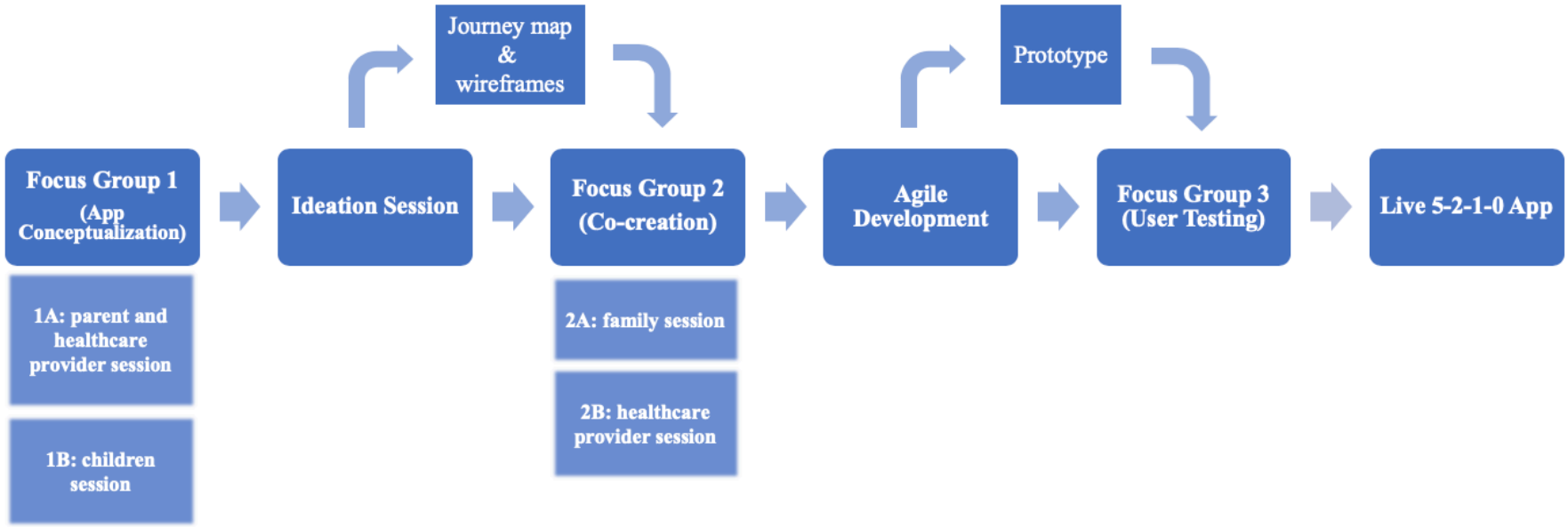


Figure 2. Schematic of research activities for Live 5-2-1-0 App development

3.5.1: Focus Group 1 (App Conceptualization)

The first focus group aimed to inform the conceptualization of the App and consisted of separate adult (parents and health care providers) and child sessions that were held concurrently on a weekday evening at BCCH. The adult and child sessions were led by a health specialist and child facilitator, both from the technology consulting firm Striven, respectively, with a technology specialist leading a section on app feature prioritization in both sessions. Guiding questions and prompts used in both sessions are presented in Appendix C.

In the adult session, parents were asked to engage in an open discussion regarding challenges in ensuring healthy habits and sources of motivation for change among children. This was followed by an activity where participants were asked to describe the timeline of their child's typical day and reflect on how healthy habits interweave and play a role in the typical day of a child. The adult session ended with an app feature prioritization activity, where participants were asked to reflect on their experiences with health apps, identify any gaps in current health apps, and rank the importance of discussed features.

The children's session began with the facilitator posing questions related to the children's current use of digital devices (e.g. smartphones, tablets) and mobile apps. Responses were recorded using drawings and short key phrases on flip charts to create a visual for children to refer to during the discussion (refer to Appendix C). This was followed by a hands-on activity, during which children were asked to split up into groups of three and draw their typical day. Children were then asked to share their drawings to identify any similarities and differences between groups, followed by a guided discussion on how mobile devices play a role in their

typical day. At the end of the session, facilitators led an open discussion where children reflected on what being healthy meant to them and shared ways that they think may motivate them to adopt healthy behaviours.

3.5.2: Ideation Session

The research team, the app development team (Tactica), and a member of the technology consulting firm (Striven) participated in an ideation session to analyze the qualitative data generated from the first focus group and to uncover themes, isolate key ideas, and identify opportunities for app design. This session was held via videoconferencing and was facilitated by the app development team. After a brief review of the data collected from the first focus group and an overview of the existing health app ecosystem related the child health behaviours (e.g. emerging features and key opportunities), participants were guided through a series of HCD ideation activities. This involved three separate inspiration rounds for the following key topics identified by the research team from the data gathered in the app conceptualization focus group: (i) family habit tracking and accountability; (ii) behaviour change techniques; and (iii) family, child, and HCP collaboration. Each inspiration round began with a five-minute 'lightning talk' which included the presentation of How Might We (HMW) questions, an HCD technique where challenges are framed as questions to prompt individuals into generating innovative solutions (25). The HMW questions posed for each topic are presented in Appendix D. This was followed by a 10-minute period where participants were asked to independently brainstorm ideas for each HMW question posed and input their ideas into an online form such that live responses were recorded and visible to all participants. The facilitator then led a 10-minute discussion where participants were guided through reflection of responses to the HMW questions, followed by a 10-minute activity where participants rated the various ideas proposed.

3.5.3: Focus Group 2A (Co-creation – family session) and 2B (HCP session)

Key themes that emerged from the first focus group and ideation session were presented in the second set of focus groups (co-creation) to inspire family and HCP stakeholders to identify desired app features. Separate sessions were held for families (children and parents) and HCPs on two separate days at BCCH, approximately one week after the ideation session.

In the family co-creation session (Focus group 2A), participants were first presented with a proposed journey map (refer to Appendix E) which provided a visual of the App user's experience from beginning to end (25), after which they were asked to provide feedback on each phase of the journey in an open discussion by answering guiding questions (refer to Appendix E). Next, facilitators presented families with a click through prototype that contained wireframes, design layouts of on-screen elements of various features (refer to Appendix E), followed by an open discussion to obtain feedback for each feature. Participants were also asked to rate various features and reward ideas by applying stickers that represented different ratings (e.g. top three features, favourite and least favourite feature, and favourite rewards) on printed wireframes of screens that were posted on the wall and a printed list of potential rewards, respectively (refer to Appendix E).

The HCP session (focus group 2B) was facilitated by the health consultant and aimed to gather feedback on the following topics: health behaviour assessment questions that would help the HCP understand baseline health behaviours of their patient; the design and components of the HCP dashboard wireframe; and the structure of in-app daily challenges to motivate children towards achieving their healthy behaviour goals. The facilitator recorded the HCP's discussion

in real time, either as an illustration for instances when HCPs discussed the design or layout of a certain screen or as a flow chart when concrete ideas were shared (refer to Appendix E).

3.5.4: Agile Development

Agile development refers the process of developing software via short iterative cycles that consists of cross-functional teams collaborating to identify key features that are desired and creating solutions that address these desires (71). Key characteristics of this methodology include frequent inspection of a software, reflection of the needs of stakeholders, and a high degree of adaptability and collaboration in cross-functional teams to allow for rapid development and delivery of products that meet the needs of its stakeholders (71). In this study, we utilised a subset of agile development process known as 'Scrum' that is characterized by high productivity, increased efficiency, and responsiveness to changing requests (71). This process began with creating user stories, or short phrases that represent the functionality that various stakeholders had expressed as desirable in the focus groups (e.g. "as a parent/child/HCP, I want to…"), and categorizing these user stories under various app features using an online project and task management tool called Trello (Atlassian Corporation Plc, Sydney, Australia). Considering the resources available and the complexity of the user stories, and with support from the app developers, the research team prioritized the user stories to provide guidance to the app developers on what features to develop first.

A key feature of the Scrum framework is the use of development cycles known as sprints (71). A total of three sprints were held for this study. For each sprint cycle, the app developers were given one week to develop app features based on the research team's prioritization. During

this time, the app developers participated in daily scrum meetings within their team to provide updates on their progress and to bring up issues that they may need support from other team members to resolve. A demo of the features that were developed during the week was sent to the research team approximately 48 hours prior to a 30-minute weekly sprint meeting between the app developers and research team such that the research team could review the work performed and provide feedback during the weekly sprint. Shorter sprints that lasted 3-4 days were performed near the end of the app development phase to address any technical issues that arose.

3.5.5: Focus Group 3 (User Testing)

The prototype generated from agile development was the focus of the third focus group, which was facilitated by two members of the app development team and members of the research team. Participants included both children and parents together in the same session, where each parent and child pair, or child only when a parent was not present, were given iPads with a pre-loaded app prototype. The participants interacted with the App prototype and were asked to provide feedback on its usability and content via questionnaires. Specifically, participants were asked to complete five tasks in the App prototype and asked to answer a Single Ease Question to rate the difficulty of the task from a scale of 1 (very difficult) to 7 (very easy) and record their responses on a form (refer to Appendix F). While participants completed each task, facilitators observed participants and recorded patterns that emerged from the participants' interactions with the prototype. Facilitators kept the provision of guidance on how to use the App to a minimum to allow participants to explore the prototype freely and to ensure the identification of any potentially unclear features or instructions in the prototype. Next,

participants were asked to brainstorm reward ideas as part of the App's gamification feature, followed by an activity where participants were asked to rate a series of rewards that researchers came up with as either "love it," "not sure," or "dislike." The focus group ended with a brainstorming session of daily challenges to be included in the App and a rating activity where participants were asked to categorize daily challenges proposed by researchers as either easy, medium, or hard.

Chapter 4: Live 5-2-1-0 App Development Results

4.1: Demographics

A total of 14 children, 12 parents, and 18 HCPs participated in at least one of three focus groups. Most children and parents participated in at least two of three focus groups. Demographics and Live 5-2-1-0 behaviours of the children participants are reported in Table 5, and demographics of parent participants are presented in Table 6. HCP participants included physicians (*n*=5), nurses (*n*=3), nurse practitioners (*n*=2), dieticians (*n*=5), pharmacists (*n*=2), and a physiotherapist (*n*=1).

Table 5. Demographics and Live 5-2-1-0 behaviours of focus group children participants (*N*=14)

Variables	Mean (SD)
Age, years	10.2 (1.3)
Sex	***n* (%)**
Male	5 (35.7)
Cultural/racial background	
Caucasian	5 (35.7)
Live 5-2-1-0 behaviours	**Median [Q1,Q3]**
Servings of fruits and vegetables per day (1 serving = ½ cup)	3.5 [2,5.5]
Hours of screen time per day (excluding time for schoolwork)	1 [1,2]
Days per week physically active for at least 1 hour (*n*=13)	5 [3,6]
Cups of sugary drinks per day	0.5 [0,1]

Table 6. Demographics of parent participants (*N*=12)

Variable	*n* (%)
Age, years	
20-29	1 (8.3)
30-39	1 (8.3)
40-49	9 (75.0)
50-59	1 (8.3)
Sex	
Male	2 (16.7)
Marital status	
Married	11 (91.7)
Divorced	1 (8.3)
Cultural/racial background	
White	7 (58.3)
Chinese	1 (8.3)
South Asian (e.g. East Indian, Pakistani, Sri Lankan, etc.)	1 (8.3)
Filipino	1 (8.3)
Japanese	1 (8.3)
Mixed race	1 (8.3)
Education level	
Trade certificate or diploma	3 (25.0)
University certificate below bachelor's level	1 (8.3)
Bachelor's degree	5 (41.7)
University degree or certificate above bachelor's degree	3 (25.0)
Annual household income	
$20,001 - $30,000	1 (10.0)
$40,001 - $50,000	1 (10.0)
$60,001 - $70,000	1 (10.0)
$80,001 - $90,000	2 (20.0)
$90,001 - $100,000	1 (10.0)
$120,001 - $140,000	1 (10.0)
$140,001 - $160,000	2 (20.0)
$160,001+	1 (10.0)

4.2: Focus Group 1A (App Conceptualization - Adult Session)

A total of eight parents (with at least one child participating) and three HCPs (two dieticians and one physician) participated in focus group 1A.

4.2.1: Life Logistics as a Barrier to Healthy Behaviour Practice

Parents revealed daily life logistics as a key challenge when sharing their experiences about ensuring healthy behaviours within the family. Parents reported fruit and vegetable intake as the most challenging to address. Barriers included lack of time due to busy schedules in order to grocery shop and prepare nutritious meals. After school activities and work responsibilities also contributed to the challenge of ensuring adequate vegetable and fruit intake.

> "When it comes down to meal planning, I find that's my biggest challenge [is] just not having it mapped out. So as a working mom, it's tough." (parent)

> "There is so much going on during the week, mostly after school, that you can't [meal plan]. (parent)

> "Shopping… is a challenge here. It's having to meal plan… to shop at a place." (parent)

To overcome these barriers, parents suggested that app content such as recipes or meal plan ideas may be useful for busy parents who find it challenging to come up with meal ideas that incorporate the daily recommended fruit and vegetable intake.

> "If this app shot out like recipes or like a meal plan for me to like look at… it covers all of these basics in terms of… what you need per day [for] healthy servings." (parent)

Disruptions in regular routines such as school holidays and vacations were also identified as key factors in preventing parents from adequate meal planning. An app feature that reminds parents of their daily schedule and provides customized meal planning tips and suggestions based on their scheduled activities was suggested.

> "If things were to fall apart, it would be if we were driving somewhere during the day… because I don't have the school thing, and then I hadn't prepared, so maybe in the morning there was something that would say 'this is what is happening today so this is how you need to prepare what to pack.'" (parent)

Parents also reported how their busy daily schedules often resulted in less time spent with their children. If parents do not engage in activities with their children that encourage healthy behaviours such as physical activity, children tend to turn to sedentary behaviours such as screen time when they are left alone.

> "Parents are so busy nowadays that… we don't have time to go out with our kids or take them to the park all the time or go for walks with them… if I were willing to spend my entire free time when I come home… with him, he wouldn't be with any screen… I am not willing to do that, and so part of the time, I'm hoping he's on screen time so I get something else done." (parent)

4.2.2: Environmental Factors Promote Sedentary Behaviour and Impede Physical Activity

Both indoor and outdoor environmental factors emerged as key elements that can influence children's adoption of healthy behaviours. Parents shared that a lack of safe and accessible places for children to play outside as a barrier for their children to engage in more physical activity and decrease sedentary behaviour.

> "I think in the suburbs where I grew up in it's different, like the yards were wider. You're not on busy streets like Vancouver. I wouldn't send my kid out on our front street to play." (parent)

Other environmental factors that served as barriers to outside play and physical activity included long winter months and costs for participating in sport programs outside of school. To overcome these external barriers, participants called for communities to build infrastructure and installations that promote healthy living.

> "Looking into how your community or… your neighbourhood can promote activity or healthy living. Like [are] there actually lights on the street or is there a sidewalk for them to walk to school, is there a park nearby, or is there just green space for them to run around, or just to play soccer on." (HCP)

Regarding the home environment, parents shared strategies on how to shift the focus away from screens, such as phones, computers, and television. One strategy was to put screens away

from the main parts of the home where family members typically spend their time, and instead, place items that encourage interaction and family time in the center of the home.

> "How can we decentralize… how they're featured in our home and push them to the fringes... instead of it being in the centre of our home, like the charging station is like right there, so easy to pick up. So… we have a chest full of craft materials. Put that in the center instead." (parent)

4.2.3: Communication Facilitates Shared Decision Making

The importance of shared decision making in reinforcing healthy behaviour among children resonated with both parents and HCPs. Parents expressed interest in an app that they could use with their children to communicate about healthy living behaviour and promote shared decision making among family members in a timely and effective manner. While parents indicated the desire to involve children in the process of healthy meal planning, many expressed that they were unsuccessful due to conflicting work and school schedules, as well as lack of interest among children when asked questions related to planning for healthy behaviours in the home.

> "When I had those conversations with my kids, it's always like 'I don't know'… I'm not going to ask like every hour till they're ready to tell me, right? So this way, at least for kids who don't communicate as much…" (parent)

Both parents and HCPs expressed that an app that provides parents and children with the opportunity to communicate about healthy living behaviours would facilitate shared decision making and empower children to be actively involved in making healthy behaviour changes. Specifically, HCPs suggested that the App could provide tips and strategies to guide parents to encourage their children to actively participate in shared decision making regarding healthy behaviours.

> "When kids feel empowered that they are making the decision… so like instead of being directive as parents, we would be non-directive and kind of help coach them and get them to their conclusion – the conclusion we want, on their own." (parent)

> "I'm just resonating with the shared decision idea and like maybe tips or something to help parents know how to help the kids [get] involved in the shared decision and having them also decide on the food but just in an easy and quicker way." (HCP)

Some participants pointed out that pop-up notifications that remind parents to seek input from children regarding healthy living behaviours would encourage shared decision making.

> "Let's say it's a tip from the App, just a pop-up tip… bring your kids to the supermarket. You know you need five vegetables. Let them pick two." (parent)

Others built upon this idea and suggested an app feature where children would be able to partake in healthy living behaviour planning for the family directly.

> "What if the App had options… before you go to the grocery store, you tell your kid to pick which fruits in the shopping list or what vegetables in the shopping list… it's like they're already bought in." (parent)

Despite the potential of the App in strengthening social interactions and facilitating shared decision making, both HCPs and parents agreed that the App should not replace authentic social interactions within families and communities, but rather augment these interactions.

