Digital cardiovascular health education among school-going adolescents in Nepal: the HRIDAYA project

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To my beloved family; this would not
have been possible without your support

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ABSTRACT

Background
The burden of cardiovascular diseases (CVD) and its risk factors are increasing among adolescents. The life course approach to CVD prevention necessitates targeted intervention among adolescents.

Aims
This thesis, which reports the results of the HRIDAYA project, aimed to identify gaps in knowledge, attitude and practice (KAP) regarding cardiovascular health among adolescents as well as their perceptions of CVD. It also aimed to assess the prerequisites for and explore their perceptions of digital health education. Finally, the thesis aimed to develop and pilot test a serious game that focused on cardiovascular health and assess its effectiveness and feasibility.

Methods
A mixed methods approach was used. A total of 649 adolescents participated in a survey and twelve focus group discussions (FGDs) conducted in the schools of the Jhaukhel-Duwakot Health Demographic Surveillance Site. The survey results were analysed using descriptive statistics and quantile regression, and FGDs were analysed using thematic analysis. These findings informed the development and pilot testing of a serious game for adolescents. The test assessed the game's effectiveness and feasibility parameters – including recruitment, participation and completion rates – and measured game experience, satisfaction, usability and acceptability.

Results
The survey identified gaps in KAP, with private school adolescents demonstrating better KAP than public school adolescents. The FGDs revealed that adolescents viewed CVD as serious and recognised the importance of a healthy diet and physical activity for prevention. They perceived digital health education positively but faced constraints such as parental permission and technical issues. A culturally relevant serious game called *Happy Heart* was developed and implemented, leading to improved knowledge in the intervention group compared to the control group. Recruitment, participation and completion rates were 74%, 56% and 25%, respectively. Median scores for positive game experience, satisfaction, acceptability and usability were 69%, 70%, 80% and 74%, respectively.

Conclusion
Adolescents had limited CVD knowledge but positive attitudes towards digital education. Although *Happy Heart* improved knowledge and was well accepted, engagement was moderate. Targeted digital education can enhance KAP on CVD among adolescents.

Keywords: adolescent, attitude, cardiovascular disease, diet, knowledge, physical activity, practice, primordial prevention

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SAMMANFATTNING PÅ SVENSKA

Hjärt-kärlsjukdomar är en av de största hälsoutmaningarna i världen. För att minska framtida risk behöver vi börja hälsoinsatser tidigt. Dagens ungdomar har ofta stor digital vana, vilket gör digital hälsoutbildning till en lovande metod för att öka medvetenheten om hjärt-kärlhälsa. Men hur mycket vet ungdomar om dessa sjukdomar, och hur kan vi bäst nå ut till dem? Det är frågor som denna doktorsavhandling, HRIDAYA-projektet, försökte besvara.

HRIDAYA fokuserade på att undersöka ungdomars kunskap, attityd och beteende kring hjärt-kärlhälsa. Därefter att förstå hur ungdomar uppfattar digital hälsoutbildning och vilka förutsättningar som krävs för att det ska fungera. Målet var att utveckla och testa ett digitalt spel – ett så kallat "serious game" – som skulle lära ungdomar om hjärt-kärlhälsa på ett roligt och engagerande sätt.

Både kvantitativa och kvalitativa metoder användes. Totalt deltog 649 ungdomar i en enkätundersökning, och 12 fokusgruppsdiskussioner hölls på skolor i Nepal. Statistisk analys av enkäten kompletterades med djupare insikter genom tematisk analys av fokusgrupperna. Resultaten användes sedan för att skapa ett spel, kallat *Happy Heart*, som testades på ungdomar för att mäta dess effektivitet och användarvänlighet. Resultaten visar:

- Det fanns tydliga kunskapsluckor om hjärt-kärlhälsa bland ungdomarna, särskilt bland de som gick i offentliga skolor jämfört med privata skolor.
- Ungdomarna såg hjärt-kärlsjukdomar som allvarliga och förstod vikten av en hälsosam livsstil, inklusive bra kost och fysisk aktivitet.
- Digital hälsoutbildning uppfattades positivt, men det fanns hinder, som behovet av föräldrars tillstånd och tekniska utmaningar.
- *Happy Heart* förbättrade kunskapen om hjärt-kärlhälsa hos de ungdomar som deltog. Dessutom fick spelet höga betyg för användarvänlighet, acceptans och nöjdhet.

Avhandlingen visar att en skräddarsydd digital hälsoutbildning, som ett spel, kan vara ett effektivt sätt att öka ungdomars kunskap om hjärt-kärlhälsa. Genom att använda teknik som ungdomar redan är bekväma med, kan vi göra lärandet både roligt och meningsfullt. Detta kan vara ett viktigt steg för att förebygga hjärt-kärlsjukdomar och främja en hälsosam livsstil från tidig ålder. Med andra ord: att kombinera hälsa och teknik kan vara nyckeln till en friskare framtid för nästa generation!

LIST OF PAPERS

This thesis is based on the following papers, referred to in the text by their Roman numerals.

I. Shakya D, Ng N, Oli N, Vaidya A, Krettek A.
Cardiovascular health knowledge, attitude and practice among school-going adolescents and the availability of digital prerequisites for health education in Bhaktapur, Nepal.
PLoS One. 2025;20(6):e0323698

II. Shakya D*, Flodin K*, Thapa DR, Subedi M, Ng N, Vaidya A, Oli N, Krettek A.
Perceptions regarding cardiovascular health and preparedness for digital health education among adolescents in an urban community of Nepal: A qualitative study.
(*Shared first authorship)
Digital Health. 2025;11:1-14

III. Bankler JV, Shakya D, Bai H, Wilhelmsson U, Ng N, Oli N, Vaidya A, Krettek A.
Developing a digital cardiovascular health education for adolescents in Nepal.
Submitted.

IV. Shakya D, Bankler JV, Bai H, Wilhelmsson U, Ng N, Oli N, Vaidya A, Krettek A.
Serious game for cardiovascular health education: The Heart-related Research Intervention with Digitalisation Among Young Adolescents (HRIDAYA) trial in Nepal.
Submitted.

PRELUDE

I have always been interested in the heart, ever since I stepped into the field of health in 2004 through Bachelors of Science in Nursing. I completed my Masters in Nursing in 2014 and my interest expanded to include non-communicable diseases (NCDs). Meanwhile, I joined Kathmandu Medical College as a Lecturer to teach nursing students. I taught nursing students the care of patients with chronic NCDs in the ICU. On the other hand, my parents' encounter with hypertension, diabetes and cardiovascular disease further strengthened my interest in this area, but I was focusing on clinical aspects of the disease. I thought curing a disease was the most important aspect of health.

However, my visits to the community with the nursing students opened me to the perspectives of the general population on healthy lifestyle and made me realize that the morbidity and mortalities in the ICUs have their roots in the lack of awareness in the community. I learnt the importance of spreading awareness regarding healthy lifestyle at an early age to build healthy habits, right from childhood. Furthermore, research on patients with stroke, renal failure and self-efficacy of patients with chronic diseases made me realize that the burden of NCDs was increasing and that preventing them was wiser than treating them.

My quest for prevention of NCDs led me to notice the studies by Professor Abhinav Vaidya and Associate Professor Natalia Oli, from the establishment of the Jhaukhel-Duwakot health demographic surveillance site (JD-HDSS) to the HARDIC trial. I jumped in when I came to know that there was a call for PhD proposals on cardiovascular diseases under their team. With the joy of being selected for the PhD, came the COVID-19 pandemic and the never-ending lockdown. My initial communication with my supervisors were all through zoom meetings and emails. Finally, I got enrolled in University of Gothenburg as a part-time PhD candidate in January, 2021.

Since I wanted to go to the roots of NCDs, in my thesis, I planned to work on improving healthy lifestyle from a young age. For this, I had to first spread awareness about what is a heart-healthy lifestyle including diet, physical activity and tobacco and alcohol abuse. This gave birth to my thesis, the HRIDAYA project, a continuation of the HARDIC trial. Ironically HARDIC in Nepali means 'heart-felt' and HRIDAYA in Nepali means 'the heart'. I am proud to have been able to forward this legacy of research on cardiovascular diseases. I decided to choose adolescents for HRIDAYA because they are in

their habit-forming years, can comprehend what I am trying to communicate to them as well as provide meaningful information during data collection.

Meanwhile, the pandemic compelled all schools and universities to start online classes. This increased the use of smartphones and internet among adults and children alike. Children from a very young age started having access to smartphones and I figured this digital penetration could be leveraged to create awareness about cardiovascular health among adolescents, a population that is already known to be technically inclined.

The enthusiasm of the adolescents towards an educational game, evident during the initial survey and focus group discussions, motivated and encouraged me. With a strong interdisciplinary collaboration, we developed *Happy Heart* and now it was time to finally implement the game. I experienced a major setback when some of the schools denied the intervention. The online classes and the excessive use of smartphones had created a state of disconnection among the children with loss of social skills, lack of communication and subdued demeanour. The schools, on the request of the parents, had prohibited students from using smartphones even at home. Hence, I had to choose only those schools who allowed the intervention.

During the development of *Happy Heart,* we kept the game simple and understandable to all adolescents. *Happy Heart* was received well by the adolescents and I was happy to hear some of them say that they were able to score five stars in all the minigames after repeated attempts. Although they found the game less engaging as compared to the fast-paced commercial mobile games, all of them agreed to the educational potential of the game.

My five-year PhD journey is not only about spreading awareness about cardiovascular diseases among adolescents, it is a story of resilience, standing up after falling down, facing challenges and most of all – enjoying the journey. The COVID pandemic, my spinal surgery, my second pregnancy, my parents' illness and losing my father in 2023 were all setbacks I faced but I chose to stand up and move, although with baby-steps, to complete this journey. It warms my heart to have been able to come to the end of this journey.

I firmly believe that *Happy Heart* has the potential to effectively reach a large number of adolescents, especially when incorporated into the school curriculum. This can sow the seed of heart-healthy-habits from a young age which aids immensely in the primordial prevention of cardiovascular disease.

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ABBREVIATIONS

AHA	American Heart Association
BMI	Body mass index
CVD	Cardiovascular diseases
FGD	Focus group discussion
HARDIC	Heart-health Associated Research Dissemination and Intervention in the Community
HBM	Health belief model
HRIDAYA	Heart-related Research Intervention with Digitalization Among Young Adolescents
JD-HDSS	Jhaukhel-Duwakot Health Demographic Surveillance Site
KAP	Knowledge, attitude and practice
MCQ	Multiple-choice question
MRQ	Multiple-response question
NCDs	Non-communicable diseases
NHRC	Nepal Health Research Council
PEN	Package for Essential Non-communicable Diseases
SCT	Social cognitive theory
SES	Socioeconomic status
SHNP	School Health and Nutrition Programme
TAM	Technology acceptance model
TPB	Theory of planned behaviour
WHO	World Health Organization

1 INTRODUCTION

1.1 GLOBAL BURDEN OF CARDIOVASCULAR DISEASE

Cardiovascular diseases (CVD) are the most common non-communicable diseases (NCDs) and the leading cause of death globally [1]. In 2022, an estimated 19.8 million people died from CVD, representing approximately 32% of all global deaths [2]. Age-standardised CVD mortality rates by region ranged from 73.6 per 100,000 in the high-income Asia–Pacific region to 432.3 per 100,000 in Eastern Europe in 2022. Age-standardised CVD mortality rates among countries in South Asia ranged from 225.4 to 326.5 per 100,000 in 2022 [2].

Projections suggest a 90% increase in CVD prevalence by 2050, with ischaemic heart disease remaining the leading cause of CVD-related death. The Southeast Asia and East Asia regions are expected to have the highest CVD prevalence and mortality [3]. In addition, globally, the CVD burden among adolescents and young adults increased substantially between 1990 and 2019 [4]. Therefore, effective targeted strategies among this age group are needed to reduce the overall CVD burden.

1.2 CVD RISK FACTORS

Modifiable CVD risk factors are commonly divided into behavioural, metabolic and environmental risk factors. Physical inactivity, high sodium intake, low fruit and vegetable intake, high sugar consumption, alcohol consumption and tobacco smoking constitute the behavioural risk factors. High blood pressure, high fasting plasma glucose, high body mass index (BMI), high cholesterol and diabetes form the metabolic risk factors. Environmental risk factor includes ambient air pollution. These risk factors can be altered via preventive actions or treatment [5]. High blood pressure was the leading modifiable risk factor for global mortality in 2021 [5]. The co-existence of cardiovascular risk factors is associated with a multiplicative risk of CVD incidence and all-cause mortality [6]. Projections suggest that high systolic blood pressure, dietary risks, high cholesterol and high BMI will be the predominant risk factors driving CVD and its mortality between 2025 and 2050.