> "I think it's important to not use the App to replace the communication that you need to have as a family and person, but also… as a complement to kind of remind yourself." (HCP)

4.2.4: Social Connectivity as a Key Motivator for Children and Families

As an extension of shared decision making, the idea of augmenting social interactions and social connectivity via the App as a means to motivate children and their families was discussed. According to HCPs, children enjoy activities that involve social interactions and are more willing to continuously engage in an app if it requires them to complete tasks with peers or compete against other users individually or collaboratively in teams, adding a component of fun.

> "Even doing it together so that both of you can achieve a goal and then you get extra points… that's just a fun element and it encourages the group to do it together." (HCP)

Based on HCPs' previous experiences with children, apps with features that allowed users to interact with peers seemed to be effective in encouraging children to participate in healthy behaviours.

> "What [made] that app become very successful was you have to [have] other people… go with you, so there's a social interaction and you have to walk miles and miles and miles to get certain things… so that worked, in terms of the physical activity part. I know a lot of our kids really benefitted." (HCP)

As children work towards making healthy behaviour changes in their own lives, not only do they take ownership over their own health, they may also develop a sense of responsibility for their family's health and therefore, encourage them to adopt healthy behaviour changes together. The sense of accountability and responsibility can in turn transform into a source of motivation for children.

> "If the child is not motivated, is forced to do something, it's not going to help… the other thing is that making the child responsible… making it as a family activity that's like 'you need the physical activity but your parents also need it, so going together and then doing some physical activity… so making them responsible for [their] parents' health to sort of start." (HCP)

Even if children may be reluctant to make healthy behaviour changes initially, parental engagement and bonding with their children were deemed as important first steps as parents can gain awareness of what their child's interests and challenges are.

> "What's best is actually to have the parents do what they're doing… Is this something that you can play together? So it ended up being more of a quality family time… even though it is with the screen but then at least, you know what they're doing and kind of be able to share that time and kind of have a bond with them." (HCP)

Participants also found the idea of in-app social media and communication features appealing. For parents, an in-app community such as blogs or group chats in which parents can communicate with other parents and share tips regarding healthy behaviours was believed to be helpful.

> "There's blogs and groups and chats… then you can help one another, not just all these recipes or all these things you're – never actually end up doing, but… people having actual conversations about helping one another." (parent)

Parents also believed that an in-app communication tool would be beneficial for children to mutually support each other as they make healthy behaviour changes. However, both parents and HCPs agreed that any communication tool should be regulated by a moderator to ensure the accuracy of the information presented.

> "Going on that whole friend thing and the role model, if this is a shared app, then there's kids that are talking to one another about their fruits and vegetables." (parent)

Lastly, HCPs suggested that an app that allowed children to be connected to other HCPs remotely would be helpful as they adopt changes in their lifestyles. Not only would children be able to directly pose any questions they may have for their HCPs, the risk of acquiring false information on the web is also mitigated.

> "Would there be a health care practitioner that would be linked to it (the App) that would be able to answer some… questions, [be]cause my concern would be there's a lot of information out in the internet… that might not be always scientifically based or best practice." (HCP)

4.2.5: Parents as Role Models for Healthy Behaviours

During a discussion about screen time, parents expressed the challenge of being a role model for their children due to the need for parents to use digital devices for work and other everyday tasks, such as banking and checking the news. Many found it difficult to persuade their children to decrease their screen time despite explaining to them the reasons for high parental use of screen time.

> "I'm forever on the stupid thing and it's just really hard to say 'you can't be on it' when I'm looking at my bank account… because I'm not doing something fun and you are, that's a really large distinction." (parent)

Some parents took the blame on themselves for their children's practice of unhealthy behaviours.

> "A long as they're busy, they don't really care for screen time so much. It's when they're bored, and that's on me and my husband." (parent)

Leading by example and being consistent with daily routines were identified as crucial for instilling healthy habits in children. When certain healthy behaviours become the norm within the household, the behaviour shapes into a habit that children are more likely to continuously engage in.

> "A big part of it is… lead by example… we try not to drive to the corner store, don't drive to dinner with friends, we'll walk there or bike there, so it becomes the norm, that's what he expects." (parent)

Based on previous encounters with families, HCPs agreed with the importance of parental involvement in guiding their children towards decreasing their screen time.

> "For screen time, I think it depends on the parents also… how strict they can be. I've had parents who say 'but they don't listen to me, and I can't restrict it,' so that's one thing that we sort of run into problems." (HCP)

HCPs also commented how parental role modelling often emerges as a key challenge that families face when addressing sugary drink consumption.

> "I think one of the biggest challenges is role modelling. So if the kids see the parent drinking ice-tea or something like that, then obviously they want to drink it as well." (HCP)

4.2.6: Education and Awareness are Key to Making Healthy Behaviour Changes

When discussing motivators that encourage healthy diet choices, parents raised the importance of developing the child's sense of agency in defining their choices through building awareness as to why healthy living is important. Children were reported to gravitate towards choices that were meaningful to them, and that personal awareness and motivation from the child would trigger decision making and build long-term habits.

> "They [children] are not saying it out loud but I think if kids understand why they are doing what they're doing, they may change their choices, right? To see what the alternatives are." (parent)

HCPs indicated that when children become aware of the reasons behind a certain health behaviour and how it may affect their everyday life, they tend to retain the information longer, which may help with promoting long-term behaviour change.

> "I think I taught kids anywhere from like six to like teens, and a lot of the younger kids actually really like the trivia questions… and those things tend to stick in their minds and when we get the feedback, they will be like 'I know there's… calcium in milk." (HCP)

Parents and HCPs pointed to how children's self-discovery of health-related knowledge often leads to better adherence, rather than a top-down approach, where parents instruct their child on what to do or eat without providing appealing rationales that children can relate to. An app that provides tips and resources on healthy behaviours was desired by parents and HCPs.

> "Instead of saying 'eat it because it's good for you and I said so,' it's awareness… these fruits and vegetables are good because of this… maybe if I bring more awareness to what they are putting in their body." (parent)

> "Once they see how much sugar is in like a can of coke or in a box of juice, they get a shock out of it and then they actually start to read labels and then when they shop with their parents, they will go like 'mom… this has a lot of sugar, let's not buy it.'" (HCP)

Other than educating children on healthy behaviours, HCPs also stressed the importance of proper parental education in addressing sugary drink consumption. The presence of many misconceptions around the healthiness of juice, chocolate milk, and yogurt beverages was worrisome for parents. For example, parents were surprised to hear that 100% fruit juice was featured in the previous version of the Canada's Food Guide.

> "I think it's misconception in the parents that the juices are fresh… and that's what you hear, 'but it's fresh fruit juice.'" (HCP)

Culture and/or ethnicity also surfaced as factors that may be related to parental beliefs around healthy behaviours. Parents' lack of exposure to and understanding of the nutrition value and composition of Western foods may lead to the development of unhealthy behaviours within the family.

> "In… my Indo-Canadian [South Asian] community, I'm always blown away by how young some of the kids are drinking pop, and I honestly wonder if it has to do with the parents just not knowing. Like they may be new immigrants, or… they haven't had that exposure to what's actually in these drinks… I think a lot of it is… educating parents, all segments of society really." (parent)

4.2.7: Peer Interactions Influence Children's Decision Making

Parents identified peer interaction as a main motivator behind their child's decision to make healthy behaviour changes. Children tended to gain awareness about healthy behaviours from their peers. According to parents, vegetarianism was a common topic among children and a few indicated that peer pressure could have led to their child's adoption of a semi- or full-vegetarian diet.

> "My son is at an age now where he starts to learn about the impact of meat eating and… this is not something that we actually started, but two of his friends have gone completely vegetarian, and he's now said he wants to do 60% vegetarian." (parent)

Parents also pointed out how peer influence was far more effective in encouraging children to adopt healthy behaviour changes compared to parental encouragement.

> "It struck me how this was more powerful than anything we could have said is his friends going [vegetarian]… whether you agree or not… he just feels that he wants to do this, and it's entirely from it." (parent)

Despite the positive changes that peer influence can achieve, parents also warned about its potential to promote unhealthy behaviour choices. Children may even use the behaviours of their peers as a means to persuade parents to allow them to practice unhealthy behaviours, such as choosing unhealthy meal options.

> "The teachers give out candy, kids bringing cupcakes for their birthdays, they have hot lunches... it's not a healthy option. And there's the peer pressure from the friends, 'well, all my friends are getting pizza, why can't I have it?'" (parent)

4.2.8: Intrinsic Rewards Lead to Development of Healthy Habits

Parents and HCPs discussed a rewards system in the App as a way to encourage positive behaviour change. Parents found it challenging to identify rewards that were not extrinsic and that children would be responsive to without further promoting unhealthy behaviours.

> "My children see [screen time] as a reward almost. It has become that way, so when they do homework or they feel like there's a need, 'oh, my break time is going to that screen.'" (parent)

Participants warned that if not carefully designed and implemented, an app that focuses on providing extrinsic rewards may have detrimental impacts on developing self-motivated healthy habits among children.

> "We tend to tie a lot of behaviours to rewards all the time. I think that's not so great because you find it kind of comes back to haunt you, [be]cause everything I ask him, [he responds] 'but what do I get for it?" (parent)

While extrinsic rewards are often appealing to children initially, the sense of novelty can fade quickly if there are no new triggers or additional extrinsic rewards to serve as a motivator.

> "My son did have a Fitbit for a few months, but just, it's like one of those things, it's exciting for a short time, and then this fades." (parent)

Rather than short-term behaviour driven by external rewards, parents indicated that intrinsic rewards would be more likely to cultivate internal motivation and build long-term habits. Parents also indicated their desire for children to develop healthy habits that can last throughout their lifetime, rather than for the short-term and contingent on immediate rewards.

> "I'm concerned when my girls turn 15, 16, and they suddenly say 'I don't want to do anything' right? I want it (the App) to be able to build habits that is going to just say this is just our lifestyle, you know, versus, I'm being rewarded for doing something." (parent)

Furthermore, parents stressed the importance of instilling the value of intrinsic rewards in children and associating healthy behaviours directly with personal satisfaction. This was believed to be able to motivate children to continue practicing healthy behaviours in the long-run.

> "The rewards should be 'wow, I made this opportunity because I was training' or you know, 'look at me kick butt in tennis [be]cause I play long-term.'" (parent)

4.2.9: Behaviour Tracking Changes Child Behaviour and Supports Health Care Providers

Parents and HCPs had differing perspectives on the potential use of the App to track children's daily Live 5-2-1-0 behaviours. HCPs supported the idea of including tracking as a key feature in the App since the data collected could be summarized in a visual interface for the user to view his or her progress, which in turn transforms into a source of motivation to continue to

work on healthy behaviour changes. This visual interface could also be used by HCPs during clinical encounters to become aware of their patient's progress since the last visit and provide the necessary support.

> "Having a graph when they come to see us… a snapshot picture. It's like, you know what, my physical activity is going up… here is activity going down. It just sort of motivates them, they're on the right track." (HCP)

HCPs also explained how the availability of tracking data would serve as conversational starters and enable them to further investigate facilitators and barriers faced by the child as they attempt to adopt healthy behaviour changes. HCPs further reported that when they perform regular check-ins with families, they tended to be more motivated to make changes.

> "I find that when we check in with the families, their kids are more motivated… when the numbers are really not where they should be going, they have that guilt and then they try to do better next time." (HCP)

While HCPs supported the idea of tracking, parents displayed mixed perspectives. Some parents were doubtful that parents and children would have the time or would remember to use the App to record information about their daily healthy behaviours.

> "Nor can I see myself or him registering he spent 15 minutes doing activities. What I can see him doing is going to the App to get ideas for the activity… but I just don't see

him going 'I did this, let me write that down.' Long term, I don't think that works. Certainly wouldn't work for me." (parent)

However, other parents remained optimistic about children and their families using the App to record daily behaviours and alluded to popular apps and their success in engaging users to track their activities.

"It does work for a lot of people… anybody used to doing Weightwatchers… or the Instagramming what they're eating." (parent)

To address the lack of enthusiasm towards tracking daily activities, HCPs suggested that providing printable versions of the tracking tool may increase the efficiency of tracking daily activities by reducing the amount of time spent on the App.

"If there is a printable version… younger kids they can just go to the paper and mark on it how much they have done, and then at the end of the day, the family can get together and update the App… reduces the amount of time they need to be on it." (HCP)

4.2.10: Data Sharing and Security Concerns

Data sharing between users was identified as an appealing app feature. However, parents raised concerns over confidentiality and privacy as the App could potentially collect data regarding

their child's daily activities. They also pointed out that while an app that collected user-inputted data was appropriate, automatic tracking of a child's location would not be acceptable.

> "If it was an app that was actually tracking the kid's activity (automatically) as opposed to them just logging it (user-inputted data), then I would worry, I wouldn't want the location to be out there." (parent)

In the case of sharing data with other users, parents wanted the option to control what information was shared and who the information was shared with. For example, parents wanted to choose which of the four Live 5-2-1-0 behaviours to share and have the ability to control who is in their child's friend list.

> "I think letting the parents control whether they want to share the five [fruits and vegetables] part, in the 5-2-1-0 message… choosing their kid's friends, that would be helpful, so then they can turn it on or turn it off." (parent)

4.3: Focus Group (App Conceptualization) 1B – Children Session

A total of nine children participated in focus group 1B.

4.3.1: Influencers and Role Models Matter

Throughout the focus group, children constantly referred to various individuals who are central in their lives as those who influence their decisions around healthy behaviours. A prominent role model identified by the children was their parents. However, discussion around children's opinion on their parents' use of electronic devices revealed that parental role modelling did

not always result in positive changes. Children tended to compare hours spent on screens after school with their parents' screen time.

> "When my dad is home, he's on a lot of electronics, so it's not really fair for us when we have a time limit."

Another key influencer that children identified was HCPs. Children viewed HCPs as an individual of authority and would more likely comply with their recommendations related to making changes to their healthy behaviours.

> "Like you go to a doctor's appointment, they might say, like, try to eat more healthier foods and then you might, you might do it."

Children also mentioned siblings (e.g. following older siblings outside to engage in physical activity) and teachers in the school setting (e.g. reminding students to finish their lunches) as influencers.

4.3.2: Factors that Discourage Screen Time

Children revealed that guilt from excessive amounts of screen time was a main factor that discouraged them from playing with their electronic devices, even when they have not exceeded their daily screen time limit.

> "After an hour I start feeling a bit guilty and then I stop."

> "I feel guilty, it's only because… maybe, I should go outside."

Guilt was often discussed in association with knowledge around optimal amounts of screen time and best practices for controlling excessive screen time. Education and awareness of the consequences of their actions seemed to play a role in their decision-making related to healthy behaviours.

> "I also heard that there is Wi-Fi radiation which is where if you… leave your phone or an iPad or any devices that use Wi-Fi in your room when you sleep, they say it affects your sleep by half an hour."

> "It's funny though because I saw [a] fact on my agenda. It said if you play [on your device] four hours a day, it's good to get out sometimes, so limit your time [to] two hours."

Children also reported how extended amounts of screen time would result in physical disturbances to their body, such as headaches and body aches, which often led to their decision to take a break from engaging in screen time.

> "Sometimes I can get headaches really easily, so I'll be watching TV [for] like 15 minutes and a headache starts hurting."

4.3.3: Social Connection and Competition as Fun Elements

Discussion about features that made apps fun for children revealed the importance of social connection in motivating children via engagement with peers. Social platforms that allow users to share photos and videos with peers were popular among the children. Children also frequently used digital messaging programs to communicate with their peers about game play and to engage in competition.

> "I'll set up a game room and I'll tell him the code and he'll join and [we] battle each other."

> "If you're… in a game, you can track and compete [with] them, or they'll let you have friendly competition. That's sort of nice."

4.3.4: Incorporation of Gamification Elements To Increase Appeal

Progressive levels, freedom to choose, and the ability to 'cheat the system' were three major themes that emerged when children discussed app features that appealed to them. Children reported the desire for an app that allowed users to experience progression through increasing levels of difficulty and identified this as an important feature in motivating them to continue to play a game. The choice to select a starting level of difficulty within an app that featured multiple levels also appealed to children.

> "Mixed levels. When I can select… easy, medium, hard… or like level one to level 20."

Another aspect related to having the choice and freedom within the App to select different modes of play and activities to participate in.

> "You can choose there to be an end, and then you can choose to always go forever. Find some new ships, find a temple, join a temple."

The ability to 'cheat the system' in games emerged as a topic of interest. Cheating via strategies such as hacking, coding, and finding cheating strategies online is seen as a challenge within a game among children. Children suggested that developers should consider minimizing the chance of hacking when designing the App.

> "Let's say in the game every day you get a reward, and it's September 1st. We change… to September 15th. You'll collect 15 days of rewards. It's a hack that works for no Wi-Fi games, but [for] games that use Wi-Fi, [it] doesn't work because they already know that it has passed the day."

4.4: Ideation Session

Eight members of the research team, one technology consultant from Striven, and three members of the app development team from Tactica participated in the ideation session.

4.4.1: Collaborative Decision Making Between Families and Health Care Providers

To address the notion of shared decision making as a key theme that emerged from focus group 1, a key discussion point for the ideation session was to identify ways for the App to facilitate

collaborative decision making, goal setting, and tracking of the Live 5-2-1-0 health behaviours between children, parents, and health care providers. A summary visual of the user's progress was proposed as potentially useful to motivate users to make healthy behaviour changes and helpful for family members to provide the necessary support. A summary visual was also believed to support HCPs as they conduct behaviour counselling during clinic encounters with users. During focus group 1, HCPs expressed their desire to be provided with information about the user's progress in making healthy behaviour changes since the last clinic visit to help them identify areas to address more efficiently and allow them to provide the necessary support and resources. However, it was noted that the user may see the visual summary as a discouraging factor and lose motivation to continue to achieve their goals if the visual summary reflected minimal progress. To address this, the idea of allowing for progressive changes in goal setting and behaviour change was proposed. Concerns about varying goals between families and HCPs and different measures used between various stakeholders were also raised. In order for goal setting and progress data to be meaningful and comprehensible, it was agreed that the visual interface/user experience design must be tailored towards each stakeholder (child, parent, and HCP) while ensuring that the metrics and measures are consistent such that they are comparable between different stakeholders.

4.4.2: Family Involvement Encourages Healthy Habit Adoption

Both parents and children had shared that parental involvement was influential in encouraging healthy behaviour change during focus group 1. To address this, the role of family involvement as a source of motivation, one of three dimensions of Fogg's Behavioural Model, emerged as another key discussion topic during the ideation session. Topics discussed included ways to

implement family habit tracking and accountability, introduce shared responsibility among family members, and involve HCPs to guide families throughout the process. With children seeing parents as role models as a key theme during the app conceptualization focus group, the idea of family challenges where parents and children work towards a goal together, such as "going out for a walk instead of watching TV," was suggested.

4.4.3: Need for Adaptive and Customizable Goals

Adaptive goals that can be changed over time and customizable according to the user's preference was discussed as an essential app feature as it was a key theme that emerged from focus group 1. With Live 5-2-1-0 consisting of four behaviours, concerns were raised among the research team when reflecting on the idea of users working on more than one healthy behaviour goal simultaneously, which was suggested by participants during focus group 1. Goal setting is typically limited to one goal for health interventions and maximum of two goals for intensive primary care interventions. In addition, users may be practicing the four healthy behaviours to different degrees. It was agreed that the App must allow users to customize goals based on the user's preference and needs, and where they are at in the behaviour change journey. One suggestion was to include a baseline health assessment that would allow children, parents, and HCPs to set goals collaboratively based on current behaviour and readiness to change via the App. In addition, users should be given a choice on the behaviour to work on regardless of results from the baseline assessment. Even though children may not choose to act upon these behaviours immediately, it is still valuable for them to become aware of what behaviours are problematic. Finally, the choice to select "small steps" towards achieving the

Live 5-2-1-0 goals was proposed, addressing children's desire for an app that allows for progression and choice of difficulty level.

4.4.4: Design Elements for Gamification

Gamification strategies that could be used to engage users in the App were discussed. With children previously indicating a desire for progress tracking in gameplay, the idea of progression dynamics in the form of a progress bar where users would be able to visualize their progress in adopting healthy behaviours was suggested. Upon considering the children's interest in an app that allowed for progression through increasing levels of difficulty as determined during focus group 1, the research team and developers decided to design an app where users must complete easier goals before attempting harder goals. In terms of rewards, parents had expressed that intrinsic rewards are more likely to lead to healthy behaviour change that is sustained. Therefore, it was agreed that the App should include a mix of intrinsic and extrinsic rewards when a user achieves a goal within the App, with an emphasis on intrinsic rewards. Intrinsic rewards may include: creating an avatar of the user and his or her home; a social fabric where children, parents, and HCPs can achieve satisfaction through collaboration and celebration of each other's accomplishments; and self-competition by earning badges to recognize forward progress. Ideas proposed for external rewards included those that further encourage healthy behaviours, that could easily be provided by parents, and that promote family engagement. The need for external rewards to be customizable was deemed important by parents during the previous focus group. An in-app rewards menu where parents can select from a list of suggested rewards or manually enter a reward of their choice was believed to be able to address this need.

4.5: Pilot Journey Map and Screen Wireframes

Information gathered in the app conceptualization focus groups and the ideation session was used to create a pilot journey map (refer to Appendix E) to reflect a user's experience using the App from the beginning to the end. A total of seven phases were identified: onboarding, assessment, share and discuss, reward setup, goal setup, prompt, and motivation. The relevant stakeholders (children, parents, and HCPs) associated with each of the phases were indicated in the journey map schematic.

A series of wireframes consisting of initial designs of various screens pertaining to each phase of the journey map were created based on ideas presented by stakeholders in the app conceptualization focus groups and interpreted by the research and development teams during ideation. These screens included the HCP dashboard, onboarding assessment, dashboard view, tiny step selection process/view, goal selection, progress bars, and rewards selection and achievement (refer to Appendix E).

4.6: Focus Group 2A (Co-creation – Family Session)

Seven parents and six children participated in the co-creation session; of these, five parents and four children had previously participated in the Focus Group 1 (app conceptualization). During the wireframe scoring activity, children and parents identified family activity challenge as the most desired feature to include in the App, followed by badges and the option to select rewards. After brainstorming a list of potential rewards, participants identified having badges per daily challenge and the ability to unlock a family challenge as desired rewards for recognizing behaviour change progress.

4.6.1: Introduction and Onboarding to App

The method of introducing the App to families was deemed to be an influential factor in its uptake and use. When asked about the best ways to introduce families to the App, parents indicated a need for an active approach rather than a passive approach, such as the having a medical office assistant introduce the App to families as they check-in for their clinic visit.

> "Someone has to introduce you to the App. You're not going to download it just because there's a sign that says 'please download that.'" (parent)

Another active approach suggested was sending an electronic app download link alongside clinic visit reminders so that families can complete them before their clinic visit.

> "When you call in to make the appointment, if the secretary emails you the link, and you can just… download the App." (parent)

Others suggested the need for reliable Wi-Fi connectivity in the waiting room for families to download the App in case they forgot to do so before the clinic visit.

> "I feel like I would download it because typically we have to wait. My only – first thing I thought of was would there be Wi-Fi in the office." (parent)

Children emphasized the importance of discovering more ways to reach parents to encourage app download and stressed how parental involvement would encourage higher uptake and use

of the App among children. This aligns well with the idea of parents as role models as expressed in the app conceptualization focus group.

> "You should find a way to contact their parents more than the actual kids because the kid will just reject it, but if parents say it's a good idea… then I think they'll start doing it." (child)

Parents expressed mixed perspectives regarding completing an assessment on the App while in the waiting room prior to their child's clinic visit. While some welcomed the idea, others commented that there may be more pertinent thoughts in mind while waiting to be seen by a physician.

> "I just find if I'm in the waiting room waiting to see the doctor, there's gonna be more pertinent things on my mind. The reason I'm taking my child to the doctor maybe? So I'm not sure if that would really [be] for us." (parent)

Parents raised the importance of designing an assessment that is brief (at most five questions) and easy to complete (e.g. swiping, yes or no responses, and no need for inputting information by typing) to increase accessibility in the waiting room. Parents also agreed that there are other individuals in settings outside of the immediate clinic office who could take on a similar role of promoting and collaboratively using the App with families. Individuals that were suggested to introduce the App included teachers, community health nurses, and mentors (e.g. Big Brothers/Big Sisters).

4.6.2: Parental Involvement via Family Challenges

The idea of completing team challenges related to the Live 5-2-1-0 behaviours as a family appealed to both children and parents, with children indicating parental involvement as a key motivator for app use. Participants were enthusiastic about the idea of keeping family members accountable by having everyone set their own goals via individual user accounts, but being able to achieve the family challenge only if family members complete their individual goals.

> "Let's say you all have the App… so one of you would do five fruits, one do two hours of TV, and do one hour activity, and another one do no sugary drinks. So you all are going to do it but if one doesn't do it when you're supposed to, they all do not get a reward. So all eyes are on each other to do their thing." (child)

While some children indicated preference to complete family challenges every 12 hours to every 24 hours, a weekly frequency emerged as the most popular choice among children and parents. Children also expressed team challenges with friends as appealing. Parents suggested that family challenges could be designated as rewards for children upon goal completion.

4.6.3: Novelty and Progression Promote User Retention

Both parents and children agreed that novelty and unpredictability are crucial factors in promoting extended app use and user retention in the long-run. Some suggested that the duration required for goal completion should be varied to add an element of surprise for users which could serve as a motivator to continue using the App. Others suggested that the App could surprise users with the reward rather than having the user select a reward of their choice.

> "If it's predictable and you know it's every ten days, does that make you less interested versus if it's a little bit of a surprise?" (parent)

Participants also pointed to the power of novelty in encouraging long-term app use among users. Some viewed the App as a source of inspiration for new ideas related to healthy behaviours that could encourage families to try something that is different from their usual routine.

> "I like the idea of inspiration… something exciting as a parent would be to try something new… I'm going to put down all the same stuff we always do… so I think having some options would be nice, take some thinking out of it for me." (parent)

Participants were also favourable of an app that is regularly updated with new content and features. Even in cases of app attrition, parents indicated that regular updates could potentially encourage users to return to the App and suggested a notification system that would notify users of new features and content added to the App if there has been low app usage.

> "If you don't use the App, is there going to be the option for push notifications where it's like… 'hey I haven't been around for a couple of days' right… is it going to come up with something like 'hey, have you seen this new feature we added on here'… get you back in there." (parent)

Having challenges that were of differing difficulty levels and the ability to progress through the levels were appealing features for both children and parents. Parents suggested the option for users to begin with an easier level to identify which of the four healthy behaviours to address before launching into the rest of the App.

> "Maybe there could be a ramp-up feature where you try it out for a week or two weeks and see where your weak spots are… you go into this lower mode… and then you really get serious, like you have two weeks to… see what your weak areas are." (parent)

Children added that rewards should be unlocked progressively as a user levels up, such that users who achieve more difficult challenges would be awarded with greater rewards.

> "[The] greater the activity is, the more coin or medal… you can win, the more you would use to get one (reward). Let's say if it was just like watch a movie, that isn't that big, so you might put that near the top as an easy reward, but then like bowling, it's bigger, you can put that near the bottom as a sort of a big thing for them." (child)

4.6.4: Customization of Reward Features Enhances User Experience

Participants stated that the ability to customize various app features would enhance the user's experience. Concerns were raised around the inability to complete challenges on a daily basis due to unexpected life events ranging from holidays to hospitalization. To address this, most participants were in favour of the option for users to put daily challenges on hold without penalizing their goal progress.

> "An option to maybe put it on hold if you were going to be away and not using your device for a certain amount of days, and… not necessary lose your streak days but not have a negative effect." (parent)

The ability to customize the difficulty level of challenges based on the user's current healthy behaviour status would be beneficial in encouraging app uptake and user retention, which could increase the likeliness of users to adopt healthy behaviour changes in the long-run.

> "For the older ones, the challenge can be a little small because… he does sports, goes running around… drinks cups of water like it's nothing, whereas the younger one, he'll completely forget." (parent)

Customization of challenges and reward ideas was also a feature that participants desired. Parents and children wanted to be able to input their own family challenges and rewards such that they align with the family's interests. Customization of challenges would also allow for a sense of novelty as families could input challenge ideas inspired by the seasons or holidays.

> "I think it would be cool if you had like the family challenges related to the season because sometimes it could be a bit easier if it was food related because sometimes you don't have the same foods as you do in the summer." (child)

> "You could also customize it to what your month is. Maybe going to a local lake…. if there's a movie your family really wants to see coming up… there's going to be all kinds of holiday activities coming up… like skating on the pond or… you can customize to what's happening to your life at that time." (parent)

Parents called for the option to customize the list of rewards that children may select from and explained how factors such as geographical location and time of the year may influence the ability of parents to provide different rewards for their children.

> "The easiest thing would be having you choose your own rewards … [be]cause I guess it would depend on your family activities, time, etcetera. I mean, depending on where you live, you might not have bikes because there's no place to store them." (parent)

Furthermore, parents stressed the importance of commitment to follow through with rewards to motivate children and indicated that the option for parents to input their own reward ideas is necessary.

> "I think the commitment to follow through if you ask me is quite important to motivate the child, so that means there has to be a flexible sort of options at the end of it." (parent)

The ability to customize the time and frequency of notification reminders for completing daily challenges was identified as a desired feature. Participants believed that reminders sent at an

ideal time and frequency for each user would increase the chance that users complete daily challenges and log it in the App.

> "Like the alarm on your phone, you could just set it, let's say you want to remind yourself… every five hours… make an alarm on your phone and turn it on each day. Every time you set, the alarm goes off, and you know." (child)

4.6.5: In-App Rewards as a Record of Achievement

Discussion around wireframes for rewards revolved around in-app interface designs that could themselves serve as rewards while adding a fun element to the user's experience using the App. Some suggested the collection of badges related to the healthy behaviour goals in the App as a record of their achievements and a visual that indicated their progress towards achieving the next badge would motivate users.

> "I have a thought, like [a] page of badges of what you already achieved, like 75% of the way to the next one." (parent)

Children expressed interest in celebratory animations that are shown in the App when users accomplish a goal. Some suggested an animation that revealed an image of the reward achieved upon completion of a goal, while others suggested celebratory animations when a user achieves a badge.

> "On the badges we can do like a scout kind of badge. It could have a picture of what you did and then it could kind of have like rainbows and sparks coming out of it." (child)

> "Let's say you finish all your drops of water, the drop can become alive and tell you that you finished and then it can do a dance." (child)

4.7: Focus Group (Co-creation) 2B – HCPs

A total of 15 HCPs from BCCH participated in the co-creation session. HCPs included physicians (*n*=4), nurses (*n*=3), nurse clinicians (*n*=2), dieticians (*n*=3), pharmacists (*n*=2), and a physiotherapist (*n*=1). Visuals that served as records of brainstorming sessions and open discussion of topics can be found in Appendix E.

4.7.1: Supporting Patient-Centered Care and Shared Decision Making

HCPs were enthusiastic about the potential of the App to support patient-centered care and the collaboration of children, families, and HCPs in decision making. Regarding their current practices in clinical encounters, HCPs shared that while collecting metrics and following the medical model of care are important, patient communication regarding areas such as quality of life and health priorities are also crucial to ensure that HCPs are providing the necessary care that patients are seeking.

> "I've got my checklist of stuff that I want to get from my patient, and the flipside of it is… what are the things the patients want to communicate to us… to help the patients

> communicate what they want the health care provider to help them with… so that we can actually address their goals, not so much our goals." (physician)

Furthermore, HCPs explained that their role in behaviour change counselling is to guide patients in a collaborative manner towards setting goals that are meaningful and achievable, rather than setting gold standard goals for patients in a paternalistic manner.

> "We have metrics… that we capture because they're how we measure the evolution of health status, but maybe their weight isn't as important as their quality of life, and how they're experiencing the world, and maybe for them it's much more… rather than me saying like I need your number to be this or that." (physician)

To facilitate discussions around healthy behaviour changes and engage in shared decision making, HCPs shared their vision of using the patient's progress in the App as conversation starters during a clinical encounter. Some indicated the difficulty in exploring the child's perspective and understanding their experiences related to healthy behaviours when encountering children who are soft-spoken. Many were optimistic about the potential of the App to help children communicate their thoughts to HCPs, such as completion of an in-app onboarding assessment with their parents prior to a clinic visit.

> "The child might be quiet, it (the App) is a good way to get the child to put their face to life." (allied health)

4.7.2: Readiness to Change Enables Healthy Behaviour Adoption

Readiness to change and intrinsic motivation are key factors that can influence one's success in adopting healthy behaviour changes. HCPs stressed that it is important for the App to be able to capture the child's readiness to make changes in addition to their current healthy behaviour status such that HCPs can provide a customized intervention that is sustainable in the long run. Specifically, HCPs called for capturing the child's emotional feelings towards each healthy behaviour and believed that children would be more likely to make changes if they felt positive towards the behaviour and are motivated internally.

> "You can ask them how happy they are and how they feel, because if they're really happy and you know, versus they hate it, that might change the way your intervention will go to help them maintain." (allied health)

To capture this emotional aspect, some suggested developing a feature where users can select their happiness level towards their progress of their chosen goal on a scale. Not only does this give the user a chance to reflect on their experience as they progress towards their goal, it can also help HCPs gauge the user's progress and provide further support.

> "Give them what their goal was and say how happy you are today about when you changed your behaviour to achieve that goal, and to give them a range of five unhappy faces to happy faces, they choose from that… trying to get them to think about what makes them happy, and… if that goal is achievable, they should be able to be happy." (physician)

Another suggestion related to capturing the user's feelings was to allow users to choose their own avatars with the option to customize their facial expressions to reflect their feelings on their goal progress.

> "The idea, happy, unhappy faces… I'm sure there's a lot of avatar type of programs that you can build into it. Have the kid… put their own happy face, and their own sad face... really makes it more about how they view they are feeling, and it's a way for them to have some customization." (physician)

4.7.3: Prompts and Novelty Trigger Behaviour Change

Triggers (Fogg's model) that could potentially promote extended app use were shared throughout the session. Participants were supportive of a notification system that would remind users to open the App to record their daily challenge progress. They believed that users would be minimally engaged or may forget to record their progress daily if a notification system was not in place.

> "I like the idea of prompts rather than having kids have to go into the App because they'll never go into the App." (physician)

Having notifications prompts to encourage users to record their progress was also believed to generate a wealth of information that HCPs can refer to when providing support to their patients.

> "If they have a prompt… it's going to be super easy for them to answer… if you can do that every day, you're going to have… tons of metrics… that you need." (physician)

Sustaining a sense of novelty throughout the entire app experience was also highlighted as a key trigger for promoting long-term use of the App. An idea proposed was to randomize goals in a variable time ratio such that users would be presented with a new goal at variable intervals, which adds an element of surprise and fun for users. The user would have the opportunity to set their own goals initially to ensure that the goals are meaningful and achievable.