The American Heart Association (AHA) introduced the concept of Life's Simple 7 in 2010 [7] and Life's Essential 8 in 2022 [8]. These constructs can be used to measure, monitor and modify cardiovascular health across one's lifespan. Ideal cardiovascular health is consistently associated with benefits in the body, from head to toe and from gestation to extreme old age [9], with a lower lifetime risk of coronary heart disease in all populations [10].

However, the concept of cardiovascular health as a culture of healthy living varies widely across the globe and is influenced by cultural norms, government policies and social structures [11]. A healthy diet and adequate physical activity may have different definitions worldwide. Adapting global recommendations to align with regional norms and cultural contexts is essential for maximising the benefits of constructs such as Life's Essential 8.

1.3 IMPORTANCE OF PRIMORDIAL PREVENTION OF CVD

The CVD burden is mainly seen in adulthood and older age groups [12]. However, exposure to CVD risk factors begins early in life, as early as the foetal stage of development [13]. Habits related to healthy living form during childhood and persist into adulthood, contributing to high burden of CVD in adulthood. Childhood risk factors such as total cholesterol, triglycerides, systolic blood pressure, BMI and smoking are associated with CVD, and childhood BMI plays an important role in directly contributing to CVD in adulthood [14].

For this reason, the World Health Organization (WHO) advocates a life course approach to CVD prevention and control, which considers health and well-being at every stage of life [15]. Reducing CVD risk factors by developing strategies with a desirable balance of lifestyle and clinical interventions at each stage of life must be a priority to decrease CVD burden [14]. Primordial prevention aims to stop the development of risk factors by eliminating conditions that foster risky behaviours or exposures in the first place. For example, encouraging a healthy diet in early childhood, promoting physical activity, avoiding alcohol, preventing the initiation of tobacco use and promoting good sleep habits are crucial to preventing CVD. Besides this, there is also a growing body of evidence emphasising the need for primary prevention strategies such as intensified efforts to identify risk factors in children and young adults, as well as knowledge gaps among this cohort, to prevent CVD [16].

1.4 ADOLESCENTS IN NEPAL

Adolescents, the population aged 10–19 years, constitute 20.1% of Nepal's population, with males slightly outnumbering females [17]. Like adults, adolescents in Nepal face a double burden of health problems. Traditional issues such as undernutrition, anaemia, infectious diseases and early marriage are more prevalent in rural areas [18,19]. Emerging problems such as obesity, NCDs, mental health issues and risky behaviours (e.g. alcohol and tobacco use and unsafe sex) are prevalent in urban areas. Although most adolescents in urban areas attend school, those in rural areas often must work or drop out of school for financial reasons. [20]. Most adolescents live with either one or both of their parents [21].

In the focus on life course approach to primordial prevention and control of CVD, adolescents are the main drivers that can change the CVD landscape in Nepal through healthy eating, adequate physical activity, tobacco- and alcohol-free living and control of metabolic risk factors of CVD. Adolescents with optimal cardiovascular health become healthy adults, which helps decrease the CVD burden in Nepal.

1.5 CVD BURDEN AND RISK FACTORS IN NEPAL

Like in other low- and middle-income countries (LMICs), in Nepal, the prevalence of CVD, as well as its risk factors, is increasing. The proportion of annual deaths from CVD increased from 12.2% in 1990 to 22.0% in 2021 [22]. The latest STEPwise approach to Surveillance (STEPS) survey in Nepal, conducted in 2019, among adults aged 15–69 years showed that 97% of adults consumed <5 servings of fruits and vegetables daily, 29% were current tobacco users, 24% were current drinkers, 24% were overweight or obese, 25% had high blood pressure, 5.8% had high fasting blood sugar and 11% had raised total cholesterol levels [23].

Cardiovascular risk factors are prevalent not only among adults [23,24] but also among adolescents [25]. Consumption of high-calorie drinks (99%), sedentary behaviour (60%), physical inactivity, insufficient fruit and vegetable intake (57%) and consumption of processed food high in salt (33%) are the most prevalent risk factors among adolescents [25].

1.6 CVD PREVENTION EFFORTS IN NEPAL

The drivers of NCD prevention in Nepal are a combination of government initiatives, non-governmental organisation efforts and community-based programmes. CVD prevention efforts in Nepal are carried out in conjunction with the prevention of all NCDs. The Government of Nepal developed a Multi-Sectoral Action Plan (2021–2025) to reduce preventable morbidity, avoidable disability and premature mortality due to NCDs [26]. Nepal has also implemented the Package of Essential Non-communicable Disease Interventions (PEN) to integrate NCD services into primary health care [27]. Most of the plans and strategies for NCDs in Nepal are related to secondary prevention with a focus on the curative aspects of the disease, are concentrated in urban areas and target adults [28].

The Ministry of Health and Population, in collaboration with the WHO, implemented a programme aimed at strengthening NCD service delivery through the capacity building of health workers [29]. Besides training, NCD prevention efforts are limited to free health camps, public awareness drives and community campaigns – all of which focus on adults and secondary prevention, with attempts for early diagnosis and treatment.

Awareness efforts targeting adolescents are less common and limited to health education at school. School-based programmes in Nepal focus on health promotion through initiatives such as the School Health and Nutrition Programme (SHNP), which is based on the WHO's concept of 'Health Promoting Schools' [30]. The SHNP, jointly run by the Ministry of Health and Population and the Ministry of Education under the National School Health and Nutrition Strategy 2006, aims to create a healthy school environment by improving nutrition, safe drinking water and hygiene behaviours and by encouraging healthy habits among students [30].

1.7 KNOWLEDGE, ATTITUDE AND PRACTICE REGARDING CVD IN NEPAL

Given the high prevalence of cardiovascular risk factors among adolescents in Nepal, this population's knowledge, attitude and practice (KAP) regarding CVD require improvement. Only 37% of adolescents in Kathmandu (the capital city) [31] and 49% in Hetauda [32] (an urban city) have good knowledge of CVD. In addition, 37%–51% of adolescents exhibit a positive attitude [31,32]. Practices related to diet and physical activity are poor; a recent

study showed that 57% of adolescents consume <5 servings of fruit and vegetables per day, 99% consume high-calorie drinks, 60% have sedentary lifestyles and 35% are physically inactive [25].

Improving KAP regarding CVD among adolescents requires targeted interventions. To develop such an intervention, KAP gaps specifically need to be identified in populations that the intervention targets. To reach a large population of adolescents, interventions need to be easily accessible and user-friendly. The AHA encourages the use of contemporary health education methods to reach this population [33]. Digital interventions are one way to attract this technologically inclined group [34–36].

1.8 INCREASING DIGITAL PENETRATION IN NEPAL OPENS OPPORTUNITIES

Nepal is moving towards digitalisation, with a mobile penetration rate of 101% and a broadband penetration rate of 140% [37]. Eighty-nine percent of the internet access in Nepal is via mobile technology [37]. The Digital Nepal Framework developed and updated by the Ministry of Communication and Information Technology aims to strengthen digital infrastructure, expand digital access and boost the digital economy [38].

Moreover, during the COVID-19 pandemic, staying at home under lockdown dramatically increased the use of digital devices for learning and entertainment among children and adolescents [36]. This increasing trend towards digitalisation can be leveraged to educate the younger population about cardiovascular health in a cost-effective way. Multiple studies suggests that the use of digital technology for health promotion and education among young people is effective and useful [39–44]. Mobile technology can be used in person and at school to create awareness among this digitally inclined population and effectively capture their interests.

1.9 SERIOUS GAMES AS A MEDIUM FOR HEALTH EDUCATION

One form of digital technology that can be used among adolescents is serious games, a resource that has not yet been fully leveraged in Nepal. Serious games are game-related technologies intended to provide education alongside entertainment [45]. They have been used in research training, assessment, skill

development and information dissemination [46–48]. They are built on the concept that when learning is based on fun elements, it creates a lasting impact on memory and retention.

Serious games have been used in various sectors worldwide [49]. Although several mobile-based interventions have been carried out in Nepal [50–52], the use of serious games has been limited. The only well-documented use is in the Maternal and Newborn Technology for Resilience in Rural Areas (MANTRA) project [53], in which it was used to communicate knowledge about maternal and neonatal health as well as geohazards. The project demonstrated significant knowledge gain in several of its learning objectives.

2 AIMS

The overall aim of this thesis was to develop a digital cardiovascular health education intervention targeted at and tailored to adolescents to decrease the CVD burden. Therefore, I developed the Heart-related Research Intervention with Digitalization Among Young Adolescents (HRIDAYA) project (Registration No. NCT06668675). The aim of the HRIDAYA project was to develop a serious game that would improve adolescents' CVD knowledge.

2.1 SPECIFIC AIMS

The specific aims were to:

- Assess adolescents' KAP regarding cardiovascular health and their access to prerequisites for digital cardiovascular health education in Nepal (Paper I).
- Explore adolescents' perceptions of CVD and their perceptions of and preparedness for digital cardiovascular health education through mobile games (Paper II).
- Develop a digital cardiovascular health education intervention for adolescents in the form of a serious game (Paper III).
- Assess the feasibility of a serious game for cardiovascular health education among adolescents and to determine whether the game increased their knowledge (primary outcome) or attitude and practice (secondary outcome) on cardiovascular health (Paper IV).

3 THESIS FRAMEWORK

Based on the aims, a thesis framework was developed depicting the flow of the HRIDAYA project as shown in Figure 1.

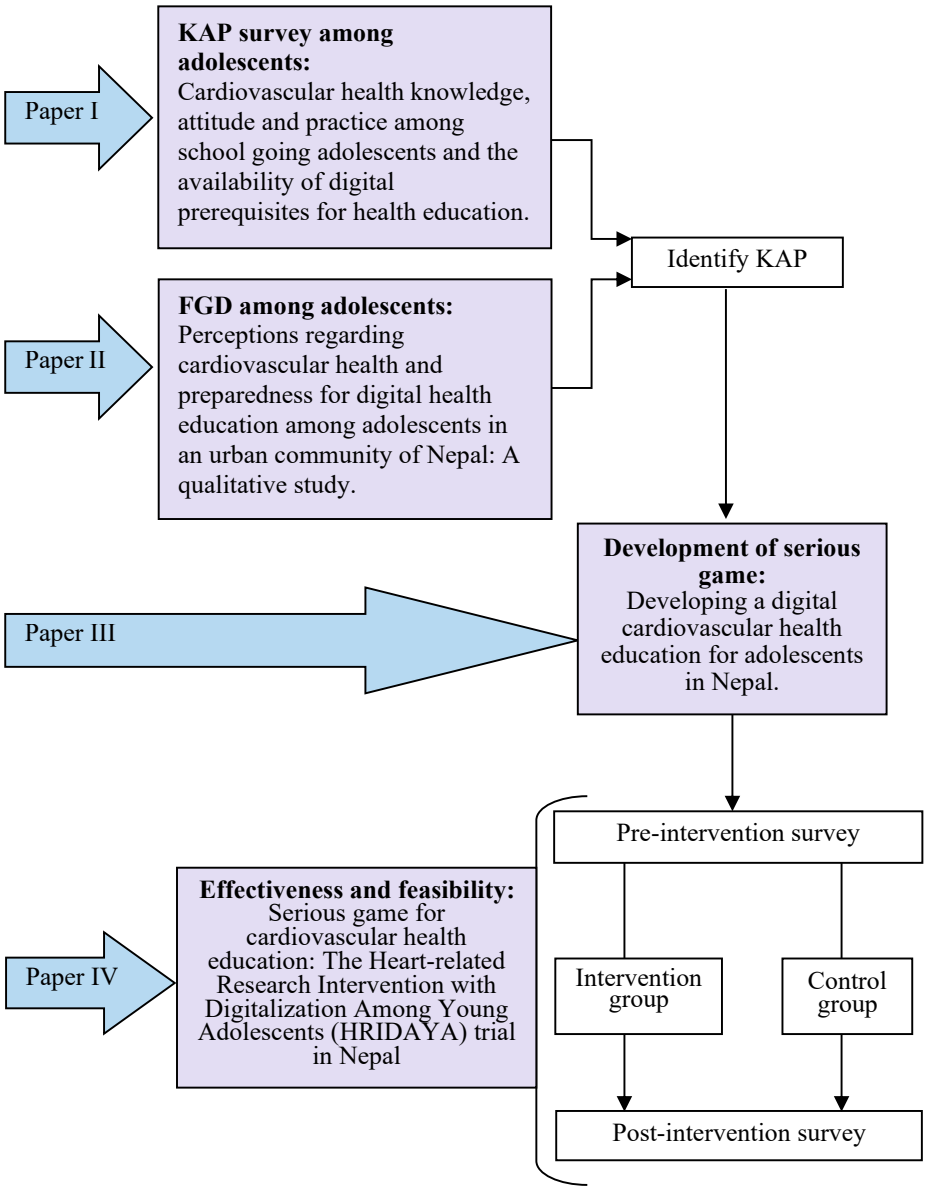

Figure 1: Diagrammatic representation of the thesis
KAP: knowledge, attitude and practice; FGD: focus group discussion

4 THEORETICAL FRAMEWORK

Theories can help one understand the core elements at play in targeted health interventions and changes in KAP. Through this thesis, I intended to improve the adolescents' knowledge about cardiovascular health and, in turn, change their attitudes and behaviours. Although adolescents can make informed choices about their behaviours, some of their practices may not be entirely in their own hands. For example, they may not have control over the meals that are cooked at home or the availability of healthy food in their school area. Moreover, most of their attitudes and perceptions are shaped by the way their families, friends and society think and behave [54,55].