> "If the ideal [number of sugary drinks] is zero and you set your target at four sugary drinks a day [because you are drinking more than four sugary drinks]… that's a good target for you. That can come up on a Monday, that can come up every two weeks, it can come up three days in a row…" (physician)

4.7.4: External Support and Education Complements App Intervention

HCPs were interested in using the App to not only learn about their patient's goal achievements, but also to identify barriers and challenges that their patient may be facing such that extra support could be provided outside of the App. A visual feature that summarizes the user's progress would allow HCPs to pinpoint specific areas to address easily in the often limited time they have with their patients during clinical encounters.

> "You can see whether five, two, the one (Live 5-2-1-0 behaviours), which one is causing the most challenge? Where do you focus your attention to? You have ten minutes with them. You might not be able to address all of the issues, right? So… where do you focus your time?" (physician)

Others also commented on the wealth of information that the App would bring to HCPs for patients who are not seen in the clinic frequently.

> "I want to know how often they meet their goals over time. If you only see them once a year, then a dashboard… you can track over time… the next time, do they get better or same." (allied health)

An app feature that allowed users in input reasons for not completing a daily challenge was deemed to be useful for HCPs to identify the major barriers that are preventing successful goal completion and to provide customized support for their patients.

> "So it didn't go well today. Why? If the answer is always, 'it was too hard' or 'I was too tired,' I would want to see what the answer on those days [were] or what proportion were the same answer so I would know if there's one thing that's the major barrier." (allied health)

Given that users may not have the opportunity to visit a HCP frequently, participants agreed that the App should contain educational content related to healthy behaviours as an extra support for families.

> "Give you little tips like 'you could try frozen vegetables'… lots of resources like community-based, like funding for activities… that families don't know about." (allied health)

Furthermore, HCPs suggested that the App could provide tips to users in a sequential manner and give users the ability to rate whether the tip was helpful or not. In the case where users exhaust the list of tips available, then the App could suggest them to seek additional advice from a HCP.

> "Maybe they can choose what would help you reach this goal… like a new recipe, resources to whatever, intervention, and… if all those things aren't working, then maybe the last resort is like, I want to see the dietician, I want schedule… but offering that as a first step." (nurse)

Building upon this notion, some participants suggested the inclusion of a flagging system within the App that would directly alert HCPs if users are facing challenges with completing their goals. Most agreed on an active approach where the App would notify HCPs via a prompt notification directing them to a dashboard rather than passively via a dashboard that HCPs must regularly monitor.

> "One thing with flagging, I think there's a difference between where you organize the information and have it on a website, like a dashboard that has all the information, versus a prompt to tell you somebody is in trouble on your dashboard." (physician)

4.8: Focus Group 3 (User Testing)

A total of 11 parents and 13 children participated in focus group 3. Nine parents and ten children have participated in at least one of the previous focus groups. Based on the feedback collected from stakeholders in the previous focus group sessions and after rounds of development via an iterative process, a prototype of the Live 5-2-1-0 app that included seven main features was created. Features included the HHQ as an onboarding assessment, goal setting, tiny steps (daily challenges), rewards, gamification, daily notifications, and an assessment dashboard. After testing the prototype, families reported ease in completing the five assigned tasks, with a median score [Q1,Q3] of 7 [6,7] (range 2 to 7) on a 7-point Likert scale, where a score of one represented "very difficult" and 7 was "very easy." The median [Q1,Q3] scores for completing the baseline assessment, setting a goal and daily challenge, responding to a daily notification, completing a daily step and receiving a reward, and reviewing the goal progress and changing goals are presented in Table 7.

In a brief discussion following prototype testing, families shared that they were pleased with the aesthetics and graphics included in the prototype, and found the App easy to use overall. Most participants identified the rewards screen as their favourite. However, they also found it the most challenging to navigate due to having too many reward options and difficulty in

scrolling through the list. Parents also suggested for a feature where customized rewards (typed in by the user) can be saved and selected again when selecting the next reward. Participants wanted to include more in-app rewards, such as animation and sound effects, for the completion of daily challenges and goals. Of the reward ideas proposed by the research team, seven of 11 regular reward ideas and 21 of 26 family challenge rewards were liked by over 50% of children who completed the scoring task (Table 8). Families also suggested five additional regular reward ideas and nine additional family challenge reward ideas that could be added to the list of rewards in the App (Table 9).

Table 7. Median scores for prototype testing during focus group 3 (user testing) on a 7-point rating scale (1 = very difficult, 7 = very easy). Q1 = first quartile; Q3 = third quartile

Task	Median [Q1,Q3]
1. Complete baseline assessment	7 [6,7]
2. Select a behaviour to work on, a reward, and tiny step	6 [5.75,7]
3. Respond to a daily notification for your current tiny step	6 [4.75,7]
4. Complete a tiny step and receive reward for completing your goal	7 [6.7]
5. Review goal progress and change your behaviour goal	6 [5.75,7]

Table 8. Rating of reward ideas during focus group 3 (user testing) (*N*=11)

	Love it!		Not sure		Dislike!		No Response	
REWARDS	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
1. Buy a new card game	9	81.8%	0	0.0%	1	9.1%	1	9.1%
2. I get to buy a new board game	8	72.7%	2	18.2%	0	0.0%	1	9.1%
3. Go skating	8	72.7%	1	9.1%	1	9.1%	1	9.1%
4. Visit a trampoline park	7	63.6%	2	18.2%	1	9.1%	1	9.1%
5. I get to pick one movie to watch	7	63.6%	2	18.2%	1	9.1%	1	9.1%
6. Visit a new playground or park	7	63.6%	2	18.2%	1	9.1%	1	9.1%
7. Buy a new piece of sports equipment (rackets, balls, skipping rope, goggles, etc.)	6	54.5%	3	27.3%	1	9.1%	1	9.1%
8. Buy a new book	5	45.5%	4	36.4%	1	9.1%	1	9.1%
9. Go to the local swimming pool	4	36.4%	4	36.4%	2	18.2%	1	9.1%
10. I get to go to the library	4	36.4%	5	45.5%	1	9.1%	1	9.1%
11. Buy a new reusable water bottle	3	27.3%	4	36.4%	3	27.3%	1	9.1%
FAMILY CHALLENGES								
1. Play a board game together instead of screen time	10	90.9%	0	0.0%	0	0.0%	1	9.1%
2. Go on a family hike or nature walk	9	81.8%	2	18.2%	0	0.0%	0	0.0%
3. Play a card game together instead of screen time	9	81.8%	1	9.1%	0	0.0%	1	9.1%
4. Plan and cook a healthy meal together	9	81.8%	1	9.1%	0	0.0%	1	9.1%

	Love it!		Not sure		Dislike!		No Response	
REWARDS	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
5. Go to a board game restaurant for dinner	9	81.8%	1	9.1%	0	0.0%	1	9.1%
6. Play charades as a family instead of screen time	9	81.8%	0	0.0%	1	9.1%	1	9.1%
7. Go to a movie as a family	8	72.7%	2	18.2%	1	9.1%	0	0.0%
8. Do an outdoor activity (i.e. beach, park, biking, boating, canoeing, kayaking, etc.) together as a family	8	72.7%	2	18.2%	0	0.0%	1	9.1%
9. Find a new recipe featuring your favourite fruit or vegetable and cook for the family	7	63.6%	3	27.3%	0	0.0%	1	9.1%
10. Set up an obstacle course in your house or backyard, and see who can complete it the fastest	7	63.6%	2	18.2%	2	18.2%	0	0.0%
11. Read a new book together instead of screen time	7	63.6%	2	18.2%	1	9.1%	1	9.1%
12. Go on a family bike ride	7	63.6%	2	18.2%	1	9.1%	1	9.1%
13. Go bowling	7	63.6%	2	18.2%	1	9.1%	1	9.1%
14. Go on a camping trip	7	63.6%	1	9.1%	2	18.2%	1	9.1%
15. Do a winter sport (skating, curling, snowshoeing, snowtubing, skiing, snowboarding, etc.)	7	63.6%	1	9.1%	2	18.2%	1	9.1%
16. Explore the farmer market and find any fruits and vegetables that your family has never tried	6	54.5%	5	45.5%	0	0.0%	0	0.0%

	Love it!		Not sure		Dislike!		No Response	
REWARDS	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
17. Have an arts and crafts night at home (paper mâché, painting, collage, etc.)	6	54.5%	4	36.4%	1	9.1%	0	0.0%
18. Play frisbee or ultimate as a family	6	54.5%	4	36.4%	1	9.1%	0	0.0%
19. Go berry picking on the weekend	6	54.5%	4	36.4%	0	0.0%	1	9.1%
20. Visit a hay maze or corn maze close to home	6	54.5%	3	27.3%	1	9.1%	1	9.1%
21. Try bouldering or rock climbing	6	54.5%	1	9.1%	3	27.3%	1	9.1%
22. Play a racket sport with the family (tennis, badminton, etc.)	5	45.5%	5	45.5%	0	0.0%	1	9.1%
23. Assemble a jigsaw-puzzle together instead of screen time	5	45.5%	3	27.3%	1	9.1%	2	18.2%
24. Rearrange the living room furniture for a week so that the TV isn't the central thing in the room	5	45.5%	2	18.2%	4	36.4%	0	0.0%
25. Walk the dog together this week	5	45.5%	1	9.1%	2	18.2%	3	27.3%
26. Play dress up as a family instead of screen time	4	36.4%	4	36.4%	2	18.2%	1	9.1%

Table 9. Additional reward ideas from focus group 3 (user testing)

Regular Rewards
1. Go on a bike ride
2. Visit a theme park (e.g. amusement park, water park, etc.)
3. Choose the restaurant for the next family dine out
4. Visit a video arcade
5. Visit a fair or event in the community
Family Challenge Rewards
1. Have a family step count competition
2. Challenge your family to meatless Monday
3. Have a family game night
4. Have a healthy and active date with one or all of your family members
5. Have a family dance competition/dance lessons
6. Save money to get a certain item for the whole family or to donate to a charity of the family's choice
7. Have a trampoline bouncing competition
8. Bake something nutritious with a family member
9. Challenge your family to have no screen time during the weekend

4.9: Final Product of the App Development Process

After a total of eight months of app development, the Live 5-2-1-0 App was launched in both the Apple App Store and Google Play Store. The current version of the App includes an onboarding process, a modified version of the HHQ, rewards selection, healthy behaviour goal setting, daily challenges, notifications, and an assessment dashboard. A user's journey of the App is presented in Figures 3 to 6 and briefly described in the sections below. Figure 7 illustrates the pathway that a user experiences from initiation of App use to achievement of healthy behavioural changes (proximal outcome for obesity prevention), and ultimately, improvement in BMI measures (distal outcome for obesity treatment).

4.9.1: Onboarding

Upon launching the App initially, the user is presented with a welcome screen that provides a simple explanation of the Live 5-2-1-0 message, followed by an onboarding process, where users are asked to input a nickname and their age, and to complete a modified version of the HHQ (Figure 3). The HHQ consists of a total of eight questions, two each about the user's current practices for the four Live 5-2-1-0 behaviours, and the user's readiness to make changes for each behaviour.

4.9.2: Goal Setting and Rewards Selection

After onboarding, users are directed to the *My Goals* screen to select one of the four healthy behaviours as the goal they would like to work on (Figure 4). Based on the user's responses to the HHQ, each behaviour goal on the *My Goals* screen is labelled with either a green, yellow, or red tab, representing meeting, almost meeting and not meeting the Live 5-2-1-0 behaviour goals, respectively. In addition, the App highlights a suggested goal for the user based on an algorithm that takes into account both the user's current healthy behaviours and their readiness to make changes as reported in the HHQ. Users can view their active goal and progress, as well as switch goals at any time via the *My Goals* functionality tab from the App's main menu.

After selecting a goal, users are directed to the *Rewards* screen, where they are instructed to discuss options with their parents and select a reward from a drop-down menu, or to input a reward of their own. Rewards featured include extrinsic rewards, such as 'go to the local swimming pool' and 'buy a new board game,' as well as family-centered activities, such as 'go berry picking together' and 'cook a healthy meal together.' Users must select 'my parents

agree to this' to ensure that parents are committed to providing the reward when their child achieves the goal. Users can view the current reward chosen and rewards that have been earned previously in the *My Rewards* screen that is accessible from the App's main menu.

4.9.3: Completing Daily Challenges and Achieving Goals

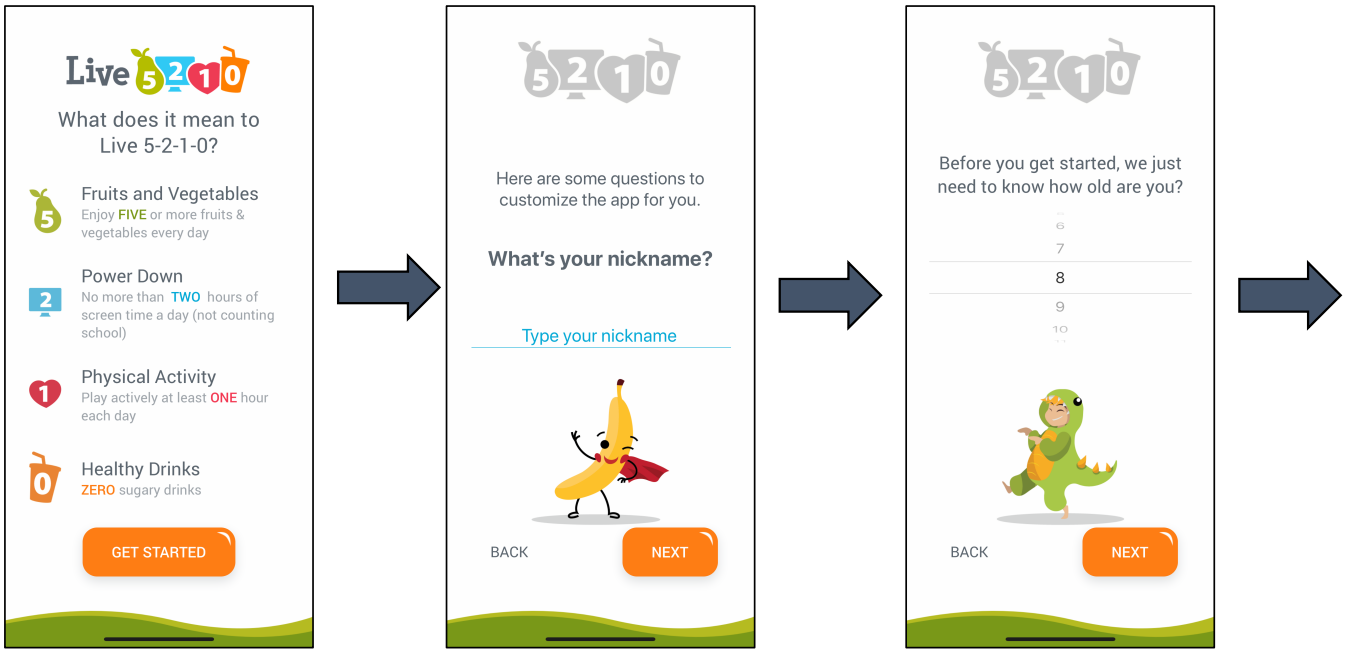
Once users have selected a goal and a reward, they are taken to the *Tiny Step Selection* screen to select a daily challenge relevant to their selected behaviour goal to complete in order to earn points towards achieving their goal (Figure 5). Daily challenges are categorized into three levels of difficulty (easy, medium, hard). Users must complete at least one daily challenge from the 'easy' category to unlock the more difficult levels. Users who enable push notifications receive a notification every evening at 7 p.m. to serve as a reminder. Each day, users are expected to log whether they completed the tiny step using the *My Tiny Step* screen, which is accessible from the main menu. A timer function is incorporated into the App such that users may only record their tiny step completion status once a day, with the time lock resetting at midnight. After recording a tiny step, users are prompted to either repeat the same tiny step or switch to a new tiny step for the following day.

A goal wheel, which is a circular progress bar, is used to visualize the user's progress towards achieving a goal. When users complete a tiny step, points are earned and used towards filling in the goal wheel. The number of points awarded increases with the difficulty of the tiny steps. Once the entire goal wheel is filled, the goal is completed and users are notified that they have earned their reward. Once a goal is completed, users are redirected to the *My Goals* screen

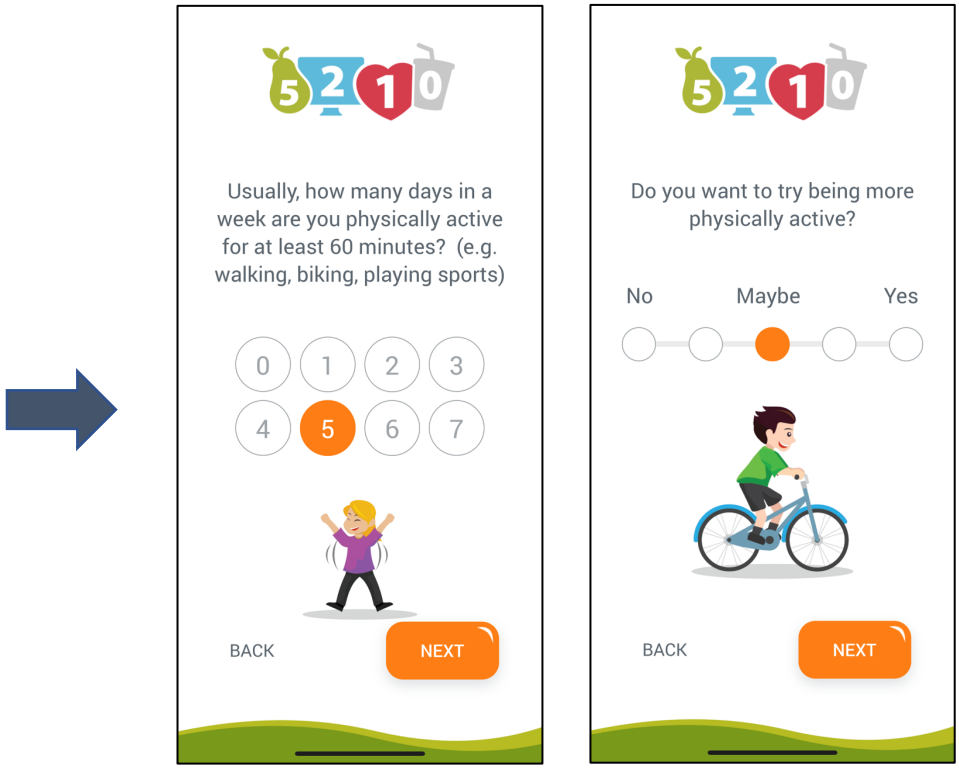
where users can repeat the process by selecting the same goal or another goal, choosing a new reward, and completing daily tiny steps to reach their goals.