I used the KAP framework, the health belief model (HBM), social cognitive theory (SCT) and the theory of planned behaviour (TPB) to understand adolescents' behaviour and learn how to influence their actions. In addition, I used the technology acceptance model (TAM) to understand adolescents' use of a serious game for cardiovascular health education.

4.1 KAP FRAMEWORK

The KAP framework proposes that knowledge influences attitudes and that attitudes in turn shape practices [56]. Knowledge refers to one's awareness of and possession of information about a subject. Attitudes consist of one's perceptions of and beliefs about an idea or behaviour. Practices comprise one's actual performance of a given behaviour. Taken together, these dimensions of the KAP framework explain how people's awareness and beliefs influence their behaviour. It is widely used in public health, education and social research to understand and change behaviours.

4.2 HEALTH BELIEF MODEL

The HBM was developed in the 1950s by social psychologists Hochbaum, Rosenstock and Kegels to explain and predict health-related behaviours [57]. The central concept in the HBM is that a person's decision to take a particular action is shaped by their perceptions of health threats and the benefits versus the drawbacks of taking action. It describes six core concepts: (i) perceived susceptibility, i.e. one's beliefs about the risk of getting a disease or condition; (ii) perceived severity, i.e. one's beliefs about how serious the consequences of the condition could be; (iii) perceived benefit, i.e. one's beliefs about the effectiveness of the recommended action to reduce risk or severity; (iv) perceived barriers, i.e. one's beliefs about the obstacles or costs that would

make it difficult to perform the action; (v) cues to action, i.e. triggers or impetus that prompt the decision to perform an action or behaviour; and (vi) self-efficacy (added later), i.e. one's confidence in one's ability to successfully perform a behaviour.

4.3 SOCIAL COGNITIVE THEORY

Albert Bandura's SCT is one of the most influential theories of behavioural change [58]. It explains the dynamic and reciprocal interactions among personal, environmental and behavioural factors in a social context to produce a behaviour, which is known as reciprocal determinism. It emphasises the core concept of 'observational learning or modelling'[58], which explains that people can change their behaviour by observing others and imitating them. Moreover, it explains that the repetition of a behaviour depends other people's responses to that behaviour, such as rewards and punishments. Together, the knowledge and skills necessary to perform a behaviour, its anticipated outcomes and one's confidence in one's ability to perform it influence the actual performance of the behaviour [58].

4.4 THEORY OF PLANNED BEHAVIOUR

The TPB was proposed by Ajzen in 1991 [54]. It describes how human action is mainly guided by behavioural intention and how this intention is influenced by three key factors: (i) attitudes towards the behaviours, i.e. a person's negative or positive evaluation of performing a behaviour; (ii) social norms, i.e. a person's perceived social pressure from family, peers and society to perform or not perform the behaviour; and (iii) perceived behavioural control (PBC), i.e. a person's perception of how easy or difficult it is to perform the behaviour.

4.5 TECHNOLOGY ACCEPTANCE MODEL

Fred David proposed the TAM in 1986 to explain and predict how users come to accept and use new technologies [59]. According to the model, the intention to use a technology is determined by (i) perceived usefulness, i.e. the degree to which a person believes that using a particular technology will enhance their performance; (ii) perceived ease of use, i.e. the degree to which a person believes that using the system will be free of effort; (iii) attitudes towards using a technology, i.e. overall affective reaction to using the technology; and (iv) behavioural intention, i.e. the motivational factor reflecting the likelihood that a person will use the technology.

4.6 THEORETICAL INTEGRATION

The basis for this theoretical framework is that knowledge of CVD and its risk factors shape adolescents' attitudes, which in turn shape their behaviours, such as adopting heart-healthy habits. The development of the KAP survey tool was based on this idea. However, perceived susceptibility to CVD, perceived severity of the disease, perceived benefits of heart-healthy habits and the perceived barriers to adopting healthy behaviours – from the HBM – influence adolescents' knowledge-seeking behaviour and their attitudes towards CVD. I used the HBM to guide focus group discussion (FGD) questions in Paper II. Knowledge and positive attitudes towards CVD make adolescents alert for 'cues to the action' of performing heart-healthy habits as described by the HBM. Exposure to cues such as *Happy Heart* can influence attitudes towards CVD and provide prompts for healthy behaviour. However, in the Nepalese context, it was essential for adolescents to accept an educational game like *Happy Heart*, which was studied using the TAM.

Attitudes towards CVD affect adolescents' perceptions of behavioural control over their environments that foster healthy practices, as explained by the TPB. However, this perception of behavioural control is also shaped by the personal (skills needed to adopt heart-healthy habits and self-efficacy), environmental (availability of healthy food and space and time for exercise) and behavioural factors (personal habits and preferences) of SCT. SCT postulates that these three factors determine how adolescents observe others, learn and try to imitate the behaviours of others, which in turn influences their practices. These concepts also emerged during the FGDs, in which the adolescents shared instances when they had to choose unhealthy food due to a lack of healthy eating places, financial constraints or their parents lacking the time to prepare healthy meals, suggesting a lack of behavioural control. Families, peers and society at large affect how adolescents view healthy diet, physical activity, and smoking and drinking behaviours. Adolescents' observations of others, in the context of societal perspectives as well as personal, environmental and behavioural factors – combined with perceived behavioural control – strongly influence intention to perform a behaviour. Once adolescents perform a behaviour, repetition of that behaviour depends on the response they get from their surroundings, such as rewards or punishment. Parents' healthy eating, encouragement from teachers to participate in sport, peers' healthy food choices and participation in physical activity can reinforce adolescents' healthy behaviours. Figure 2 presents the theoretical framework of the thesis.

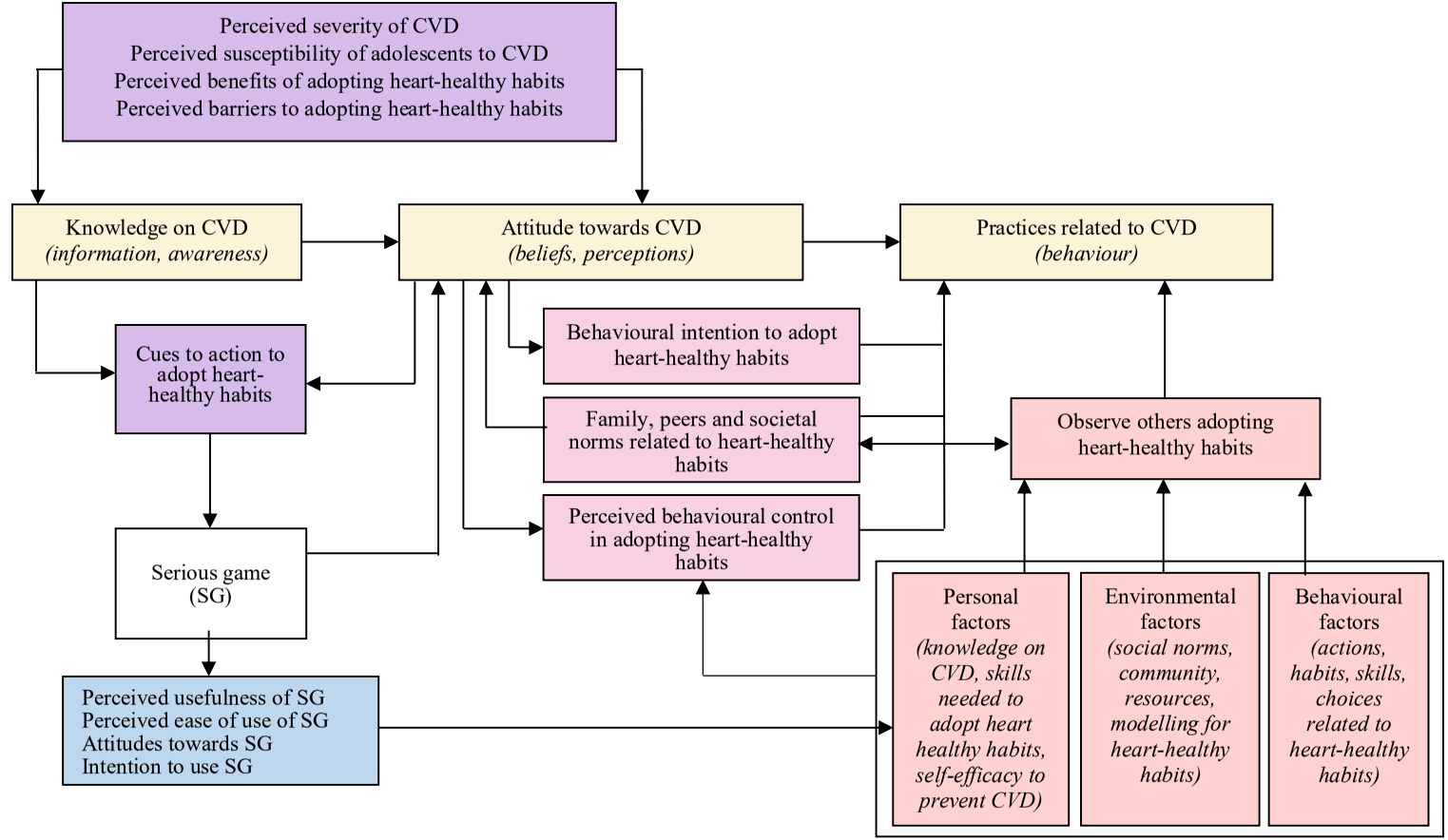

Figure 2: Theoretical framework of the thesis

Health belief model; Knowledge, attitudes and practices framework; Theory of planned behaviour; Social cognitive theory; Technology acceptance model

5 METHODOLOGICAL CONSIDERATIONS

A mixed methods approach was applied in this thesis, which contains four papers: two quantitative studies, one qualitative study and one game development study.

5.1 OVERVIEW OF THESIS PAPERS

An overview of the papers included in this thesis is provided in Table 1.

Table 1: Overview of thesis papers

Paper	Design	Participants	Tool	Data collection period	Analysis
I	Quantitative, cross-sectional	Adolescents Grades 8–10	KAP questionnaire	June – November 2022	Chi-square test, Mann–Whitney U test, quantile regression
II	Qualitative FGD	Adolescents Grades 8–10	FGD guidelines	July – December 2022	Qualitative thematic analysis
III	Intervention development	Adolescents Grades 8–10	Involvement of target users for serious game development	August 2022 – May 2023	Interdisciplinary collaborative efforts in the design
IV	Pilot community trial	Adolescents Grades 8–10	KAP questionnaire; Feasibility parameters such as recruitment, participation and completion rates	June – August 2023	Frequency, percentage, median, interquartile range, median test, quantile regression, rate calculation

KAP: knowledge, attitude and practice; FGD: focus group discussion

5.2 STUDY DESIGN AND INTERVENTION

A mixed methods approach was applied in this thesis. The quantitative surveys in Papers I and IV were based on KAP questionnaires, and the qualitative study presented in Paper II was based on FGDs that followed an FGD guide. Paper III describes the game development process, i.e. how the feedback from target users was utilised and how culturalisation helped shape the game.

I applied a convergent design, which involved simultaneous collection of both quantitative and qualitative data, analysing them separately and then bringing the results together to compare, contrast and combine them. Areas of convergence, divergence and complementarity were identified. This enabled a deeper and fuller understanding of the studied phenomenon.

The HRIDAYA project consisted of four phases: (i) conducting a quantitative study to identify KAP gaps, (ii) conducting a qualitative study to compare and validate the findings of the quantitative study, (iii) developing a health education intervention based on the identified gaps and (iv) pilot testing the intervention for effectiveness and feasibility. In Paper I, I used a quantitative, cross-sectional survey to identify gaps in KAP on CVD and to assess the prerequisites for the digitalisation of health education. In Paper II, I explored the perceptions of CVD among adolescents and their preparedness for digitalised health education, validating the results of Paper I.

Synthesising the results of Papers I and II provided a broader perspective on adolescents' KAP regarding CVD and their perceptions of the disease. It also deepened our understanding of their access to smartphones and the internet as well as their familiarity with mobile games.

Based on these findings, we developed a serious game for cardiovascular health education in collaboration with the Division of Game Development, School of Informatics, University of Skövde. The serious game *Happy Heart* was used as an intervention among adolescents in Nepal. The details of the game development process are described in Paper III.

Next, I conducted a pilot study with *Happy Heart* to evaluate its effectiveness and the feasibility of using it as a health education intervention (Paper IV).

Intervention

Based on the gaps identified in Papers I and II, health researchers and game developers collaborated to develop an intervention for the HRIDAYA project, a serious game called *Happy Heart*. The Heart-health Associated Research Dissemination and Intervention in the Community (HARDIC) manual was used as a foundation for the content on diet and physical activity [60]. The HARDIC manual is the training manual developed during the HARDIC trial covering content for healthy diet and physical activity [60]. *Happy Heart* consisted of seven minigames related to diet and physical activity.

After the adolescents installed the game on mobile phones to which they had access, they played the game at home over the next two weeks. The adolescents then clicked the 'upload' button to link their gameplay data to the server at the School of Informatics, University of Skövde. The data from the server were then retrieved during the analysis to measure the feasibility parameters.

5.3 STUDY SITE

The HRIDAYA project was conducted at the Jhaukhel-Duwakot Health Demographic Surveillance Site (JD-HDSS), a semi-urban community in Nepal, 13 km from Kathmandu, the capital city. The surveillance site was established in 2010 in the then villages of Jhaukhel and Duwakot in Bhaktapur district [61]. However, since the Government of Nepal adopted a federal system in 2015, the villages have become Wards 1–3 of the Changunarayan municipality, Bhaktapur.

The JD-HDSS was chosen as the study site because many studies conducted here have shown a high burden of behavioural risk factors among adults, such as unhealthy diet, physical inactivity and smoking susceptibility as well as poor knowledge about CVD. The HARDIC trial, which was also conducted in the JD-HDSS, used peer evaluation among mothers of children under 5 years of age to improve knowledge on healthy diet [60]. Aiming to continue CVD research in the JD-HDSS, this thesis focused on adolescents in this area, with researchers of the HARDIC trial acting as my supervisors.

Adolescents in the JD-HDSS were approached through their schools. All public and private schools in the JD-HDSS providing education up to Grade 10 were selected for the study. The school type was taken as a proxy for socioeconomic status of the adolescents [62]. According to the District

Education Office of Bhaktapur district, two public schools provide education up to Grade 10 in this area. Communication with the principal of one of the private schools revealed that eight private schools provide education up to Grade 10. Therefore, these ten schools were included in the study.

5.4 STUDY POPULATION

Nepal's education system is structured and regulated by the Government of Nepal through the Ministry of Education, Science and Technology. The education system is divided into early childhood education for children aged 3–5 years, basic education for children in Grades 1–8, secondary education for adolescents in Grades 9–12 and higher education for bachelor's, master's and PhD students [63]. There are 7,468 schools in Nepal that provide education up to Grade 10 [64].

I chose adolescents in Grades 8–10 enrolled in ten public and private schools in the JD-HDSS as the study population for two main reasons: First, adolescence is a stage in life in which children can purposefully choose their diet and physical activity as well as interact effectively to provide meaningful research data. Second, adolescents are generally inclined towards technology and familiar with digital media such as smartphones. Therefore, this population was deemed to be appropriate for my thesis because it aims to use a digital health education to improve cardiovascular health.

5.5 SAMPLING AND SAMPLE SIZE

Paper I

For the first quantitative survey, I included all adolescents in Grades 8–10 in all the schools of JD-HDSS, except one private school where we pre-tested the tools. There were 865 adolescents enrolled in the nine schools, of which 683 consented to participate. Omitting absentees and students who submitted incomplete forms yielded 649 adolescents for the final analysis.

Paper II

For this study, I purposively selected two public and four private schools, ensuring maximum variability in the sample in terms of geographic location, tuition fees, number of students, experience with online classes, and computer and internet facilities at school.

Separate FGDs for boys and girls were conducted at each of the selected schools. Initially, I had planned to conduct FGDs in two public and two private schools. However, given the heterogeneity of the groups, and in order to achieve data saturation, two additional private schools were included. Finally, data were collected from fifty-eight girls and fifty-six boys through twelve FGDs.

Paper IV

For the serious game intervention, I chose six schools: one public school and two private schools each for the intervention and control arms. Those schools that gave permission for digital education were purposively allocated to the intervention arm. There were 731 adolescents in the selected schools, but only 469 received parental consent to participate. Among them, 435 completed the pre-intervention survey (the KAP survey before providing the game), and 333 completed both the pre- and post-intervention surveys (the KAP survey after providing the game).

5.6 TOOLS

Paper I

For the first section of the survey in Paper I, I developed a KAP questionnaire with three parts that pertained to knowledge, attitude and practice regarding cardiovascular health. Each part contained items related to three domains: diet, physical activity, and smoking and alcohol intake. The knowledge and attitude items were based on the questionnaire used in the HARDIC trial [60], whereas the questions on practice were based on the 2015 Global School-based Student Health Survey [65] and the 2019 WHO STEPS survey [66]. The knowledge questions consisted of multiple-choice questions (MCQs) and multiple response questions (MRQs) that assessed what the adolescents thought was correct. The attitude part consisted of items on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The practice questions asked the adolescents about the amount of fruits; vegetables; and salt-, sugar- and fat-rich foods they had consumed in the past week.

The questionnaire was translated into Nepali and pre-tested at a private school inside the JD-HDSS and a public school just outside the JD-HDSS. After pre-testing, we simplified the language to make it more understandable for adolescents. Since this tool was a self-administered questionnaire, we added

pictures inside the questionnaire instead of showing it in separate showcards, which is more feasible for face-to-face interviews. There were thirteen questions on knowledge, twenty-six items on attitudes and twenty-five questions on practices in the final version of the questionnaire.

The second section of the survey asked adolescents if they had access to smartphones and the internet, the types of smartphones they used and if they had ever played mobile games. They were also asked if they were allowed to use smartphones and play mobile games at home.

As for anthropometric measurements, height was measured using a stadiometer (Plastic stadiometer HMS PL), weight was measured using a calibrated Rossmax digital weighing machine and waist and hip circumference were measured using a non-elastic measuring tape according to WHO-recommended techniques [66].

Paper II

Paper II explored adolescents' perceptions of CVD using the HBM and their preparedness for digital cardiovascular health education using the TAM. I prepared a FGD guide with open-ended questions ranging from general questions to exploratory as well as probing questions based on the two models. Examples of the questions based on the HBM included the following:

- 'What do you know about heart disease?'
- 'How likely do you think you are to get heart disease?'
- 'What motivates you to adopt heart-healthy habits?'

The following are some examples of questions based on the TAM:

- 'What are your experiences with using a smartphone in your family?'
- 'Do you think a game would be useful to learn about heart-healthy habits? If so, how?'
- 'How easy do you think it would be to play such a game? Why do you think so?'

I also asked probing questions as needed to ensure that the objectives of the study were fully addressed. I used an audio recorder for voice recording and notepads for taking notes. The FGD guides were translated into Nepali and

pre-tested at a private school among girls and boys in separate FGDs. These FGDs were not included in the analysis.

Paper III

Health researchers and game developers from Sweden and Nepal were the main contributors to the development of the game *Happy Heart*. Multiple online meetings and visits to Nepal by the game developers ensured that they had an understanding of the cultural context, way of living, and visual and colour preferences, which helped make the game relatable and understandable.

The HARDIC manual and the gaps identified in Paper I were important tools that shaped the development of the game. A PhD student in game development and a lecturer in the department of game development were involved in the creating the graphics and designing the game. Game development proceeded in three crucial steps:

a. Defining learning goals: From the HARDIC manual, we selected the content for the knowledge gaps identified in Paper I to formulate the learning objectives of the game.

b. Developing the game concept: Choosing the concept for the game required consideration of the target audience (adolescents), where they would play the game (at home), for how long they would play it (short accessible play sessions) and their game literacy [67]. We avoided visual complexity to prevent learners' distraction from core educational content [68], adopted an abstract graphic style with hard shading according to the adolescents' choices [69] and determined which culturally relevant objects and environmental features should be incorporated into the game [70]. We developed a paper-based prototype of the game in which the interactions with players were manually facilitated and tested it among ten adolescents from the target audience [71]. This was followed by the development of the digital version of the game.

c. Establishing active culturalisation throughout the development process: We applied culturalisation early in the process. The initial drafting and testing of the minigames ensured early cultural alignment. We compiled a comprehensive list of culturally relevant food items and their nutritional content (sugar, salt and fat levels) and categorised them into nutritional groups. Culturally relevant physical activities were selected. Reviewing

the design drafts and the early digital prototypes ensured that the content reflected the targeted adolescents' everyday realities.

Paper IV

Paper IV evaluated the effectiveness of *Happy Heart*; assessed participants' experiences and satisfaction with the game, as well as its acceptability and usability; and analysed the feasibility of using the game. For Part I of this tool, I used a shorter modified version of the KAP survey questionnaire used in Paper I that aligned with the ideas taught by *Happy Heart*. It contained thirteen questions on knowledge, fifteen items on attitudes and sixteen questions on practice regarding diet and physical activity for cardiovascular health. The knowledge section consisted of MCQs and MRQs. The attitude section contained items on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The practice section asked the adolescents about their consumption of fruits; vegetables; and salt-, sugar- and fat-rich foods in the past week.

Part II of the tool, a modified version of Jennet's immersion questionnaire [72], consisted of eleven items related to game experience on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Satisfaction was assessed on a scale ranging from 1 (least satisfied) to 10 (most satisfied). The questionnaire on acceptability was adapted from the Theoretical Framework of Acceptability questionnaire [73] and consisted of seven items on a 5-point Likert scale (similar to the game experience questionnaire). The questionnaire on usability, which had ten items, was adapted from the system usability scale used for evaluating new hardware and software, also on a 5-point Likert scale [74]. All the tools were translated into Nepali and pre-tested as described in Paper I.

5.7 DATA COLLECTION

Paper I

I co-ordinated with the principals of the schools to determine a time for data collection. Data were collected via self-administered questionnaires in classrooms in the absence of any school teacher. Enumerators were present to help answer any queries. The questionnaires were collected after 30 minutes. The adolescents' height, weight, and hip and waist circumference were then measured using the WHO-recommended technique [66]. Waist circumference

was measured at the widest part of the buttocks with feet together, and hip circumference was measured at the middle point between the bottom of the last rib and the top of the hip bone.

Paper II

After co-ordinating with the principals of the schools, teachers from each class selected 3–4 adolescents to participate in FGDs. I conducted twelve FGDs, two in each school – one with boys and one with girls. Around 8–11 adolescents participated in each FGD. I, or a research assistant with a master of science in nursing, conducted the FGDs, and a note taker with a bachelor of science in nursing documented non-verbal cues and group dynamics. A voice recorder was used with permission from the adolescents.

Each FGD lasted 45–60 minutes. At the beginning of each FGD, the purpose of the study was explained, and they were informed that their opinions would remain confidential and would not affect their grades. They were encouraged to speak freely and without hesitation. Informal questions (e.g. asking if they had eaten lunch, how their studies were going and which class they were missing because of the FGD) helped them relax and open up. Neither teachers nor school administrators were allowed to participate in FGDs. All the FGDs were conducted in Nepali on school premises.

Paper IV

For the pilot trial in the HRIDAYA project, data collection proceeded in five steps: First, I explained the purpose of the study to the adolescents in the intervention and control groups, their expected role and how the study will unfold. Second, I conducted the pre-intervention survey among the adolescents in both groups. The survey was conducted in classrooms in the absence of any teachers or administrators. Third, I shared a video with the intervention group explaining what the game looked like, how to install it and how to upload their game data to the server. Fourth, I provided a link to download the game *Happy Heart* through the Viber and Messenger groups created for this purpose. The adolescents were asked to install the game on the mobile devices to which they had access and provide us with the unique player ID given to them by the system upon installation. Multiple efforts were needed to obtain as many player IDs as possible because it was the only connection between the survey data and the game data on the server. The adolescents then played the game at home in their leisure over the next two weeks, after which they were asked to

click the 'upload' button to send their gameplay data to the server at the School of Informatics, University of Skövde. The fifth step involved conducting the post-intervention survey among the intervention and control groups. However, in the intervention group, the survey also collected data on their experiences and satisfaction with the game as well as its acceptability and usability.

Among the 435 adolescents who completed the pre-intervention survey, 268 were in the intervention group (191 were in the control group). Among those 268 adolescents, 180 installed the game and provided their player ID. After two weeks of gameplay at home, 164 adolescents in the intervention group completed the post-intervention survey, and 108 uploaded their gameplay data. Ninety-six adolescents in the intervention group both uploaded their data and completed the post-intervention survey.

5.8 DATA MANAGEMENT AND ANALYSIS

We prepared a data management plan at the beginning of the study to guide data collection, storage and management throughout the project. The plan highlighted that all the data need to be coded and de-identified. All paper-based identifiers and data would be stored in locked cabinets. All digital data were stored on password-protected laptops and saved on a hard drive in a locked cabinet. All data were stored and analysed in Nepal. All analyses were carried out using the de-identified data. The data could be used only by project members directly associated with this research; however, they can be made available to the public upon reasonable request once the publication process has concluded. All the studies in this thesis followed this data management plan.