4.9.4: Assessment Dashboard and App Menu

The Assessment Dashboard, accessed via the App's main menu under *Assessment,* was designed to serve as a visual summary for children, parents and HCPs to view the user's progress in each of the four Live 5-2-1-0 behaviours (Figure 6). For each behaviour, the dashboard includes the user's most recent HHQ assessment response (current behaviour practices and readiness to change), the number of goals completed (number of times the goal wheel was completed), the number of tiny steps completed, and a record of all the tiny steps completed previously, categorized by the level of difficulty.

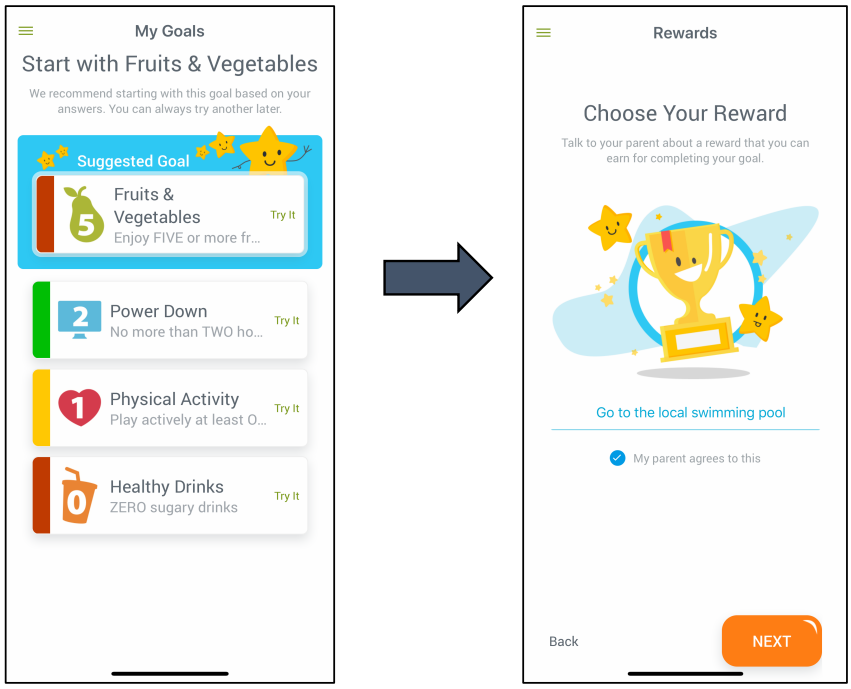


Welcome Screen Username Age



Modified Healthy Habits Questionnaire

Figure 3. Screenshots of the onboarding process



Goal Setting Reward Selection

Figure 4. Screenshots of goal setting and reward selection screens

Tiny Step Selection

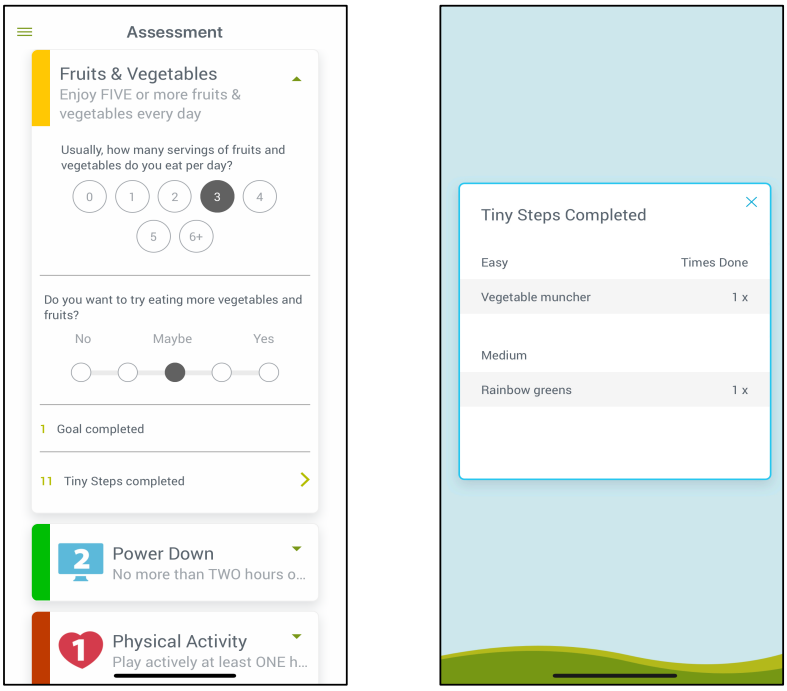
Tiny Step Logging and Goal Progress Wheel

Tiny Step Completed

Tiny Step Not Completed

Rewards Earned

Figure 5. Screenshots of tiny step selection and goal achievement



Assessment Dashboard Tiny Steps Completed

Figure 6. Screenshots of assessment dashboard and tiny steps record

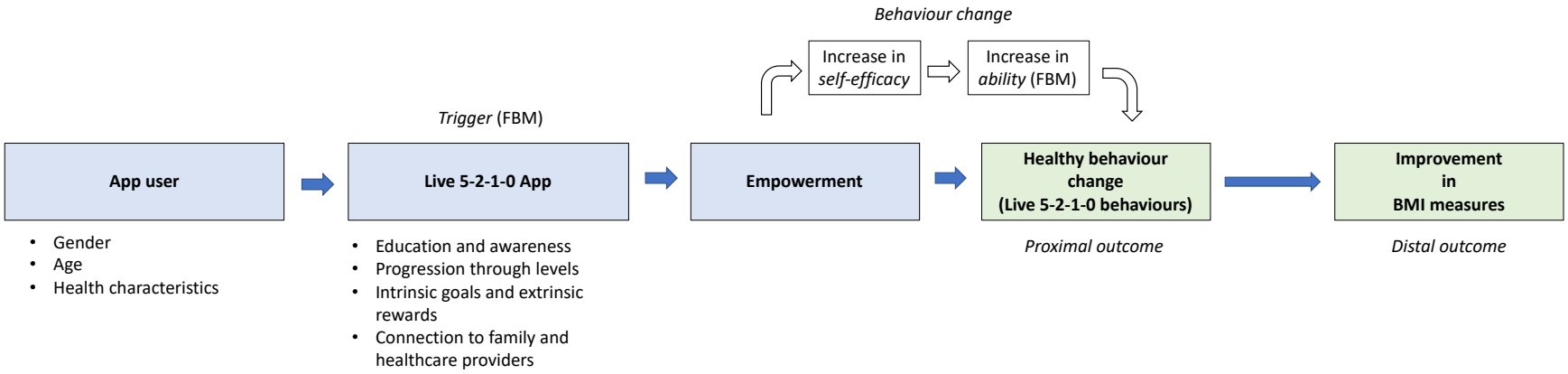


Figure 7. Pathway from initiation of App use to achievement of healthy behavioural changes and BMI measures

Chapter 5: Discussion

When designing a mobile health app, acquiring a strong understanding of the perspectives, desires, and needs of the target population is crucial to ensure its effectiveness in promoting healthy behaviours and to promote uptake and long-term use of the App. Unlike the many mobile health and fitness apps on the market that were designed and created based solely on developer's ideas of what users are seeking, our study demonstrates the process of how a mobile health app can be co-created by incorporating the voice of relevant stakeholders and end-users at each stage of the design and development process. Several key findings related to mobile health apps targeting healthy behaviour change among children emerged from this study. Our qualitative data revealed that across the three sets of focus groups, participants viewed shared decision making as a critical app component that could support children in adopting healthy behaviour changes, and that developing a sense of self-efficacy by way of education would empower children to take ownership of their own health. Secondly, the inclusion of intrinsic goals and extrinsic rewards were believed to motivate users in adopting behaviour changes in a progressive manner. Lastly, the integration of family connectivity and connectivity to HCPs were thought to provide users with a strong support network as they make progress towards achieving the Live 5-2-1-0 goals. Most importantly, our study demonstrates that developing a mobile app using a participatory approach by engaging stakeholders directly is feasible.

5.1: Co-creation and Participatory Approaches Allow for Efficient Development of Apps Meaningful to Users

A novel aspect of our study is the incorporation of stakeholders (children, parents, and HCPs) throughout all the stages of app development. Guided by co-creation and participatory action research principles, we were able to design and develop a mobile health app with features and content that are meaningful and relevant to the behaviours and lifestyles of its stakeholders. The collaboration between stakeholders, researchers, and app developers is a unique feature of this app development process. Researchers were able to address concerns regarding healthy behaviours in children in an efficient manner by directly engaging stakeholders as partners in research. With researchers serving as a liaison between stakeholders and app developers, ideas proposed by stakeholders were analyzed by researchers through a methodological and critical perspective, and resulting findings were relayed to app developers to transform abstract ideas into concrete app features. An app prototype created based on the ideas proposed by stakeholders was then presented to stakeholders for user-testing and feedback to determine whether the App addressed their desires and needs. This process highlights the many strengths of participatory research, including the focus on everyday living of stakeholders, the incorporation of diverse perspectives, and the ability to address pressing issues via action and research (72).

Researchers of apps that do not incorporate co-creation and participatory approaches are often left disappointed when app features that they believed would appeal to users and augment user experience are not well-received. In a pilot study investigating the effectiveness of a researcher developed app based on the addiction treatment approach on weight loss, the inclusion of a

peer support component via buddy chat and in-app bulletin boards was thought to encourage user engagement (36). Contrary to the researcher's expectations, study participants shared that they felt uncomfortable interacting with other app users who they did not personally know, especially around sensitive topics such as body weight. If end users had participated in the app development process, their perspectives regarding peer support could have been captured and resources spent in developing peer support features could have been used to enhance other app components. In our study, contrary to our expectations, both children and parents expressed a desire for an app that promoted family engagement throughout the focus groups. To address this, we incorporated family challenges rewards and tiny steps that were intended to be completed with the support of family members. Without engaging stakeholders in the design process, the idea of family engagement may not have been recognized as a desired element and incorporated into the App. Acquiring input from end users with regard to their preferences for specific app features during development can also contribute to improved user experience and increased app use. Participants of an intervention aimed at promoting physical activity and reducing screen-time via a researcher developed app found tailored motivating messages a nuisance as they were too frequent and repetitive and sent at inappropriate times (73). In our focus groups, the preferences of children and parents were sought to ensure that the frequency and time that notifications were sent would best compliment the user's lifestyle and increase the likelihood of users tracking their daily challenges on a daily basis. Based on their feedback, the current version of the App is designed to send a daily notification at 7 p.m. to remind users to complete their tiny step.

5.2: Shared Decision Making Supports Children in Making Health Behaviour Changes

5.2.1: Shared Decision Making Enhances Patient-centered Care and Promotes Behaviour Change

A dominant theme that emerged across all the focus groups and was expressed by children, parents, and HCPs as critical was the need for the App to support shared decision making regarding making healthy behaviour changes. Stakeholders believed that shared decision making would allow for the creation of a support system between the child, the family, and the HCP as the child progresses through the journey of adopting healthy behaviour changes. By combining the HCP's medical expertise and knowledge with the patient's goals and preferences, shared decision making is seen as a way to facilitate patient-centered care (74) and increases the patient's chances of achieving his or her desired health outcome (75). An investigation of the impact of shared decision making on health outcomes and healthcare quality revealed that poor execution of shared decision making was associated with worse patient-reported health outcomes and higher utilization of healthcare services (76). Furthermore, in a study that investigated the effects of a palliative care program centered around shared decision-making between pediatric patients, family members, and HCPs on quality of life, significant improvements in parent-reported pediatric quality of life were reported at the end of the intervention (77). In fact, positive effects of shared decision making on health behavioural outcomes among children have been reported previously. In a controlled family-based health education intervention based on shared decision-making principles, children in the intervention group demonstrated significant improvements in healthy

behaviours, including the use of healthier fats, reduction in the frequency of adding salt to food, and increasing amounts of exercise, compared to controls (78). The *assessment* screen in the App is intended to facilitate shared decision making between children, parents, and HCPs by providing HCPs with a visual summary of the child's progress in making healthy behaviour changes and serving as a conversation starter during healthy behaviour counselling in a clinical setting.

5.2.2: Children Are Active Agents of Behaviour Change

In order for shared decision making to be effective among children, throughout the entire app development process, parents and HCPs stressed the need for the App to facilitate the empowerment of children to take responsibility for their own health. Adults and HCPs believed that children would more likely engage with the App and adopt healthy behaviour changes if the App educated children about healthy behaviours in a way that is meaningful to them. Indeed, previous literature has pointed to the fundamental role of education and information exchange in developing a sense of internal control and self-efficacy (79). Increased self-efficacy is often linked to decreasing stress levels, which can encourage children to become active agents in behaviour change by becoming more involved in discussions regarding their care and making informed decisions in a collaborative manner with their families and HCP (80,81). With app development centered around FBM, the emergence of self-efficacy as a theme that was repeated throughout the app development process was not surprising. According to the concept of self-efficacy, whether an individual will engage in behaviour change and sustain the new behaviour is dependent on their expectations of the outcomes and their perceived ability to carry out the behaviour (82). This exact concept is reflected in FBM

as one of the three factors that lead to successful behaviour change: *ability*. FBM posits that individuals are more likely to perceive themselves as having a high ability to achieve a task when the task is simple, and that simplicity of a task is characterized by a multitude of elements, including requiring a low level of cognitive effort and the lack of disruption to normal routines (24). When children gain awareness and are educated about healthy behaviours by using the App, the knowledge gained in turn may lower the amount of conscious cognitive effort that they need to put forth in order to achieve healthy behaviour changes. Similarly, the empowerment of children, another key theme that emerged from the focus groups, may lead to the development of healthy behaviours into a habit and thus, increase the child's perception of their *ability* to achieve healthy behaviour changes. An example of how we applied this in our App is offering tiny steps of varying difficulty levels to support progressive behaviour change, which can motivate and empower children to take responsibility for their health.

5.3: Intrinsic Goals and Extrinsic Rewards as Motivators for Progressive Behaviour Change

To allow children to interact with the App as active agents of their own behaviour change, the App was designed such that users had the freedom to select goals and rewards of their choice. Rather than expecting users to simply adopt the entire Live 5-2-1-0 message as their goal, the App allows users to select one of the four behaviours to work on based on their own perception of their *ability* and readiness to make changes. More importantly, for each overarching behaviour goal, users are given the freedom to select daily challenges of varying level of difficulty to complete, allowing users to gradually progress towards meeting the Live 5-2-1-0 behaviours at their own pace. Since users may fall along a wide spectrum in terms of where

they are at relative to the Live 5-2-1-0 behaviour targets, the flexibility that the App provides through progressive levels makes the behaviour change journey much more accessible to all users, regardless of their current healthy behaviour practices and level of motivation. By providing a chance for users to master easier daily challenges first before advancing to moderate and difficult ones, the App has the potential to provoke a feeling of self-satisfaction among users. This intrinsic reward of self-satisfaction can in turn become a source of motivation for progression towards achieving the Live 5-2-1-0 behaviour targets. Goals that contain intrinsic value are thought to be an important factor in influencing successful behaviour change. In a study that examined intrinsic and extrinsic exercise goals and their relationship with cognitive, affective, and behavioral outcomes, setting goals that contain intrinsic value and are meaningful to the individual was found to be positively associated with self-reported exercise behaviour and psychological well-being, and negatively associated with exercise anxiety (83).

Children, parents, and stakeholders all agreed that the inclusion of extrinsic rewards would motivate users to adopt healthy behaviour changes during the focus groups. However, parents and healthcare providers agreed that materialistic rewards could potentially become a financial burden on some families and foster materialism. Therefore, other than including materialistic rewards, such as buying a new board game or a new piece of sports equipment, non-materialistic rewards, such as family challenges (e.g. family bike ride, walking the dog together), were also incorporated as rewards. While the inclusion of gamification elements in the App has the ability to engage and motivate users**,** children participants pointed out its association with extrinsic rewards and highlighted that gamification may lead to users cheating

the system if not designed carefully. Users may be more interested in receiving the extrinsic rewards rather than making healthy behaviour changes and find ways to cheat in order to obtain rewards more frequently by exploiting the points system. To address this problem, we designed a timer that would only enable users to record their daily challenge completion status and earn points towards their reward once per day.

5.4: Integration of Family Connectivity and Connection with Healthcare Providers Encourages the Adoption of Healthy Behaviours

The integration of family connectivity and connection with HCPs emerged as a key theme throughout the focus groups and guided the design and development of the App. Participants were confident in the ability of social connectivity to encourage the adoption of healthy behaviours and to transform changes into long-term habits. Parents and children identified family connectedness as a key motivator, and children were enthusiastic about the idea of making healthy behaviour changes as a family through family challenges. Results from studies that investigated the difference in effectiveness of obesity prevention and treatment interventions with or without parental involvement have been mixed. An obesity prevention and treatment family therapy intervention reported positive intervention effects when both children and parents completed the intervention together (84). The education of both parents and children in healthy behaviour changes was found to be positively associated with children's weight loss. However, investigations about the effect of interventions in which only children were targeted have been inconclusive (84), and some have found no significant effects of family involvement on childhood obesity prevention and treatment interventions (85). Although the current version of the App neither supports parental profiles nor multiple accounts due to limited resources, the App encourages parents to participate in their child's

progression towards making healthy behaviour changes by including reward options that involve performing an activity with the family (e.g. going on a picnic with your family, family board game night, etc.). In addition, some of the daily challenges included in the App were designed with the expectation that parents would provide support for their child (e.g. meal planning to address daily challenges related to fruits and vegetables). To facilitate parental involvement, parents had suggested the inclusion of app features that could assist in meal planning and involve children in grocery shopping planning. However, due to the focus on child behaviour for this first version of the App, these suggested futures will be saved for future iterations of the App.

Connection to HCP via the App also emerged as a desired feature among all participants. Parents and children would like to communicate with their HCPs outside of clinic visits, and HCPs believed that providing ongoing support between clinic visits via the App would increase the success rate of healthy behaviour adoption among children as it minimizes patient barriers to approaching their HCP. In an intervention aimed at supporting asthma self-management among adolescents via a smartphone app, the inclusion of a pharmacist chat function for participants to ask questions, access information, and receive guidance about their care positively affected adherence to medication (86). Our current mechanism for child-provider interaction is the assessment dashboard that enables users to better communicate with their HCPs regarding their progress during clinic visits. Other than serving as a tool for HCPs during healthy behaviour counselling, the assessment dashboard is believed to be useful for children and parents to keep track of their progress. In a primary care-based intervention that addressed childhood overweight via the 5-2-1-0 goals and included use of resources such as a goal tracker

for families to record their behaviours, youth and parents reported increased self-perceived quality of care and counselling from their HCP, while HCPs felt better supported in providing medical evaluations for patients who are overweight, and improved counselling on healthy behaviours via goal setting and motivational interviewing (87). Future versions of the App could also consider two-way communication and remote monitoring of progress by HCP.

5.5: Strengths and Limitations

The Live 5-2-1-0 App is one of a small group of mobile health apps aimed at promoting healthy behaviour changes among children that employed human-centered design and engaged stakeholders as collaborators throughout the entire app development process. Engagement of children and parents allowed for the identification of the needs and perspectives of users, while engagement of HCPs provided insight into how the App could best be incorporated in their medical practice to enhance patient care. The current method of utilising focus groups at crucial points of the app development process and engaging in agile app development to create the Live 5-2-1-0 App can potentially be applied to other groups interested in developing a mobile app to support health interventions.

Despite these strengths, our app development process also has several limitations. One of the key limitations is the inability to include all features that were identified and discussed by participants during the focus groups in this iteration of the App due to limited resources available. To create an app that resembled the overall vision of study participants as much as possible given the limited resources, the research team, with guidance from the app development team, prioritized features that emerged from the focus groups prior to the agile development phase. For teams who encounter a similar issue, incorporating a feature

prioritization activity directly with stakeholders during the app development process could ensure that features deemed as critical to the App's usability are incorporated. Furthermore, stakeholders could be invited to participate in sprints during agile development, during which they could provide direct input on decisions around prioritization and resource allocation among features proposed in the focus groups.

An important feature that was not included in this initial version of the App was ability to connect with other users, which would have addressed the identification of peer interactions as key influencers in a child's decision making during the focus groups. Parents described instances where children would adopt dramatic behaviour changes due to peer influence, whereas children shared that the ability to interact with peers and compete against each other was appealing. The inclusion of peer networks has previously been suggested as critical in efforts that aimed at promoting and maintaining healthy behaviour changes among children (88). The availability of social support from peers have previously been associated with improvements in healthy behaviours. In a qualitative exploration of peer support related to weight status, physical activity, and healthy eating in low-income African-American adolescents, participants acknowledged the potential of peer support in encouraging them to make improvements to their diet and physical activity levels (89). However, other than the presence of peer support, the quality of peer support is a key determinant in the promotion of healthy behaviours among children and adolescents. When children perceived the peer support they received as positive, they were more likely to engage in increased amounts of physical activity (90,91) and making healthy food choices (86). Given these promising results, features facilitating peer interaction will be considered for the next iteration of the App.

Another limitation stems from the recruitment of children and parents, which was completed via voluntary response sampling. Interested families were instructed to self-identify and contact the research team to participate in the study. Since participants were self-selected volunteers, there could be an overrepresentation of participants with higher socioeconomic status who had the ability to travel and the time to attend the series of focus groups, resulting in voluntary response bias. In addition, by only including children and parents who were able to communicate in English, the perspectives of individuals who are non-English speaking or uncomfortable participating in a focus group held in English, such as immigrant groups, may not have been fully accounted for. Immigrant children are often at high risk for developing obesity since they and their parents often have limited language proficiency, which may hinder them from navigating their living environments, participating in outdoor recreation activities, and accessing the healthcare system (92). The App may have the greatest potential in promoting healthy behaviours in immigrant population groups, whose needs were not addressed in our study. However, our sample did include representation of several different ethnic groups, and cultural perspectives regarding healthy behaviours were discussed several times during the focus groups. Thus, given these limitations related to sampling, the perspectives gathered in this study may not be generalizable to the target population.

Lastly, the open discussion nature of the focus groups may have favoured those who were more verbose and comfortable speaking out in a group setting, which may have resulted in the failure to capture all perspectives within the sample. To mitigate the effects of this limitation, facilitators did attempt to encourage equal participation using techniques such as redirecting

comments and questions to other participants and giving participants time to discuss in small groups before sharing with others. Nonetheless, the journey that an individual experiences while using the current iteration of the App may not fully reflect what study participants had envisioned.

5.6: Future Directions

To assess the effectiveness in promoting healthy behaviour change and usability of the Live 5-2-1-0 App, a randomized controlled pilot study and a one-group pretest-posttest quasi-experimental pilot study will be conducted at the General Pediatrics clinic at BCCH and in a weight management program (Shapedown BC), respectively. Results from these studies will inform the feasibility of using the App as a tool in behavioural weight management programs and primary care clinics, and provide a basis for designing full-scale studies in the future. Finally, usability and feasibility feedback from the quasi-experimental studies as well as any outstanding features that were not included in this version of the App will be incorporated in future iterations.

5.7: Conclusions

The design and development process of the Live 5-2-1-0 App, aimed at promoting healthy behaviours changes among children, was described. Results from this study demonstrate the feasibility of co-creating a mobile health app with children, parents, and HCPs through participatory action research. Stakeholders desired an app that allowed for goal setting and daily challenges in a gamified manner and had the ability to track progress in healthy behaviour changes over time. Although further work is needed to investigate the effectiveness of the App in promoting behaviour change, our findings may potentially serve as a reference for those

who are interested in developing mobile apps that address behaviour change via collaboration with stakeholders throughout the development process.

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Appendices

Appendix A: Systematic Literature Review Search and Data Extraction

Table A1. Search strategy and results from Ovid MEDLINE

#	Searches	Results
1	(mhealth or ehealth).tw,kw.	4709
2	(iterative develop* or co-creat*).tw,kw.	706
3	(mobile app* or software design or user-computer interface).tw,kw.	3247
4	gamif*.tw,kw.	349
5	(interactivity or user experience or human-centered design).tw,kw.	2348
6	(smartphone or tablet or iphone or android or ipad).tw,kw.	30797
7	CHILD HEALTH/ or HEALTH BEHAVIOR/ or HEALTH PROMOTION/ or HEALTH/ or ADOLESCENT HEALTH/	130237
8	OBESITY MANAGEMENT/ or PEDIATRIC OBESITY/	5768
9	(health or obesity management or pediatric obesity).tw,kw.	1592823
10	Chronic Disease/ or chronic disease*.tw,kw.	291344
11	(physical activity or physical fitness or exercise or active play).tw,kw.	307873
12	healthy lifestyle/ or sedentary lifestyle/	7822
13	(sedentary or screen time).tw,kw.	27445
14	Healthy Diet/	1692
15	healthy diet.tw,kw.	3289
16	(vegetable* or fruit*).tw,kw.	114377
17	(sugary drink* or sugary beverage*).tw,kw.	405
18	focus groups/ or "surveys and questionnaires"/	426564
19	preventive health services/ or "early intervention (education)"/ or health education/	72362
20	(focus group* or survey* or questionnaire* or preventive health or health education or health intervention).tw,kw.	955983
21	or/1-6	39929
22	or/7-17	2217851
23	or/18-20	1145863
24	and/21-23	3085

#	Searches	Results
25	limit 24 to yr="2008 - 2018"	2904
26	exp child/ or exp "congenital, hereditary, and neonatal diseases and abnormalities"/ or exp infant/ or adolescent/ or exp pediatrics/ or child, abandoned/ or exp child, exceptional/ or child, orphaned/ or child, unwanted/ or minors/ or (pediatric* or paediatric* or child* or newborn* or congenital* or infan* or baby or babies or neonat* or pre-term or preterm* or premature birth* or NICU or preschool* or pre-school* or kindergarten* or kindergarden* or elementary school* or nursery school* or (day care* not adult*) or schoolchild* or toddler* or boy or boys or girl* or middle school* or pubescen* or juvenile* or teen* or youth* or high school* or adolesc* or pre-pubesc* or prepubesc*).mp. or (child* or adolesc* or pediat* or paediat*).jn.	4712421
27	25 and 26	811

Table A2. Search strategy and results from EMBASE

#	Searches	Results
1	(mhealth or ehealth).tw,kw.	4594
2	(iterative develop* or co-creat*).tw,kw.	841
3	mobile application/ or mobile app*.tw,kw.	7310
4	software design.kw,tw. or software design/	1055
5	user-computer interface.tw,kw. or computer interface/	28891
6	gamif*.tw,kw.	363
7	(interactivity or user experience or human-centered design).tw,kw.	2878
8	microcomputer/ or smartphone/	20480
9	(smartphone or tablet or iphone or android or ipad).tw,kw.	51331
10	child health care/ or child health/	56115
11	health behavior/	59041
12	health education/ or health promotion/ or health program/ or prevention/	475810
13	obesity/ or adolescent obesity/ or childhood obesity/	375115
14	(health or obesity management or pediatric obesity).tw,kw.	2015552
15	chronic disease/ or chronic disease*.tw,kw.	202984
16	exercise/ or physical activity/ or fitness/	369464

#	Searches	Results
17	(physical activity or physical fitness or exercise or active play).tw,kw.	407593
18	healthy lifestyle/	1765
19	sedentary lifestyle/	10981
20	(sedentary or screen time).tw,kw.	36052
21	healthy diet/ or healthy diet.tw,kw.	5803
22	(vegetable* or fruit*).tw,kw.	137395
23	(sugary drink* or sugary beverage*).tw,kw.	577
24	focus group.tw,kw.	24366
25	questionnaire*.tw,kw. or questionnaire/	785892
26	health survey/ or survey*.tw,kw.	766403
27	preventive medicine/ or preventive health service/	48082
28	(preventive health or health education or health intervention).tw,kw.	40954
29	or/1-9	106578
30	or/10-21	3162489
31	or/24-28	1450412
32	and/29-31	5361
33	limit 32 to yr="2008 - 2018"	4793
34	exp child/ or exp "congenital, hereditary, and neonatal diseases and abnormalities"/ or exp infant/ or exp adolescence/ or exp infant, newborn/ or exp child, preschool/ or (pediatric* or paediatric* or child* or newborn* or congenital* or infan* or baby or babies or neonat* or pre-term or premature birth or NICU or preschool* or preschool* or kindergarten* or elementary school* or nursery school* or schoolchild* or toddler* or boy or boys or girl* or middle school* or pubescen* or juvenile* or teen* or youth* or high school* or adolesc* or pre-pubesc*).mp. or (child* or adolesc* or pediat* or paediat*).jn.	4706366
35	33 and 34	1183

Table A3. Search strategy and results from PsycINFO

#	Query	Limiters/Expanders	Results
S25	S20 AND S21 AND S22	Limiters - Published Date: 20080101-20181231; Age Groups: Childhood (birth-12 yrs), Neonatal (birth-1 mo), Infancy (2-23 mo), Preschool Age (2-5	131

#	Query	Limiters/Expanders	Results
		yrs), School Age (6-12 yrs), Adolescence (13-17 yrs) Search modes - Boolean/Phrase	
S24	S20 AND S21 AND S22	Limiters - Published Date: 20080101-20181231 Search modes - Boolean/Phrase	681
S23	S20 AND S21 AND S22	Search modes - Boolean/Phrase	761
S22	S16 OR S17 OR S18 OR S19	Search modes - Boolean/Phrase	551,003
S21	S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15	Search modes - Boolean/Phrase	240,258
S20	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7	Search modes - Boolean/Phrase	26,188
S19	DE "Health Education" OR AB(health N3 education) OR TI(health N3 education)	Search modes - Boolean/Phrase	32,411
S18	DE "Early Intervention" OR AB((preventive N3 health) or (health N3 intervention)) OR TI((preventive N3 health) or (health N3 intervention))	Search modes - Boolean/Phrase	27,902
S17	AB(focus group*) OR TI(focus group*)	Search modes - Boolean/Phrase	31,790
S16	DE "Surveys" OR DE "Questionnaires" OR AB(survey* or questionnaire*) OR TI(survey* or questionnaire*)	Search modes - Boolean/Phrase	482,681
S15	AB(sugary drink* OR sugary beverage*) OR TI(sugary drink* OR sugary beverage*)	Search modes - Boolean/Phrase	113
S14	AB(vegetable* OR fruit*) OR TI(vegetable* OR fruit*)	Search modes - Boolean/Phrase	17,938
S13	AB(healthy diet*) OR TI(healthy diet*)	Search modes - Boolean/Phrase	1,256
S12	DE "Screen Time" OR AB(screen N3 time) OR TI(screen N3 time)	Search modes - Boolean/Phrase	1,088
S11	DE "Physical Activity" OR DE "Active Living" OR DE "Physical Fitness" OR DE "Exercise" OR AB((physical N3 activity) or (physical N3 fitness) or (exercise) or (active N3 play)) OR TI((physical N3 activity) or (physical N3 fitness) or (exercise) or (active N3 play))	Search modes - Boolean/Phrase	89,876
S10	DE "Chronic Illness" OR AB(chronic disease*) OR TI(chronic disease*)	Search modes - Boolean/Phrase	21,258

#	Query	Limiters/Expanders	Results
S9	DE "Sedentary Behavior" OR DE "Overweight" OR AB((obesity) or (sedentary)) OR TI((obesity) or (sedentary))	Search modes - Boolean/Phrase	36,378
S8	DE "Health Behavior" OR DE "Health Education" OR DE "Health Promotion" OR AB((child N3 health) OR (health N3 behavio#r) OR (health N3 promotion) OR (adolescent N3 health)) OR TI((child N3 health) OR (health N3 behavio#r) OR (health N3 promotion) OR (adolescent N3 health))	Search modes - Boolean/Phrase	112,935
S7	AB(smartphone* OR tablet* OR iphone* OR android* OR ipad*) OR TI(smartphone* OR tablet* OR iphone* OR android* OR ipad*)	Search modes - Boolean/Phrase	7,195
S6	AB(interactivity OR (user N3 experience) OR (human-centered N3 design)) OR TI(interactivity OR (user N3 experience) OR (human-centered N3 design))	Search modes - Boolean/Phrase	4,913
S5	AB(gamif*) OR TI(gamif*)	Search modes - Boolean/Phrase	347
S4	AB((mobile N3 app*) OR (software N3 design) OR (user-computer N3 interface)) OR TI((mobile N3 app*) OR (software N3 design) OR (user-computer N3 interface))	Search modes - Boolean/Phrase	2,611
S3	(DE "Human Computer Interaction")	Search modes - Boolean/Phrase	9,730
S2	AB((iterative N3 develop*) OR co-creat* OR cocreat*) OR TI((iterative N3 develop*) OR co-creat* OR cocreat*)	Search modes - Boolean/Phrase	2,672
S1	AB(mhealth OR ehealth) OR TI(mhealth OR ehealth)	Search modes - Boolean/Phrase	856

Table A4. Search strategy and results from CINAHL Complete

#	Query	Limiters/Expanders	Results
S34	S28 AND S32	Limiters - Published Date: 20080101-20181231 Search modes - Boolean/Phrase	600
S33	S28 AND S32	Search modes - Boolean/Phrase	661
S32	S29 AND S30 AND S31	Search modes - Boolean/Phrase	3,593