Paper I

In Paper I, data were collected on adolescents' KAP regarding CVD as well as prerequisites for digital health education. The collected data were checked for completeness and out-of-range scores and entered into SPSS Statistics version 28 (IBM, Armonk, NY, USA).

In the knowledge section, MCQs had four options with one correct answer, whereas MRQs could have multiple correct answers. I scored each correct answer as 1 and each incorrect answer as 0, without any negative scoring. In the attitudes section, a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) was used. Negatively framed questions were reverse

coded. To score practice, I followed the AHA guidelines for daily consumption of fruits; vegetables; and salt-, sugar- and fat-rich foods.

All individual scores were summed to obtain the domain 'raw' scores for diet, physical activity, and smoking and alcohol intake. These domain scores were converted into a scale of 0 to 100. The domain raw scores were again summed to obtain the raw scores for KAP and then converted into percentages to obtain the percent scores for knowledge, attitudes and practices. This ensured the scores' comparability across domains and KAP dimensions.

A Shapiro–Wilk test obtained a result of $p < 0.05$, signifying that the KAP data were not normally distributed. Therefore, descriptive statistics such as frequency, percentage, median and interquartile range were computed. I used the chi-square test to compare practices and the Mann–Whitney U test to compare KAP percent scores across the two school types. Multivariable quantile regression was used to assess the association of KAP percent scores with the independent variables. The questions for assessing digital prerequisites were analysed descriptively in terms of frequency and percentages.

A descriptive item analysis was performed by calculating the frequency and percentage of responses for each KAP questionnaire item. To identify the gaps in KAP, Bloom's cutoff (<60% = poor, 60%–70% = average, >80% = good) was used [75–77]. Regarding knowledge, areas where <60% of the adolescents answered correctly were identified as knowledge gaps. Regarding attitude, the frequency of neutral to positive attitudes, i.e. scores of 3, 4 and 5, were summed to identify the percentage of adolescents with positive attitudes; areas in which <60% of the adolescents had positive attitudes were identified as attitude gaps. Regarding practice, all behaviours were grouped into two categories based on AHA guidelines: eating ≥5 servings of fruits and vegetables per day; drinking soft drinks less than once per day; and eating foods high in salt, sugar and fat less than once per day was classified as positive behaviour.

Paper II

The data for Paper II consisted of audio recordings and field notes. A transcriber with a bachelor's in sociology and a master's in rural development transcribed all the audio recordings verbatim correlating with the field notes and translators with a master's in nursing then translated the documents. I verified the quality of the transcriptions and translations, anonymised them and

stored them along with the audio recordings on a hard drive as described in the data management plan.

Two individual researchers, one with a PhD in Health and Care Sciences and another a Licentiate student in Medical Sciences, performed thematic analysis by manual coding using a deductive approach based on the HBM and the TAM. The deductive approach applied the existing theories such as HBM and TAM to describe the phenomenon at hand. First, the translations were read and then re-read to facilitate immersion into the content and interpretation of the meaning of the data. Codes were then derived from similar data features that formed a coherent unit. Codes giving similar meanings were combined to form sub-themes and these in turn were grouped together to the appropriate themes for each model dimension.

Paper IV

The data collected in Paper IV included the KAP questionnaires from the pre- and post-intervention surveys and the related tools that measured experiences, satisfaction, acceptability and usability. I scored the KAP questionnaires in the same way as in Paper I, which yielded the final percent scores for knowledge, attitude and practice for both the pre- and the post-intervention surveys. I used a group-wise median test to compare the median percent scores of KAP across the adolescents who played all seven games (full exposure), those who played ≤6 games or viewed the journal (partial exposure) and the control group (no exposure). To assess the influence of independent variables on the KAP scores, I used quantile regression.

The Likert scales for positive game experience, acceptability and usability were scored after reverse coding negatively framed questions and then converted into percentages. Satisfaction scores from 1 to 10 were also converted to percentages. Median scores and interquartile ranges are reported for all the questionnaires.

Feasibility parameters are reported as recruitment, participation and completion rates, which are presented as percentages. The recruitment rate refers to the percentage of eligible adolescents who completed the pre-intervention survey, installed the game and provided their player ID. The participation rate refers to the percentage of adolescents who played at least one game. The completion rate refers to the percentage of adolescents who played all seven games.

5.9 ETHICAL CONSIDERATIONS

Ethical approval for the thesis was obtained from the Nepal Health Research Council (NHRC; registration number 660/2021, approval numbers 1828 and 862), Nepal's national body for ethical approval. Additionally, I obtained written permission from the principals of the schools included in the thesis.

For the surveys in Papers I and IV, I sent an information sheet along with a consent form in Nepali home to the parents via the adolescents and asked them to return it once signed. Repeated follow-ups were necessary to ensure that as many adolescents as possible returned the form. Before the survey, written assent was obtained from the adolescents. I explained the objectives of the studies to all participants before data collection and informed the adolescents that they could withdraw from the study at any time they wanted and without explanation. This process safeguarded their autonomy and ensured that both the parents and adolescents provided fully informed consent and assent. Confidentiality was maintained by coding the data and removing any identifying details. All identifiers were kept on a separate hard drive stored in a locked cabinet as explained in the data management plan. Since adolescents are considered a vulnerable group, obtaining parental consent and adolescents' assent and keeping their data confidential was necessary to safeguard their rights related to the principle of non-maleficence.

In Paper II, we obtained permission from the adolescents to audio record the FGDs. I addressed all their health-related queries at the end of the FGDs. After transcribing and translating the data, I removed all identifying details and stored the identifiers in a separate hard drive stored in a locked cabinet as explained in the data management plan. We did not use any identifying data of the respondents in any published articles or reports.

The purpose of the HRIDAYA project was to impart knowledge about cardiovascular health to adolescents through a digital health education intervention in line with the principle of beneficence. At the end of the intervention, pamphlets about cardiovascular health, translated into Nepali, were distributed to the adolescents so that they could share them with family members. This was done to allow not only the adolescents but also their families to gain knowledge in this area. In line with the principle of justice, we also gave adolescents in the control group the opportunity to play *Happy Heart* after the intervention period was over. The pamphlet about cardiovascular health was also distributed to adolescents in the control schools.

All the data were collected, stored and analysed in Nepal, and no personal information or data were stored in Sweden as stated in the data management plan. All papers in the thesis followed the principles stipulated in Declaration of Helsinki developed by the World Medical Association [78] and guidelines for research involving children/adolescents [79]. Additionally, given the Nepalese context of the research, the 2022 National Ethical Guidelines for Health Research, which were created by the NHRC, were followed [80].

6 RESULTS

Since this thesis is a mixed methods study and the four papers produced as part of this thesis align well to fulfil the objectives of the thesis, the results of the thesis are presented as a synthesis of all four papers. This chapter triangulates the findings of Papers I–III and reports the results of Paper IV.

6.1 IDENTIFYING GAPS IN KAP REGARDING CARDIOVASCULAR HEALTH (PAPER I)

The initial survey collected data from 649 adolescents, of which 80% were between 13 and 15 years old; 51% were boys; one-third each were from Grades 8, 9 and 10; and 60% were from private schools. The mean height of the boys and girls were 161 ± 8.2 cm and 152 ± 5.7 cm, respectively; their mean weight was 49 ± 10.7 kg and 46.5 ± 8.1 kg; their mean waist circumference was 67 ± 8.2 cm and 65 ± 6.9 cm; their mean hip circumference was 83 ± 7.9 cm and 86 ± 6.8 cm; their mean waist-to-hip ratio was 0.8 ± 0.1 and 0.76 ± 0.1; and their mean BMI was 18.8 ± 3.2 and 19.9 ± 3.2.

In the results of the descriptive item analysis, Bloom's cutoff was used to classify knowledge as good (>80%), average (60%–80%) or poor (<60%) [75–77]. Areas where <60% of the adolescents answered correctly were identified as knowledge gaps (see Table 2). Adolescents had good knowledge that fruits (90%) and vegetables (88%) are good for the heart and that eating a variety of foods (89%) and hygienic foods (91%) is good for one's health. The adolescents also realised that burgers, sausages and pizza (98%), deep fried vegetables (95%), soft drinks (95%), fatty foods (99%), doughnuts and cookies (99%), red meat (81%), instant noodles (99%) and traditional sweets (92%) are bad for cardiovascular health.

Regarding physical activity, adolescents had good knowledge that exercise improves physical health (87%), helps fight disease (81%) and keeps the heart healthy (82%). Adolescents were aware that smoking causes lung cancer (96%), that chewing tobacco causes oral lesions (89%) and that alcohol is harmful during pregnancy (97%). They also realised that drinking increases the likelihood of accidents (87%), damages the liver (83%) and does not solve problems (94%).

*Table 2: Knowledge gaps identified among adolescents (*n = *649)*

Domain	Knowledge area	*n* (%)
Conditions that can predispose a person to heart disease	High blood sugar	198 (30.5)
	High blood pressure	309 (47.6)
	High blood lipids	198 (30.5)
	Lack of exercise	270 (41.6)
	Obesity	302 (46.5)
	Sedentary lifestyle	185 (28.5)
	Stress	325 (50.1)
	Family history of heart disease	299 (46.1)
Diet	Fish is good for one's health	146 (22.5)
	Healthy plate concept	130 (20)
	Five servings of fruits and vegetables	25 (3.9)
Physical activity (PA)	PA can minimise injuries by strengthening muscles	228 (35.1)
	PA increases the strength of the heart	330 (50.8)
	PA burns fat	313 (48.2)
	Recommended level of activity for adolescents	358 (55.2)
	Sedentary lifestyle	354 (54.5)
Alcohol/ tobacco use	Smoking can cause diabetes	53 (8.2)
	Smoking can cause hypertension	194 (29.9)
	Smoking can cause stroke	140 (21.6)
	Smoking can increase the risk of tuberculosis	270 (41.6)
	Alcohol can cause numbness and tingling in limbs	275 (42.4)
	Smoking can cause heart disease	341 (52.5)
	Alcohol can cause anxiety and difficulty concentrating	365 (56.2)
	Alcohol can cause heart disease	381 (58.7)

In the attitude part of the questionnaire, adolescents expressed positive attitudes towards most of the items. Almost all adolescents perceived that healthy food is important (97%), that young people also need to think about healthy food (94%) and that healthy food is not only for the sick (86%). Adolescents also realise that physical activity is important even for young people (93%) and that exercise should not be considered only after weight gain (90%). Ninety-eight percent of the adolescents disagreed that smoking is cool, increases friendship (97%), helps cope with problems (95%) and makes people confident (89%). Adolescents also disagreed that all people with high blood pressure and sugar levels (80%), obesity (96%) and hereditary predisposition (90%) will definitely have heart disease. Areas where <60% of the adolescents had positive attitudes were identified as attitude gaps (Table 3).

*Table 3: Attitude gaps identified among adolescents (*n = *649)*

Domain	Attitude area	*n* (%)
Diet	High-calorie foods with lots of fats and carbohydrates help fight disease.	383 (59)
Physical activity	Indoor games are a source of physical activity.	246 (37.9)
Alcohol/tobacco use	Some amount of drinking is good for one's health.	172 (26.5)

In the practice part of the questionnaire, all behaviours were grouped into two categories based on AHA guidelines. Eating ≥5 servings of fruits and vegetables per day; drinking soft drinks less than once per day; and eating foods high in salt, sugar and fats less than once per day was classified as positive behaviour. An item-wise descriptive analysis for practice is shown in Table 4.

*Table 4: Practices that prevent cardiovascular diseases among adolescents (*n = *649)*

Domain	Practice area	*n* (%)
Diet	Eating ≥5 servings of fruits and vegetables per day	80 (12.3)
	Drinking soft drinks less than once per day	416 (64.1)
	Eating foods with high salt content such as chips, crackers, *daalmoth* and *paapad* less than once per day	212 (32.7)
	Eating foods with high fat content such as ghee and fried food less than once per day	301 (46.4)
	Eating foods with high sugar content such as chocolate and *mithai* less than once per day	231 (35.6)
Physical activity	Being physically active for ≥60 minutes per day	405 (62.4)
Alcohol/ tobacco use	Never smoked	623 (96)
	Never used smokeless tobacco	639 (98.5)
	Never consumed alcohol-containing drinks	530 (81.7)

Daalmoth: a traditional crispy, spicy, salty dry snack made from deep fried lentils, nuts, spices and oil; *Paapad:* a thin, crispy snack made from dried lentils; *Mithai:* traditional Nepali sweets such as *jeri* and *barfi.*

Percent scores were calculated for KAP ranging from 0-100. The median scores of overall knowledge, attitude and practice along with their inter-quartile range (IQR) are shown in Table 5.

*Table 5: Overall median scores for knowledge, attitude and practice (*n = *649)*

	Median (interquartile range)
Knowledge percent score	69.1 (63.1–74.4)
Attitude percent score	77.9 (73.3–82.3)
Practice percent score	76.7 (72.2–81.1)

6.2 EXPLORING PERCEPTIONS OF CVD AMONG ADOLESCENTS (PAPER II)

In addition to the quantitative survey described in Paper I, I conducted FGDs simultaneously. Thematic analysis of the FGDs based on the HBM yielded the six core themes described below. The six themes and thirteen sub-themes with quotes are shown in Table 6.

Table 6: Themes, sub-themes and quotes based on the HBM

Themes	Sub-themes	Examples of quotes
Perceived susceptibility	Specific groups prone to be affected by CVD	'The weak ones and elderly are at higher risk… because they are already weak.' (Public school, girl)
	Causes and preventive measures related to CVD	'Food from outside or street food like instant noodles, biscuits and *panipuri* may cause heart disease.' (Public school, girl)
Perceived severity	Different CVD burdens	'People will fall. This can be any place and at any time because of low blood pressure.' (Public school, girl)
	Impacts of CVD on everyday life	'He will not be able to earn money and support his family.' (Public school, boy)
Cues to action	Raising awareness and increasing knowledge	'Social media might also help to create awareness.' (Private school, girl)
	Motivation through family, neighbours and home environment	'If everyone at home eats healthy food, then I must also eat healthy food.' (Private school, girl)
Perceived benefits	Health- and habit-related improvements	'Chances of getting diseases are reduced. It saves lives.' (Public school, boy)
	Improved living conditions	'If we are healthy, we can work till old age; we will be free from disease.' (Private school, girl)
Perceived barriers	Temptation of unhealthy food	'Because of its good taste, we prefer junk food over others.' (Public school, girl)
	Limited availability of healthy food environments	'If a canteen was available, we probably wouldn't have to eat that much junk.' (Public school, boy)
	Limited time and motivation	'When the family does not have enough time to prepare snacks, then we have to eat outside.' (Public school, girl)
Self-efficacy	Own responsibility and ability to prevent CVD	'There is a chance because of junk food, lack of exercise and hereditary predisposition.' (Private school, boy)
	Being dependent on others	'While going outdoors, if someone else sitting nearby smokes, it may affect us.' (Public school, boy)

Perceived susceptibility: This theme pertains to who the adolescents thought could be affected by CVD. They thought that the elderly, small children, weak people, drug users, smokers and people who consume alcohol are susceptible to heart disease. They also thought that a lack of exercise, a sedentary lifestyle and consuming unhealthy food can predispose one to CVD.

Perceived severity: This theme pertains to how the adolescents perceived the severity of CVD and how it can influence a person's daily life. They believed that people with CVD are weak, have problems with blood circulation and faint due to low blood pressure. They stated that patients with CVD will not be able to earn their living and support their families and that society may have negative attitudes towards them.

Cues to action: This theme pertains to how the adolescents described spreading awareness as necessary, especially among the elderly, and emphasised using social media for this purpose. Adolescents also said that knowledge about causes of CVD, seeing someone suffering due to the disease and being exposed to healthy eating habits in the family motivates them to adopt heart-healthy habits.

Perceived benefits: This theme pertains to how the adolescents focused on the benefits of adopting heart-heathy habits, such as remaining disease free, being able to live a healthier and more productive life and being able to encourage the upcoming generation to adopt heart-healthy habits. They perceived that the positive changes in daily routines would be good for their health.

Perceived barriers: This theme pertains to the factors that prevent people from adopting heart-heathy habits. The adolescents confessed that the attractive appearance of food in advertisements and the taste of junk food make them irresistible. They also mentioned that the lack of availability of a healthy eating place or a good school canteen forces them to eat unhealthily. They said that their parents lack the time to prepare a healthy tiffin, as they go to work early in the morning. One adolescent emphasised personal motivation to exercise instead of watching TV or scrolling on the phone.

Self-efficacy: This theme pertains to the adolescents' ability and confidence in themselves to prevent CVD. Many adolescents said that it was their own responsibility to adopt heart-healthy habits. Some said that there is a 50-50 chance of developing CVD because many factors are out of their control, such as pollution, passive smoking, hereditary predisposition or a lack of time for

their parents to prepare healthy meals at home. Others were more confident that they would not develop CVD because they were physically active and eating right.

6.3 DIGITAL HEALTH EDUCATION PREREQUISITES (PAPERS I AND II)

The digitalisation part of the thesis was assessed both quantitatively through a survey and qualitatively through FGDs. The survey in Paper I assessed digital prerequisites such as smartphones and internet access for digital cardiovascular health education (Table 7).

*Table 7: Prerequisites for digital health education among adolescents (*n *= 649)*

Items	*n* (%)
Availability of smartphones in the family	
Have their own smartphone	327 (50.4)
Family members have smartphones	313 (48.2)
No smartphone in the family	9 (1.4)
Type of smartphone among those who have access (*n* = 640)	
No smartphone	9 (1.4)
Android-based smartphone	495 (76.3)
iPhone	70 (10.8)
Both Android-based smartphone and iPhone	75 (11.6)
Access to internet	594 (91.5)
Permission to use smartphone	
Allowed to use smartphone without restrictions	141 (21.7)
Allowed to use smartphone with restrictions	376 (57.9)
Allowed to use smartphone only on weekends	107 (16.5)
Never allowed to use smartphone	25 (3.9)
Play mobile games	438 (67.5)

The FGDs in Paper II explored adolescents' preparedness for digital cardiovascular health education. Thematic analysis of the FGDs based on the TAM yielded the five core themes described below. The five themes and ten sub-themes, along with related quotes, are shown in Table 8.

Table 8: Themes, sub-themes and quotes based on the TAM

Themes	Sub-themes	Examples of quotes
Perceived usefulness	Provide knowledge and awareness	'It will be beneficial to many and create awareness about heart disease.' (Private school, girl)
	Obtain information, express creativity and derive entertainment	'We will get information along with entertainment.' (Private school, girl)
Perceived ease of use	Ease of learning and playing games	'If such games can be played on mobile phones, we can easily learn things and it will be useful.' (Private school, girl)
	Limited technical challenges	'If the power supply gets cut off, only then will we have a problem. Otherwise, there won't be any problems.' (Public school, girl)
Attitudes towards using	Game features and design are essential	'The design must be appealing. The design of the game is of primary importance.' (Private school, boy)
	Adventurous and challenging games are preferable	'It will be more interesting if it is like an adventure game with increasing levels.' (Private school, girl)
Behavioural intention to use	Realistic and useful games in daily life	'It must be interesting and should motivate us to adopt heart-healthy habits.' (Private school, boy)
	Ability to play with friends and share the game with family	'The game should be playable in a group with friends.' (Public school, boy)
Actual usage/ preparedness	Parental permission to play	'They will allow us to play if the game is related to heart disease, its preventive factors and if it provides information related to heart disease. If it is like other games, they will not allow us to play.' (Private school, boy)
	Obstacles to playing	'Shooting in a game is cool, but eating fruits and vegetables is not cool.' (Private school, boy)

Perceived usefulness: Adolescents perceived digital cardiovascular health education in the form of a mobile game as very useful. They stated that such a game would raise awareness about heart disease, help people recognise early symptoms and act on time. They expressed an interest in learning about heart disease by playing a game that would enhance their creativity and focus on heart-healthy habits.

Perceived ease of use: Some adolescents thought that games make things easier to understand and memorise. Others thought that successfully learning

by playing a game would depend on the type of game and familiarity with playing games and that although it may be difficult at first, it would become easy after getting accustomed to it. Technical challenges such as slow internet, power cuts and slow mobile speed were mentioned as barriers to use.

Attitudes towards using an educational mobile game: All adolescents were interested in playing the game and learning from it. However, they emphasised game features and design, good graphics and animation to keep them interested in the game. They preferred games that were challenging, games with increasing levels, adventure games, and games that could be played in a group and provided the possibility of completing missions.

Behavioural intention to use: Adolescents stressed that the game would need to be realistic in order to motivate them to adopt healthy habits. They also said that they would be interested in the game if it could be played offline along with an online version where they could collaborate in a group.

Actual usage/preparedness: Adolescents expressed that they would be interested in the mobile game if their parents allowed them to play it. Therefore, they stressed the need to explain to their parents that it is an educational game about heart disease. Adolescents mentioned having lots of homework and insufficient time to play mobile games. However, when they played, they preferred games that were not interrupted by advertisements. For adolescents who used their parents' phones, obstacles to playing included parents needing the phone at the same time as them. They were also sceptical about how interesting a game about eating fruits and vegetables would be.

6.4 DEVELOPMENT AND CULTURALISATION OF THE GAME (PAPER III)

The adolescents' cardiovascular knowledge gaps and their perceptions of CVD and using a mobile game for cardiovascular health education were used in the development of the game. Combining the gaps from Paper I and the insights into the prevalence and role of certain foods in Nepalese households from the HARDIC manual gave us a structured list of topics along with a clear strategy for presenting them. This formed the basis for structuring the content around seven minigames, allowing players to explore key concepts in a structured manner without being overwhelmed by the wide range of topics addressed. The user interface of *Happy Heart* is shown in Figure 3.

Figure 3: Happy Heart user interface

Since we had planned to allow the adolescents to play the game for only two weeks, we targeted a change in knowledge instead of attitudes or behaviour, which take longer to change. However, a change in knowledge is believed to bring about changes in attitudes and practices [56].

Simple, straightforward knowledge intended for cardiovascular health, as recommended by the AHA, was easy to integrate into the game design. However, a deeper understanding of cardiovascular health requires knowledge of complex concepts, such as the differences between simple sugars and refined sugars as well as between good and bad fats. Integrating these complex concepts into the game design increased gameplay complexity, which conflicted with the design goal of maintaining simplicity and clarity. To resolve this, we created an in-game journal that provided supplementary information and was accessible from the game's main menu. I authored the content for the journal.

Culturalisation of the game content played a major role in achieving the educational goals of *Happy Heart*. Some examples of the culturalisation efforts used in the game are listed below.

- We had initially planned to represent the sugar content in food items with sugar cubes, a not-so-popular form of sugar available in the Nepalese kitchen. However, depicting sugar amounts in tablespoons (commonly used measurement in the Nepalese kitchen) created confusion regarding the size of the spoon. Therefore, we decided to illustrate sugar content in relative terms, i.e. as a percentage of the food depicted.

- We chose local food items that are a part of the daily lives of adolescents (see Figure 4), such as samosa, *barfi*, *jeri* and *sel*, as well as commonly

available vegetables, such as gourd and buckwheat. Pictures of red meat were accompanied by a small icon of a buffalo, indicating that the meat was from a buffalo, a common source of red meat in Nepal.

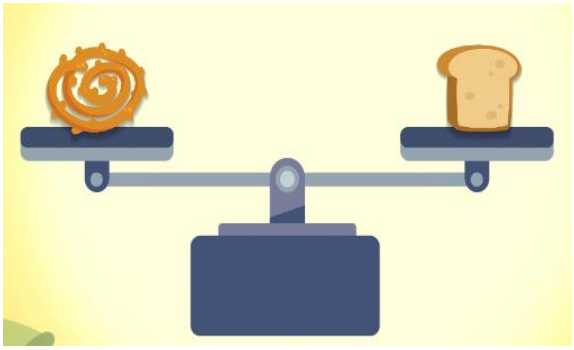

Figure 4: Depiction of local food items (jeri and bread)

- Walking to school is an effective form of physical activity for adolescents. However, this was not feasible in the target setting due to the poor condition of roads and heavy traffic, which pose a health risk to adolescents. Hence, this was replaced by other common activities, such as gardening and carrying heavy loads.

- The game's visuals incorporated traditional Nepalese colours and patterns to create an environment that felt familiar and appealing to users (see Figure 5) [69].

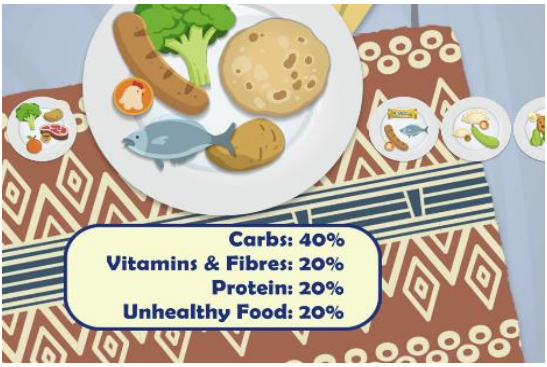

Figure 5: Tablecloth with Nepalese colours and patterns

- We chose a one-to-five-star rating system to give players feedback on their performance, a rating system that is commonly used in Nepal.