#	Query	Limiters/Expanders	Results
S31	S23 OR S24 OR S25 OR S26 OR S27	Search modes - Boolean/Phrase	769,415
S30	S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22	Search modes - Boolean/Phrase	1,072,167
S29	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9	Search modes - Boolean/Phrase	36,597
S28	(pediatric* or paediatric* or child* or newborn* or congenital* or infan* or baby or babies or neonat* or “pre-term” or preterm or “premature birth*” or NICU or preschool* or “preschool*” or kindergarten* or “elementary school*” or “nursery school*” or schoolchild* or toddler* or boy or boys or girl* or “middle school*” or pubescen* or juvenile* or teen* or youth* or “high school*” or adolesc*or prepubesc* or “pre-pubesc*” or "(MH "Child+") OR (MH "Adolescence+") OR (MH "Minors (Legal)") or "(MH "Child Abuse, Sexual") OR (MH "Child Behavior Disorders+") OR (MH "Child, Medically Fragile") OR (MH "Child Day Care") OR (MH "Child Behavior+") OR (MH "Child Mortality") OR (MH "Child Passenger Safety") OR (MH "Child Development Disorders, Pervasive+") OR (MH "Child Custody") OR (MH "Child Abuse+") OR (MH "Child Nutritional Physiology+") OR (MH "Child Behavior Checklist")) OR SO (child* or pediatric* or paediatric* or adolescent)	Search modes - Boolean/Phrase	912,703
S27	(MH "Early Intervention+") OR (MH "Intervention Trials") OR AB((preventive N3 health) OR (health N3 education) or (health N3 intervention)) OR TI((preventive N3 health) or (health N3 education) or (health N3 intervention))	Search modes - Boolean/Phrase	65,170
S26	(MH "Health Education+") OR (MH "Student Health Education") OR AB(health N3 education) OR TI(health N3 education)	Search modes - Boolean/Phrase	128,473
S25	(MH "Focus Groups") OR AB(focus N3 group*) or TI(focus N3 group*)	Search modes - Boolean/Phrase	43,292
S24	(MH "Structured Questionnaires") OR (MH "Open-Ended Questionnaires") OR (MH "Questionnaires+") OR AB(questionnaire*) OR TI(questionnaire*)	Search modes - Boolean/Phrase	391,937

#	Query	Limiters/Expanders	Results
S23	(MH "Surveys+") OR (MH "Survey Research") OR AB(survey*) OR TI(survey*)	Search modes - Boolean/Phrase	335,929
S22	(MH "Carbonated Beverages") OR AB((sugary N3 drink*) or (sugary N3 beverage*)) OR TI((sugary N3 drink*) or (sugary N3 beverage*))	Search modes - Boolean/Phrase	2,494
S21	(MH "Fruit+") OR AB(fruit*) OR TI(fruit*)	Search modes - Boolean/Phrase	30,831
S20	(MH "Vegetables+") OR AB(vegetable*) OR TI(vegetable*)	Search modes - Boolean/Phrase	27,106
S19	AB(healthy N3 diet) OR TI(healthy N3 diet)	Search modes - Boolean/Phrase	2,718
S18	AB(screen N3 time) OR TI(screen N3 time)	Search modes - Boolean/Phrase	1,190
S17	(MH "Exercise+") OR AB(exercise*) OR TI(exercise*)	Search modes - Boolean/Phrase	151,106
S16	(MH "Physical Fitness+") OR AB(physical N3 fitness) OR TI(physical N3 fitness)	Search modes - Boolean/Phrase	16,762
S15	(MH "Physical Activity") OR AB((physical N3 activity) or (active N3 play)) OR TI((physical N3 activity) or (active N3 play))	Search modes - Boolean/Phrase	61,556
S14	(MH "Chronic Disease") OR AB(chronic disease*) OR TI(chronic disease*)	Search modes - Boolean/Phrase	101,105
S13	(MH "Life Style, Sedentary") OR AB(sedentary) OR TI(sedentary)	Search modes - Boolean/Phrase	12,055
S12	(MH "Pediatric Obesity") OR (MH "Attitude to Obesity") OR AB(obesity N3 management) OR TI(obesity N3 management)	Search modes - Boolean/Phrase	13,234
S11	(MH "Health Promotion+") OR AB(health N3 promotion) OR TI(health N3 promotion)	Search modes - Boolean/Phrase	63,018
S10	(MH "Health Behavior+") or AB((health N3 behavio#r) or (child N3 health) or (health or adolescent N3 health)) OR TI((health N3 behavio#r) or (child N3 health) or (health or adolescent N3 health))	Search modes - Boolean/Phrase	794,540
S9	AB(iphone* OR android* OR ipad*) OR TI(iphone* OR android* OR ipad*)	Search modes - Boolean/Phrase	1,786
S8	(MH "Computers, Portable+") OR AB(tablet*) OR TI(tablet*)	Search modes - Boolean/Phrase	13,292
S7	AB(interactivity OR (user N3 experience) OR (human-centered N3 design)) OR	Search modes - Boolean/Phrase	2,343

#	Query	Limiters/Expanders	Results
	TI(interactivity OR (user N3 experience) OR (human-centered N3 design))		
S6	AB(gamif*) OR TI(gamif*)	Search modes - Boolean/Phrase	231
S5	(MH "Software Design") or AB(software N3 design) OR TI(software N3 design)	Search modes - Boolean/Phrase	2,945
S4	(MH "User-Computer Interface+") OR (MH "Smartphone") OR AB((user-computer N3 interface) or smartphone) OR TI((user-computer N3 interface) or smartphone)	Search modes - Boolean/Phrase	13,529
S3	AB((iterative N3 develop*) OR co-creat* OR cocreat*) OR TI((iterative N3 develop*) OR co-creat* OR cocreat*)	Search modes - Boolean/Phrase	1,018
S2	AB(mhealth OR ehealth) OR TI(mhealth OR ehealth)	Search modes - Boolean/Phrase	2,359
S1	(MH "Mobile Applications") OR AB(mobile N3 app*) OR TI(mobile N3 app*)	Search modes - Boolean/Phrase	5,742

Table A5. Search strategy and results from ERIC

#	Query	Limiters/Expanders	Results
S32	S28 AND S29 AND S30	Limiters - Published Date: 20080101-20181231; Education Level: Early Childhood Education, Elementary Education, Grade 1, Grade 2, Grade 3, Grade 4, Grade 5, Grade 6, Grade 7, Kindergarten, Primary Education Search modes - Boolean/Phrase	33
S31	S28 AND S29 AND S30	Search modes - Boolean/Phrase	141
S30	S23 OR S24 OR S25 OR S26 OR S27	Search modes - Boolean/Phrase	215,148
S29	S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22	Search modes - Boolean/Phrase	111,148
S28	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9	Search modes - Boolean/Phrase	6,310
S27	(MH "Early Intervention+") OR (MH "Intervention Trials") OR AB((preventive N3 health) OR (health N3 education) or (health N3 intervention)) OR TI((preventive N3 health) or (health N3 education) or (health N3 intervention))	Search modes - Boolean/Phrase	15,817

#	Query	Limiters/Expanders	Results
S26	(MH "Health Education+") OR (MH "Student Health Education") OR AB(health N3 education) OR TI(health N3 education)	Search modes - Boolean/Phrase	14,368
S25	(MH "Focus Groups") OR AB(focus N3 group*) or TI(focus N3 group*)	Search modes - Boolean/Phrase	13,225
S24	(MH "Structured Questionnaires") OR (MH "Open-Ended Questionnaires") OR (MH "Questionnaires+") OR AB(questionnaire*) OR TI(questionnaire*)	Search modes - Boolean/Phrase	71,510
S23	(MH "Surveys+") OR (MH "Survey Research") OR AB(survey*) OR TI(survey*)	Search modes - Boolean/Phrase	142,655
S22	(MH "Carbonated Beverages") OR AB((sugary N3 drink*) or (sugary N3 beverage*)) OR TI((sugary N3 drink*) or (sugary N3 beverage*))	Search modes - Boolean/Phrase	16
S21	(MH "Fruit+") OR AB(fruit*) OR TI(fruit*)	Search modes - Boolean/Phrase	3,416
S20	(MH "Vegetables+") OR AB(vegetable*) OR TI(vegetable*)	Search modes - Boolean/Phrase	1,121
S19	AB(healthy N3 diet) OR TI(healthy N3 diet)	Search modes - Boolean/Phrase	124
S18	AB(screen N3 time) OR TI(screen N3 time)	Search modes - Boolean/Phrase	169
S17	(MH "Exercise+") OR AB(exercise*) OR TI(exercise*)	Search modes - Boolean/Phrase	28,359
S16	(MH "Physical Fitness+") OR AB(physical N3 fitness) OR TI(physical N3 fitness)	Search modes - Boolean/Phrase	1,681
S15	(MH "Physical Activity") OR AB((physical N3 activity) or (active N3 play)) OR TI((physical N3 activity) or (active N3 play))	Search modes - Boolean/Phrase	6,683
S14	(MH "Chronic Disease") OR AB(chronic disease*) OR TI(chronic disease*)	Search modes - Boolean/Phrase	552
S13	(MH "Life Style, Sedentary") OR AB(sedentary) OR TI(sedentary)	Search modes - Boolean/Phrase	534
S12	(MH "Pediatric Obesity") OR (MH "Attitude to Obesity") OR AB(obesity N3 management) OR TI(obesity N3 management)	Search modes - Boolean/Phrase	20
S11	(MH "Health Promotion+") OR AB(health N3 promotion) OR TI(health N3 promotion)	Search modes - Boolean/Phrase	2,209
S10	(MH "Health Behavior+") or AB((health N3 behavio#r) or (child N3 health) or (health or	Search modes - Boolean/Phrase	76,800

#	Query	Limiters/Expanders	Results
	adolescent N3 health)) OR TI((health N3 behavio#r) or (child N3 health) or (health or adolescent N3 health))		
S9	AB(iphone* OR android* OR ipad*) OR TI(iphone* OR android* OR ipad*)	Search modes - Boolean/Phrase	905
S8	(MH "Computers, Portable+") OR AB(tablet*) OR TI(tablet*)	Search modes - Boolean/Phrase	1,207
S7	AB(interactivity OR (user N3 experience) OR (human-centered N3 design)) OR TI(interactivity OR (user N3 experience) OR (human-centered N3 design))	Search modes - Boolean/Phrase	1,873
S6	AB(gamif*) OR TI(gamif*)	Search modes - Boolean/Phrase	184
S5	(MH "Software Design") or AB(software N3 design) OR TI(software N3 design)	Search modes - Boolean/Phrase	766
S4	(MH "User-Computer Interface+") OR (MH "Smartphone") OR AB((user-computer N3 interface) or smartphone) OR TI((user-computer N3 interface) or smartphone)	Search modes - Boolean/Phrase	610
S3	AB((iterative N3 develop*) OR co-creat* OR cocreat*) OR TI((iterative N3 develop*) OR co-creat* OR cocreat*)	Search modes - Boolean/Phrase	652
S2	AB(mhealth OR ehealth) OR TI(mhealth OR ehealth)	Search modes - Boolean/Phrase	43
S1	(MH "Mobile Applications") OR AB(mobile N3 app*) OR TI(mobile N3 app*)	Search modes - Boolean/Phrase	785

Table A6. Data extraction template

Study Details

- Title
- Author(s)
- Year

Study Characteristics

- Study design type
- Study duration
- Mobile app features
- Intervention design
- Multicomponent/standalone intervention
- Behaviour change theory

Study Sample

- Inclusion/exclusion criteria
- Sample size
- Sociodemographic characteristics
    - Age
    - Sex
    - Ethnicity/race
    - Socioeconomic status
    - Risk of obesity

Results

- Outcome measures
- App evaluation (if applicable)

Appendix B: Healthy Habits Questionnaire

Healthy Habits Questionnaire

To be filled out by yourself, if you are 10 or older.

Live 5 2 1 0

Study ID: _____ **Today's Date:** _____

We want to provide the best care to our patients, and this includes discussing healthy living habits as a way to prevent future health problems. While you are waiting for your appointment, please take the time to answer the following questions.

1. How many servings per day of vegetables and fruits do you eat? (1 serving = 1/2 cup)	0 servings	1 serving	2 servings	3 servings	4 servings	5 servings	6+ servings	
2. How many sweet drinks (e.g. pop, juice, energy drinks, or iced tea) do you drink every day? (1 drink = 1 cup)	0 drinks	1 drink	2 drinks	3 drinks	4 drinks	5 drinks	6+ drinks	
3. How many times per week do you eat take-out food, fast-food, or restaurant food?	0 times	1 time	2 times	3 times	4 times	5 times	6+ times	
4. How many days per week do you eat at the dinner table together as a family?	0 days	1 day	2 days	3 days	4 days	5 days	6+ days	
5. How many mornings a week do you skip breakfast?	0 times	1 time	2 times	3 times	4 times	5 times	6 times	7 times
6. Do you ever worry that food will run out before your family gets money to buy more?	OFTEN	SOMETIMES	RARELY	NEVER				
7. How many days per week are you physically active for **at least 1 hour**? (e.g. gym class at school, running, biking, swimming, playing)	0 days	1 day	2 days	3 days	4 days	5 days	6 days	7 days
8. How many hours a day do you spend using the computer, watching TV, playing video games or using a smartphone for fun (please **do not** include time spent for schoolwork)?	0 hours	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7+ hours
9. When do you go to sleep and wake up?	**Bedtime:** _____ PM				**Wake up:** _____ AM			
10. Do you have a TV or computer in your bedroom?	YES				NO			

11. We are interested in the health of your close family members, including your parents, siblings, grandparents, aunts and uncles. Have any of them been diagnosed with:

	Yes	No	Don't know	If yes, who?
Diabetes				
High blood pressure				
High cholesterol				
Heart disease or stroke				
Obesity				

12. Please check the box you think best describes how you feel about your lifestyle habits:

I am NOT worried about…	I am A LITTLE worried about…	I am VERY worried about…	
			What I eat and drink
			How much time my child spends being physically active
			How much time my child spends watching electronic screens (e.g. TV, computer/tablet, video games, smartphone)
			My child's sleep

13. Now that you are thinking about it, is there one thing you would like to help to work on today? YES NO MAYBE

If yes, which one would you like to discuss today?

- ☐ Eating habits
- ☐ Physical activity
- ☐ Screen time
- ☐ Sleep habits
- ☐ Other: _____

Please give the completed form to your clinician. Thank you.

Adapted from the Hawaii 5210 Lifestyle Survey for Adolescents, the Maine Youth Overweight Collaborative 'Keep ME Healthy' Healthy Habits Survey, and the Let's Go! Childhood Obesity Resource Toolkit for Health Care Professionals (4th Ed.) 5210 Healthy Habits Questionnaire.

supporting the Live 5-2-1-0 campaign by SCOPE www.live5210.ca

Figure 2B. Healthy Habits Questionnaire

Appendix C: Focus Group 1 (App Conceptualization) Materials

Table C1. Guiding questions and prompts used during focus group 1 (app conceptualization)

Guiding Questions	Prompts
Adult Session	
1. What are the current challenges in ensuring healthy habits (diet, screen-time, physical activity)?	• Which of the habits is the most difficult to introduce and follow? • What motivates your kids to do something different? • Which habits/behaviors would most benefit from increased engagement? • Where are the gaps? • Parents perspective: What are the challenges in keeping your child healthy? What are the gaps? • Healthcare provider perspective: What are the current gaps in adherence/engagement with Live 5-2-1-0 from users and families?
2. What is your child's "typical" day like?	• What are the key touchpoints in your child's day? (school, meals at home, online engagement, etc.) • Which touchpoint requires more engagement?
3. How is your child with developing habits and adhering to specific healthy behaviours?	• Where and how are habits primarily formed? • Who are the key influencers in your child's day and how do these interactions occur? • How would we prioritize the child's needs through the child's journey? • What type of features in an app would meet these needs?
4. What ehealth apps are children currently using?	• What makes these apps appealing to your children? • What features or elements are current apps missing?