Happy Heart consisted of seven minigames that were designed to be played in sequence, and completing one game unlocked the subsequent game (see Figure 6). *Name the food* served to familiarise adolescents with the depictions and the names of the food items to facilitate subsequent games. *Food sorter* tasked the adolescents with sorting food items into their major nutrient groups or the unhealthy food group via a simple drag-and-drop mechanism, allowing them to learn which food items are healthy/unhealthy for the heart. *Sugar rush*, *Salt seeker* and *Fat buster* allowed players to practice estimating the amount of sugar, salt and fat in the depicted food item or compare the levels between the choices of food items given. *Plan your meal* helped adolescents learn how they can balance their nutrients in a day by planning their five daily meals. This encouraged them to assemble food in a health-conscious way, balancing the amount of carbohydrates, proteins and fats they consume in a day, which was calculated by the game at the end of the minigame. *Activate* taught the adolescents about the amount and type of physical activity they would need to ensure good cardiovascular health. It allowed them to choose the physical activities they would like to perform for 1 hour a day and evaluated their choices at the end of the minigame.

Figure 6: The seven minigames

6.5 MAPPING GAPS IN KAP AND CVD PERCEPTIONS INTO GAME MECHANICS: INTEGRATING PAPERS I, II AND III

This section presents Papers I–III in unison from a zoomed-out perspective to elucidate the overall flow of events in the study. Table 9 shows how the gaps in KAP and adolescents' perceptions of CVD were considered in creating *Happy Heart*.

Table 9: Triangulation of quantitative (Paper I) and qualitative (Paper II) studies for game development (Paper III)

Assessed areas	**Paper I (quantitative)**	**Paper II (qualitative)**	**Paper III (game development)**
Knowledge on CVD risk factors	Adolescents lacked knowledge about CVD risk factors such as hypertension, diabetes, obesity and stress.	The elderly, children and weak people are prone to heart disease. *(convergent)*	The game focused on diet and physical activity to help reduce other health conditions leading to CVD.
Knowledge on diet	Lack of knowledge on a healthy plate, servings of fruits and vegetables, and the health benefits of fish.	Outside food, junk food and foods high in fat cause heart disease; however, the good taste of junk food creates temptation. *(complimentary)*	Dealt with in *Sugar rush*, *Salt seeker* and *Fat buster* (where adolescents observed the levels of sugar, salt and fat in food) and *Plan your meal*, where they planned five meals to create a balanced diet for a day.
Attitudes towards diet	High-calorie foods with lots of fats and carbohydrates help fight disease.	Foods high in fat are bad for one's health. *(divergent)*	Dealt with in *Fat buster*, where adolescents identified foods with relatively high fat content.
Practices related to diet	Only 12% of the adolescents ate five servings of fruits and vegetables per day; 67% ate salty food more than once per day; 64% ate sugary food more than once per day.	Even if the adolescents realised they were eating unhealthy food, practical constraints included a lack of time, the lack of a healthy eating canteen and the easy availability of packaged food.	Dealt with in *Plan your meal*, where adolescents planned five meals to create a balanced diet for a day.

Assessed areas	Paper I (quantitative)	Paper II (qualitative)	Paper III (game development)
		(complimentary)	
Knowledge on physical activity	Recommended level of physical activity, sedentary lifestyle.	A lack of exercise can lead to heart disease, and the environment should be conducive to physical activity. *(complimentary)*	Dealt with in *Activate*, where adolescents chose portions of physical activity throughout the day that would sum to 60 minutes of exercise.
Attitudes towards physical activity	Adolescents thought indoor games are also a source of physical activity.		
Practices related to physical activity	38% were physically active for <60 mins per day.		
Knowledge on tobacco and alcohol use	Adolescents identified tobacco and alcohol as harmful but did not understand their effects on health.	People who smoke and drink are at risk of heart disease; smoke from someone else smoking nearby is harmful to us. *(convergent)*	Since the message on tobacco and alcohol is simply to avoid them, the adolescents dragged alcohol bottles and cigarettes to the trash can during play, signifying that they are to be discarded altogether.
Attitudes towards tobacco and alcohol use	Adolescents think that a certain amount of alcohol is good for one's health.		
Practices related to tobacco and alcohol use	96% never smoked, and 82% never consumed alcohol-containing drinks.		
Digital prerequisites	98.6% had access to smartphones; 92% had access to the internet at home; 76% had access to Android-based phones; 68% had played mobile games; 23% played mobile games daily.	Social media can help create awareness. *(convergent)*	*Happy Heart* was built for Android-based phones due to their predominance in the survey. Since many of the adolescents were familiar with mobile games, simple drag-and-drop and sliding mechanisms were used.

6.6 ASSESSING THE GAMES' EFFECTIVENESS AND FEASIBILITY (PAPER IV)

This section describes the pilot testing of *Happy Heart*. The descriptive analysis of all the participants showed that 78% were aged 13–15 years, 53%

were boys and 69% were from private schools. Adolescents from Grades 8, 9 and 10 comprised 31%, 36% and 33% of the sample, respectively.

Of the 180 adolescents who installed and played the game, 108 uploaded their gameplay data. Of these 108 adolescents, ninety-six uploaded their data and completed the post-intervention survey. Of these ninety-six adolescents, forty-three had played all seven minigames (full exposure group), and fifty-three had played six or fewer games or had only viewed the journal (partial exposure group). Among the 191 adolescents in the control group who completed the pre-intervention survey, 169 completed the post-intervention survey. The control group did not receive the game (no exposure group). We conducted a group-wise median test among the no exposure, partial exposure and full exposure groups that revealed changes in knowledge and practices between the no exposure and full exposure groups (Figure 7).

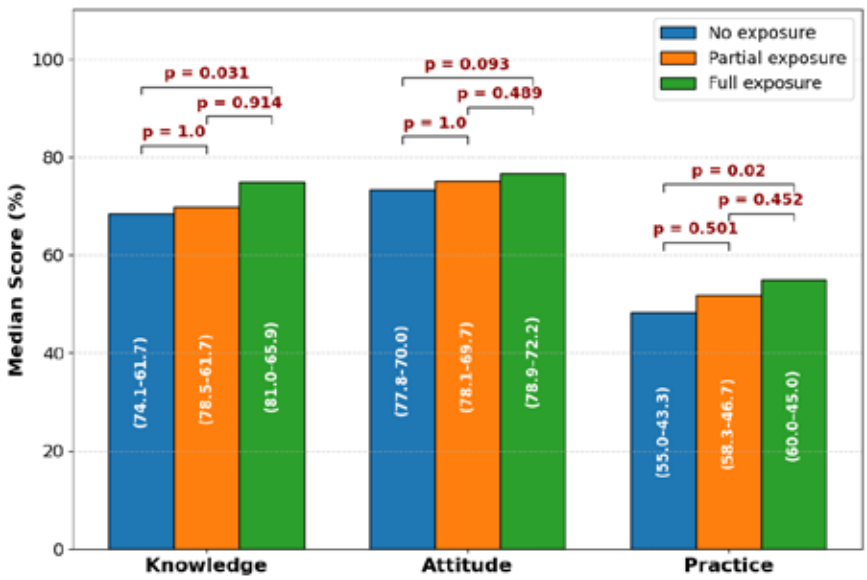

Figure 7: Bar diagram showing post-intervention median scores for knowledge, attitude and practice. The ranges inside the bar indicates IQR and the p-value indicates group-wise comparison

The analysis showed that adolescents rated the acceptability and usability of the game higher than their game experiences and satisfaction with playing it (see Figure 8).

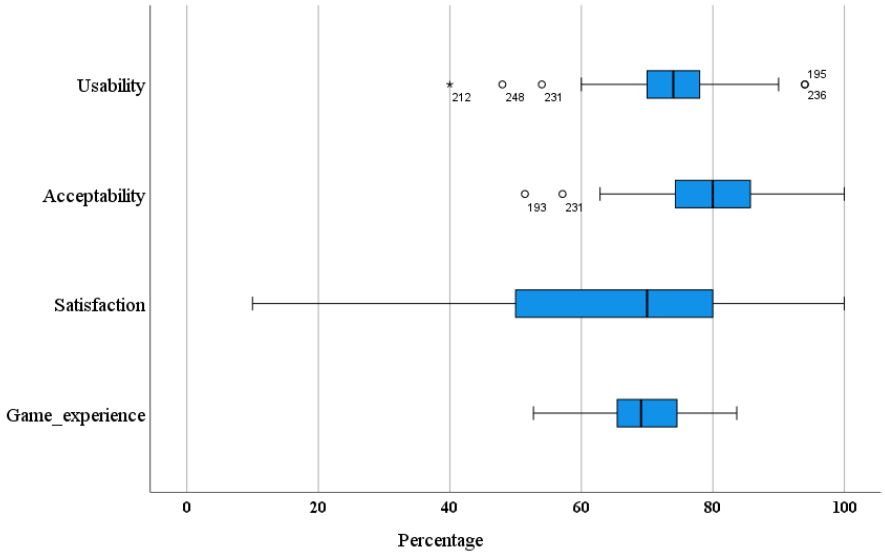

Figure 8: Box plot showing adolescents' rating of game experiences, satisfaction, acceptability and usability of Happy Heart. The lines inside the box shows the median, the box shows the interquartile range and the whiskers show the minimum and maximum values. The small circles show the outliers.

I used the recruitment, participation and completion rates to assess the feasibility of using the game (see Figure 9). The participation rate decreased by one-third of the recruitment rate, and the completion rate decreased by one-third of the participation rate.

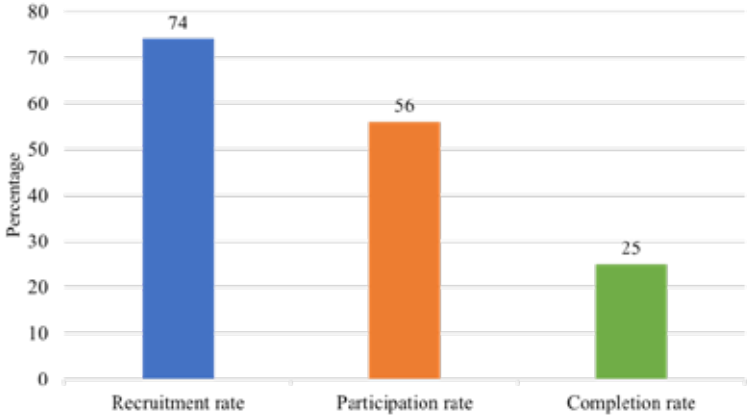

Figure 9: Feasibility of using a serious game for cardiovascular health education. Recruitment rate (installed game/completed pre-intervention survey) × 100; Participation rate (played at least one game/installed game) × 100; Completion rate (played all seven games/installed game) × 100.

7 DISCUSSION

The adolescents demonstrated a lack of KAP regarding CVD and its risk factors. Although they perceived CVD as a serious disease, they also described the practical obstacles to adopting heart-healthy habits. The results revealed high digital access among adolescents and a positive perception of digital health education. *Happy Heart* was developed based on the findings of the qualitative and quantitative studies. Pilot testing of *Happy Heart* showed an increase in knowledge. The participation rate decreased by one-third of the recruitment rate, and the completion rate dropped by one-third of the participation rate. Adolescents rated acceptability and usability of the game higher than their experiences and satisfaction with playing it.

7.1 UNDERSTANDING THE GAPS IN KAP

Rapid urbanisation and epidemiological transition [81] have changed the lifestyle of the Nepalese population, leading to increases in CVD prevalence and its risk factors. The effects of this change are also evident among the younger population in the country. To curb the increasing burden of NCDs, the Nepalese government formulated the Multi-Sectoral Action Plan for NCDs [26] and the PEN plan [27]. However, because CVD manifests in adulthood, most of these efforts target curative aspects of the disease for adults [28]. With its limited resources, Nepal has focused more on health promotion than disease prevention among adolescents, a relatively healthy population in the country. School-based programmes for all school-going children, such as providing safe drinking water, a nutritious diet, smoke- and drug-free schools and information about good hygiene habits [30] align with health promotion. However, CVD awareness is not covered in the curriculum. As a result, while adolescents are aware that a healthy diet and physical activity are important, they do not connect them to CVD prevention.

This disconnection can explain the gaps identified in KAP among the adolescents. Most of the adolescents did not know about the healthy plate concept or the recommended servings of fruits and vegetables or physical activity per day. While they were aware that smoking and alcohol intake are harmful, they did not know their effects on the body. Although the adolescents were physically active for more than 60 mins per day, they lacked knowledge of the difference between physical inactivity and sedentary behaviour. Their dietary behaviours were also poor. However, a broader understanding of the

circumstances surrounding the adolescents is necessary before interpreting the KAP gaps.

The inclination of adolescents to engage in healthy behaviours is shaped by parental practices, culture, societal norms and environmental factors. As explained by SCT [58], adolescents learn by observing others, and their behaviours are shaped by responses to those behaviours. Similarly, family members' eating habits can shape children's feeding habits. Moreover, despite their intention to eat healthily, as explained by the TPB [54], adolescents often lack the behavioural control to practice healthy habits. In this study, the participants mentioned having to eat whatever is cooked at home, not being able to bring healthy tiffin to school due to their parents' lack of time to cook and having to eat whatever is available in the school canteen as constraints that they perceived to be beyond their control.