Guiding Questions	Prompts
5. Given the features discussed, which features would be the most important? Why?	• How would you want to see or track your child's progress on health milestones? • Do you or your child track your physical activity? • What would be your preferences regarding data, privacy and security?
Children	
1. Which apps do you like using right now, and why?	• What apps/games do you currently use? • What apps that help you be healthy are you using? What do they do? What do you like about them? • Which apps are most exciting to you? • What are the best aspects of your favourite app? What makes them fun?
2. How do you use apps?	• What devices do you use? • What do you use your device for?
3. How is your typical day like?	• How do you get to school? • When do you use your phone/tablet during the day? • How much time do you spend using your phone/tablet per day? • What makes you stop using your phone? • Do you use apps with your family? • When are you the healthiest? • When are you the least healthy? What is stopping you from being healthier?
4. What makes you want to be healthy?	• What do you like to do to be healthy? Why?
5. What do other people do to help you be healthy?	• What do doctors/parents do to help you be healthy? What works? What doesn't work? • Who do you listen to the most and why? (i.e. parents, siblings, friends, teachers, doctors)

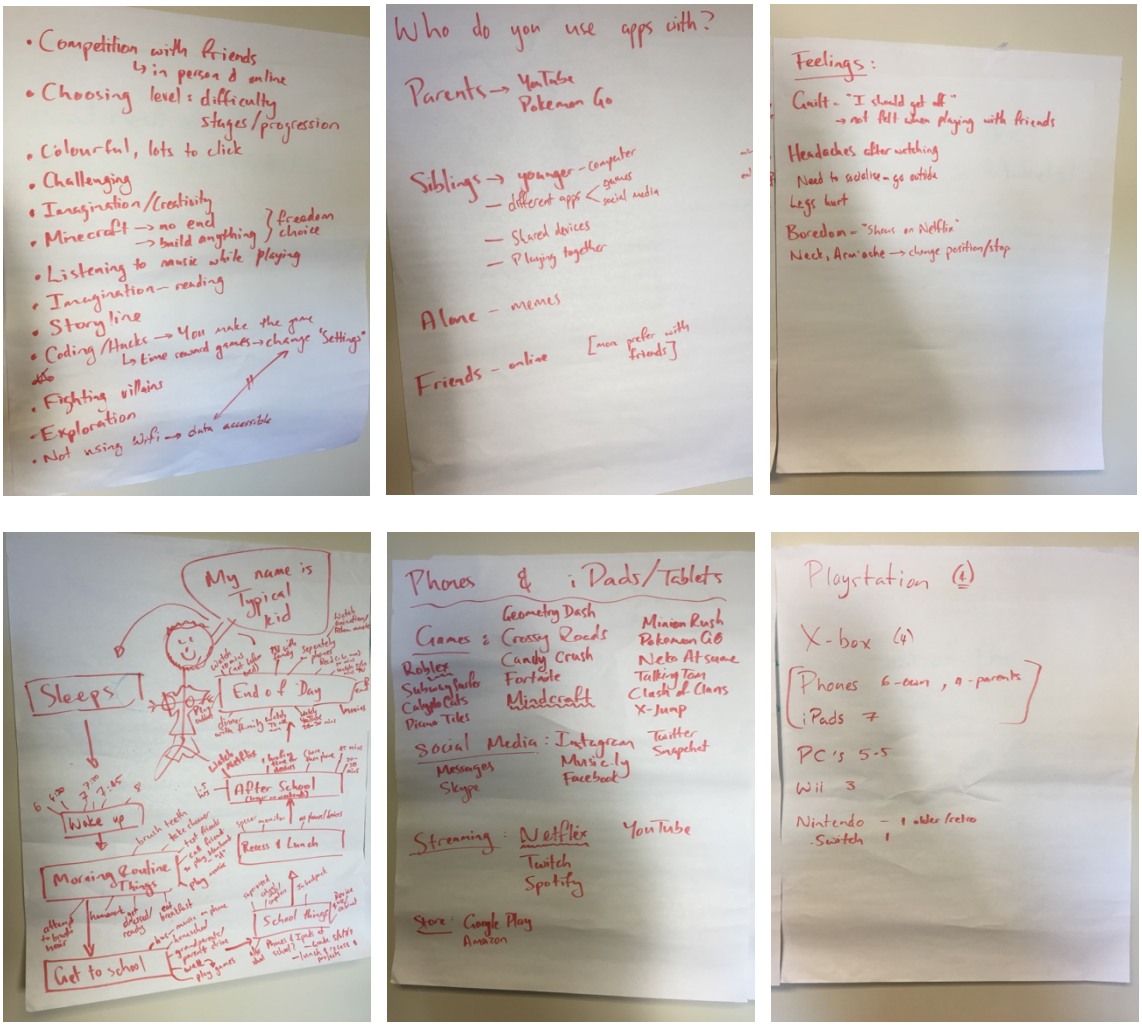

Figure C1. Visual records of discussion in focus group 1B (app conceptualization – children session)

Appendix D: Ideation Session Materials

Table D1. "How Might We" questions used in the ideation session

Topic	How Might We…
Family habit tracking and accountability	Use behaviour change theory? • Change the family environment to ease healthy behaviour? • Use alternative behaviours to reduce screen time and increase activity? • Use different types of prompts to encourage healthy behaviours? Promote & guide goal setting?
Behaviour change techniques and ideation	Incorporate gamification techniques? • Incorporate intrinsic rewards? • Incorporate extrinsic rewards? • Reward kids in a way that maintains healthy Live 5-2-1-0 habits? Implement family habit tracking and accountability?
Family, child and health care provider (HCP) collaboration	Facilitate family, child, HCP collaboration (within closed systems)? • Implement collaboration with family, child and HCPs that doesn't replace in-person interactions, but supplements them? Implement a referral pathway? Link a community to health providers? Integrate community influence and support within the tool?

Appendix E: Focus group 2 (Co-creation) Materials

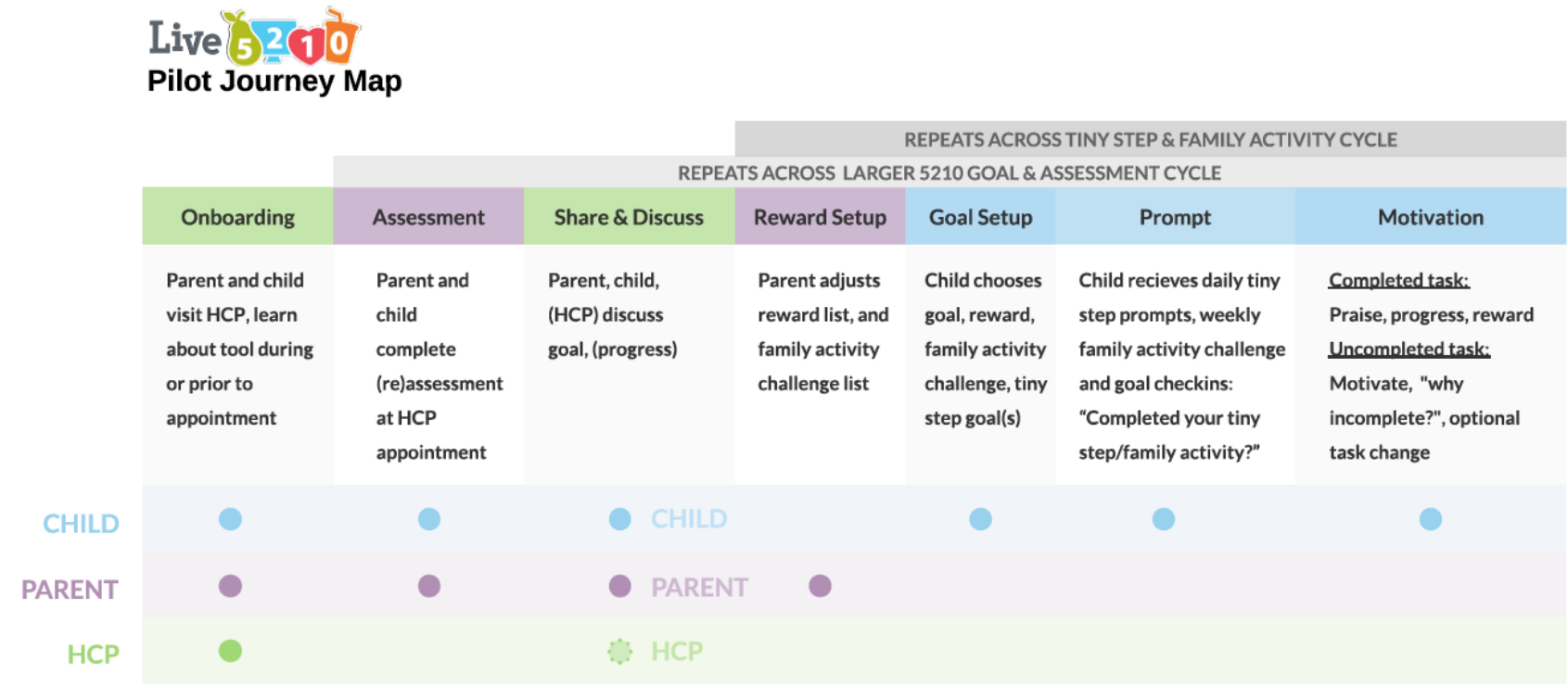

Figure E1. Journey map presented to participants in focus group 2A (co-creation – family session)

Table E1. Guiding questions for focus group 2 (co-creation)

Stage	Guiding Questions
Onboarding	(For HCPs)Do HCPs feel they'd take a moment at the start of an appointment, or that clerks or assistants would actually point out the tool if introduction was walking into an appointment? • What might this process of introducing the parent and child actually look like in the HCPs day to day?
Assessment	Is it realistic to do the intake assessment together while they're waiting? For example, is the wait generally short, or occupied by other tasks? • How long does the parent and child usually wait for the HCP? • How might we facilitate doing the assessment during the wait for the appointment?
Share & Discuss	How long does the HCP usually have with the parent and child for an appointment? • How long would be "too long" for the HCP to spend in the "Share & Discuss" phase? Do the parents, kids and HCPs all agree on what information they'd like to see going into a discussion about health? What is important for each group to know? What are some ways discussing the assessment won't be overlooked during the appointment? • Will there be enough time to go over the assessment and those results together?
Reward Setup	Do parents think it is alright to have the reward section be open for kids to select the rewards, even if that might mean the child making assumptions about what kind of rewards are feasible? Some families try not to give physical items as rewards — what are some other ways we can reward kids?
Goal Setup	What takes priority when selecting a Live 5-2-1-0 goal? • Having the child select a goal that aligns with the doctors suggestions or the tools starting question results? • Allowing the child have agency in picking their own goal?

Stage	Guiding Questions
Prompt	(For children): Now that you've picked a "tiny step" that you want to do regularly, would you want to be reminded to do it? What would be the best way to remind you?
	Are there any daily chores or activities that kids have to do, and using that as a starter comparison, do you see daily prompts being too much or do little?
	How often is often enough for check-ins to see if a daily step has been completed?
Motivation	What are your initial thoughts on the elements of completed tasks, such as praise, progress increases, rewards becomes closer or is given, and possible discovery tip?
	What are your initial thoughts on the elements of uncompleted tasks? (i.e. understanding why it wasn't completed to adjust that behaviour; picking a new task to try to complete)

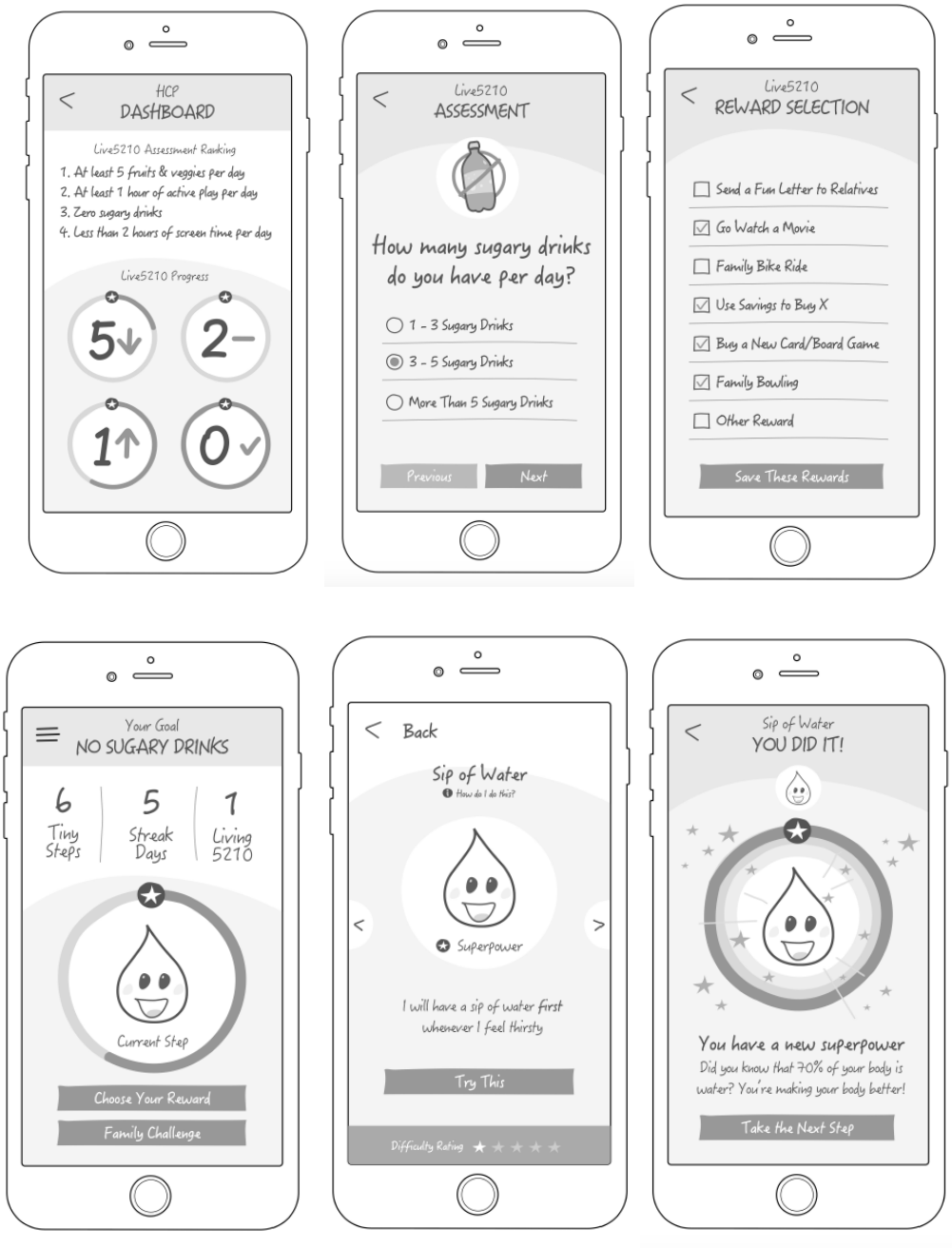

Figure E2. Wireframes of click through prototype presented to participants in focus group 2A (co-creation – family session)

Figure E3. Scoring sheets from focus group 2A (co-creation) with families

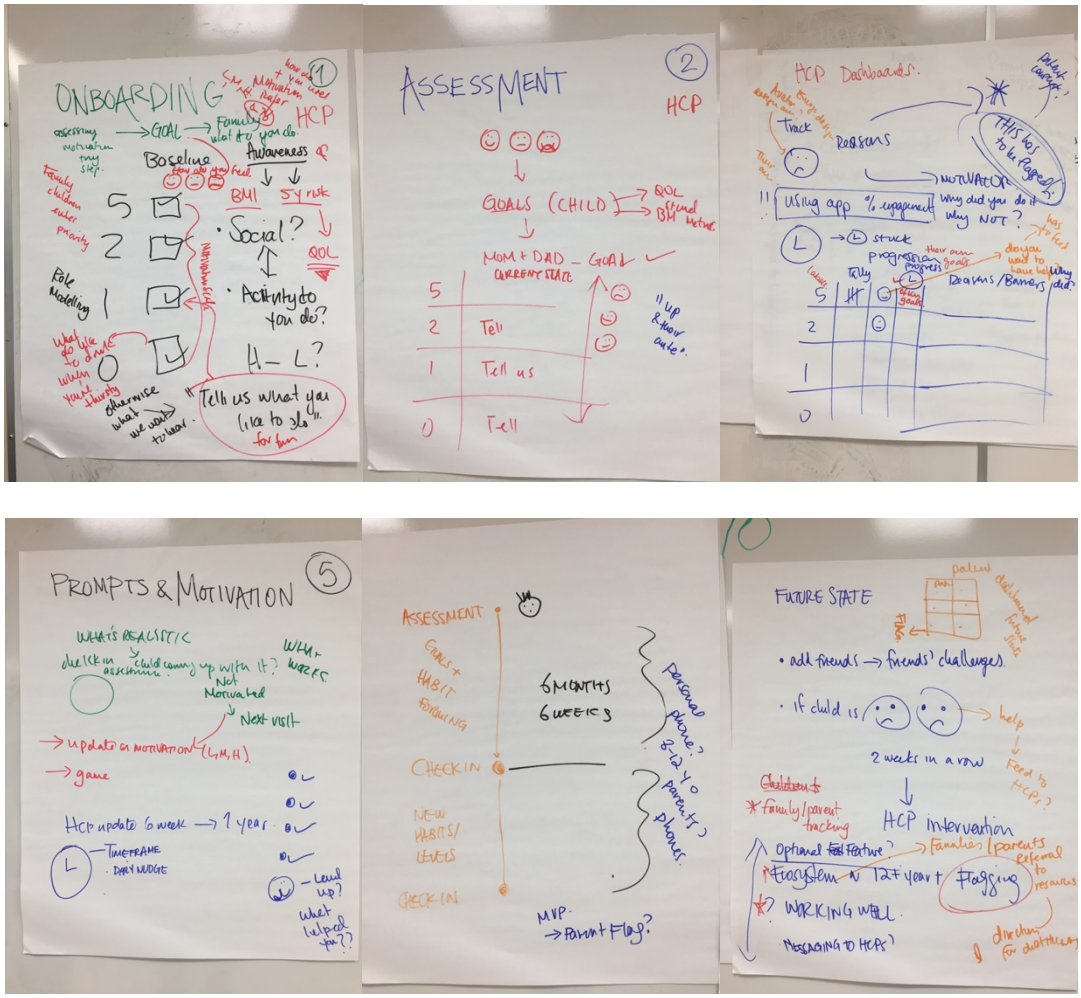

Figure E4. Visual records of brainstorming session and discussion from focus group 2B (co-creation) with healthcare provider

Appendix F: Focus Group 3 (User Testing) Materials

LIVE 5210 APP

My age/my child's age (in years) is: 7 8 9 10 11 12 13

Task 1: Complete baseline assessment

1. **How easy or hard was it to complete the task?**
   Mark only one oval.

	1	2	3	4	5	6	7	
Very Difficult	◯	◯	◯	◯	◯	◯	◯	Very Easy

Task 2: Select a behaviour to work on, a reward, and tiny step

2. **How easy or hard was it to complete the task?**
   Mark only one oval.

	1	2	3	4	5	6	7	
Very Difficult	◯	◯	◯	◯	◯	◯	◯	Very Easy

Task 3: Respond to a daily notification for your current tiny step

3. **How easy or hard was it to complete the task?**
   Mark only one oval.

	1	2	3	4	5	6	7	
Very Difficult	◯	◯	◯	◯	◯	◯	◯	Very Easy

Task 4: Complete a tiny step and receive reward for completing your goal

4. **How easy or hard was it to complete the task?**
   Mark only one oval.

	1	2	3	4	5	6	7	
Very Difficult	◯	◯	◯	◯	◯	◯	◯	Very Easy

Task 5: Review goal progress and change your behaviour goal

5. **How easy or hard was it to complete the task?**
   Mark only one oval.

	1	2	3	4	5	6	7	
Very Difficult	◯	◯	◯	◯	◯	◯	◯	Very Easy

Figure F1. Single ease question form for prototype testing activity