In addition, adolescents had a low perceived susceptibility to CVD, as explained by the HBM [57], and thought that CVD occurs in the weak, in children and in the elderly, but not active and healthy people like them. Financial constraints and prioritisation of more pressing matters at home deviated their attention from the importance of healthy behaviours. The combination of all these factors created a low motivation for healthy practices.

7.2 SOCIOECONOMIC DISPARITIES AND CARDIOVASCULAR HEALTH

In this thesis, the type of school was taken as a proxy for socioeconomic status (SES). Parents with a higher SES were more likely to enrol their children in private schools [62]. Although education in private schools is more costly, these schools tend to have better resources and more qualified teachers [82–84]. Private school adolescents were found to have better KAP regarding CVD and its risk factors. Even after *Happy Heart*, improvements in knowledge and practices were found to be greater among private school adolescents.

Individuals with a higher SES often tend to received better educations and have more awareness of and better access to health information and resources [85]. Moreover, a digital divide exists between different socioeconomic levels, influencing access to digital devices and resources, which may have caused the disparity between public and private schools [86]. The feasibility parameters for *Happy Heart* also showed a better response among private school

adolescents, likely due to a more adaptive approach among adolescents from a higher SES [87].

Viewing CVD risk factors through the lens of SES reveals how social and economic inequalities shape risk factor clusters and the outcomes they produce. Evidence suggests that lower SES is linked to poorer diet and lower physical activity [88–90]. People with a lower SES rely on cheaper, more calorie-dense and less nutrient-rich food [91].

Evidence shows that people with a lower SES are less likely to undertake vigorous activity even if they are more likely to walk for transport [92], whereas those with a higher SES are more likely to engage in leisure time physical activity [93,94]. People with a sedentary lifestyle and occupational sitting have a higher risk of CVD mortality, suggesting that lifestyle mediates the relationship between SES and health [95].

7.3 OBSTACLES TO LEVERAGING DIGITAL HEALTH EDUCATION IN NEPAL

The increasing mobile and internet penetration rate in Nepal has opened doors to many possibilities for digitalised interventions, especially among adolescents – a population inclined towards technology. I based the HRIDAYA project on this concept and assessed adolescents' access to smartphones and the internet in Paper I and explored their perceptions of digitalised health education in Paper II.

Paper I demonstrated that adolescents generally had high access to digital technologies, though personal ownership was limited. Despite high access, practical problems arose in the implementation of *Happy Heart*.

First, since the implementation period was in 2023, after the COVID-19 pandemic, I had assumed that the children would be familiar with digital media due to their online classes and that the implementation process would be hassle free. However, some of the schools denied participation when I approached them about the serious game intervention because parents complained that their children were already hooked to their mobile devices and using the internet for social media. Parents had requested that the school administration restrict mobile use, even at home. While parents allow their children to use mobile phones and the internet for educational purposes, they are concerned about excessive mobile and internet use and its effects on adolescents' health

[96–99]. The issue with parental permission [96,100] created problems, and ultimately, the schools that granted permission were selected for the intervention. To utilise serious games to their full potential, parents need to be counselled that mobile games can be educational [46]. Schools can play a major role in dispelling this misconception among parents [46].

Second, the adolescents had reported that they had to access smartphones through their parents or siblings. It is not uncommon for family members to share mobile phones to minimise costs in Nepal [101]. However, mere access to a smartphone does not equate to the ability to use it effectively when required. Parents' and siblings' schedules, as well as their social obligations, needed to be considered, as these could delay phone use.

7.4 EFFECTIVENESS OF USING SERIOUS GAMES FOR HEALTH EDUCATION

Serious games have been successfully implemented for health education (e.g. for nutrition and healthy lifestyle) in high-income countries [41,42,102]. They have shown effective improvements in knowledge [41,43,102], behavioural intention [39] and health outcomes [42,103]. This is in line with this thesis findings where the knowledge of the adolescents improved after *Happy Heart*. Evidence shows that improvements in knowledge and attitudes were more promising than in behaviour, and games tailored to the target audience, as well as those that are a part of multi-component programmes, are more successful in changing behaviour [104]. Long-term follow-up [42], turning improved knowledge into practice [41] and incorporating emotionally engaging features for sustained knowledge and behavioural change [102] have been reported as challenges in developing an effective serious game.

Besides similar challenges in *Happy Heart,* we also faced problems in incorporating smoking and drinking into the game. Unlike diet and physical activity, the concepts of smoking and drinking have a single message – that they are detrimental to cardiovascular health. No amount of smoking or drinking can be considered beneficial for cardiovascular health. A separate minigame dedicated to communicating this single message was determined to be unnecessary. Rather, during the minigame *Sort the food*, the players needed to drag and drop the images of alcohol and cigarettes into the trash bin, signifying that they were not cardiovascular-health-promoting options.

The analysis based on the TAM revealed that the adolescents perceived digital health education to be useful, that digital media is easy to use and that they intended to use it once available. This was confirmed after testing the game, as the median acceptability and usability of *Happy Heart* were calculated to be 80% and 74%, respectively. However, since the adolescents were accustomed to fast-paced, commercially available action games, they perceived *Happy Heart* to be less interesting and captivating [105] despite being educational [46].

Nevertheless, serious games such as *Happy Heart* have immense potential in health education if they are incorporated into the school curriculum [46,104]. The use of games for educational purposes can go a long way to creating awareness among digitally inclined adolescents. Instead of competing with other commercial mobile games, serious games can compete with homework, effectively enhancing school-based learning.

7.5 UNDERSTANDING FEASIBILITY PARAMETERS

The enrolment of adolescents in the trial in Paper IV required parental consent, adolescents' assent and their presence in school during consent form distribution and the pre- and post-intervention surveys. Problems with parental consent included parents lacking the time to read the information sheet and sign the consent form, parental illiteracy and prioritisation of other family problems over participation of their children in this trial as well as adolescents forgetting to bring the consent form to school. Repeated follow-up to minimise the effects of forgetfulness without creating undue pressure for enrolment increased the recruitment rate.

After recruitment to the trial, when it was time to install *Happy Heart* on the adolescents' mobile devices, we faced another problem. Since mobile phones are not allowed on school premises, we had to solve installation problems after school. Some installation problems were due to some of the mobile phones being older models, and others were due to connectivity issues. However, once all these problems were solved, we asked the adolescents to play the game for two weeks.

Since it is common for Nepalese households to share mobile phones to minimise costs [101], 48% of the adolescents used their family's smartphones. This sharing of phones created access problems, such as adolescents needing to use the phone at the same time as the parents, parents being available for

only a short time at home due to long working hours and slow/lagging phones. Moreover, weak connectivity and a lack of access to the phone prevented the adolescents from uploading their gameplay data. These issues affected the participation and completion rates.

In addition, adolescents accustomed to fast-paced games found *Happy Heart* not as captivating and suggested that the game would be better suited to younger children. However, the adolescents acknowledged the educational importance of the game. This explains the lower satisfaction and game experience despite its higher acceptability and usability. *Happy Heart* needs to be integrated into the school curriculum and used as an academic activity instead of competing with commercially available fast-paced games. This can improve the participation and completion rate and aid in delivering cardiovascular health knowledge effectively among adolescents.

7.6 CONTRIBUTIONS OF THE HRIDAYA PROJECT TO PRIMORDIAL CVD PREVENTION IN NEPAL

The existing adolescent related health policies include the National Adolescent Health and Development Strategy (NAHDS) [106] and the National School Health and Nutrition Strategy (NSHNS) [30]. The NAHDS aims to improve the health, well-being and development of adolescents in Nepal by ensuring equitable, accessible adolescent-friendly services as well as empowerment and a supportive environment. The NSHNS operationalises the nutrition, physical health, hygiene and life skill components of the NAHDS by focusing on school-going adolescents through their SHNP. The SHNP provides health checkups, deworming, micronutrient supplementation, safe drinking water and sanitation. However, the SHNP does not target cardiovascular health.

The school curriculum includes topics such as nutrition, physical activity, healthy living, infectious diseases and NCDs. However, the interrelation among these topics needs to be emphasised at upcoming curriculum revisions. Adding a component on digital health education related to cardiovascular health can augment the SHNP and teach about healthy diet and the importance of physical activity.

On the foundation of existing health policies and strategies surrounding NCDs and adolescent health in Nepal, the HRIDAYA project used contemporary digital means to provide education about CVD. At a time when primordial CVD prevention among the younger age is widely recommended [16], the use

of digital media helps cover a large portion of this population in a way that is interesting to them. With its interdisciplinary collaboration, the use of contemporary digital means and the HRIDAYA project show the way forward for primordial CVD prevention in Nepal.

7.7 STRENGTHS AND LIMITATIONS OF THE HRIDAYA PROJECT

The HRIDAYA project is a unique primordial CVD prevention endeavour with multiple strengths. It culminated in the creation of a serious game, the use of which has been rare in Nepal. Many mobile-based interventions have been conducted in Nepal, but the HRIDAYA project is the first to use a serious game about CVD among adolescents. Another major strength of this thesis concerns its interdisciplinary collaboration, which ensured that CVD was viewed from different angles before *Happy Heart* was created. The collaboration contributed technical and subject matter expertise that made it possible to develop a digital health education game like *Happy Heart* in a resource-limited country like Nepal. Moreover, the mixed methods approach with triangulation of the quantitative and qualitative findings made the project unique by proving richer, more credible, and more comprehensive data than using either method alone.

However, since the HRIDAYA project is a pilot trial, the results of this thesis should be interpreted with caution. Because some of the adolescents did not upload their gameplay data, only a small number of adolescents' data were available for analysis. Hence, even though many adolescents completed the post-intervention survey, they could not all be included in the gameplay analysis. The possibility of contamination of the control group with the game provided in the intervention group cannot be excluded. Scaling up the HRIDAYA project is necessary to obtain better information about participation and completion rates.

7.8 SCALABILITY AND SUSTAINABILITY OF HAPPY HEART AND THE HRIDAYA PROJECT

Happy Heart has immense potential to reach all Nepalese adolescents for primordial prevention with the involvement of schools at the curriculum level. Adding specific sections on CVD under NCDs to the curriculum and practicing *Happy Heart* in parallel with traditional lessons on health education can boost

its usage and benefit all Nepalese adolescents. This is true for all LMICs in which a cost-effective medium is necessary to spread knowledge about cardiovascular health for primordial CVD prevention [107,108]. Integrating *Happy Heart* into the school curriculum also requires digital access at schools and co-operation with teachers for its smooth running. To ensure its sustainability, the game can also be developed to incorporate features such as group playing, score sharing and more engaging game mechanics [46].

The HRIDAYA project can be scaled up to include a representative sample of schools from all the provinces of Nepal. It can also be replicated in other LMICs and resource-limited settings, since primordial prevention among adolescents by educating them regarding cardiovascular health is essential to curb the substantial burden of CVD in LMICs, the main drivers of the global CVD burden.

7.9 INTERDISCIPLINARY COLLABORATION: OPPORTUNITIES AND LESSONS LEARNT

CVD and its risk factors arise from complex interactions between biological, lifestyle, environmental, social, economic and policy factors that no single discipline can address [109,110]. It needs to be tackled from multiple angles, so an interdisciplinary team is essential. Therefore, at the heart of the HRIDAYA project was a collaboration between health sciences, social sciences, public health, nursing and game development. This collaboration provided opportunities to share ideas, explain each other's perspectives for a common goal and learn from one another. Through this joint effort, we converted the gaps identified among adolescents in the schools into the game mechanics of *Happy Heart* in order to improve adolescents' CVD knowledge.

However, such a collaboration has its own set of challenges. Email communication requires adequate time to allow everyone to respond [111]. Differing thought processes and perceptions need extra explanations and sensitivities at times. Each discipline operates within its own framework of knowledge, terminology, and problem-solving approach. As a result, what seems obvious to one professional may be unfamiliar or interpreted differently by another. Taking time to clarify concepts, explain reasoning, and acknowledge these differences fosters mutual understanding, respect, and effective teamwork. We established a common language and a shared understanding of terms to ensure that we were on the same page [112]. Since our interdisciplinary collaboration involved different time zones, careful co-

ordination of schedules to accommodate everyone's availability through various office hours and vacations was required. Developing working relationships takes time [113]; however, each member's commitment and accountability in their area and keeping the group's common goal above everything else helped us complete the HRIDAYA project successfully. The generation of new knowledge, exposure to newer methods and theories, opportunities for networking, collaboration and learning team work [113,114] benefitted all of us.

8 CONCLUSION

The HRIDAYA project is a unique project for primordial prevention of CVD targeted towards adolescents. It not only addresses the rising burden of CVD risk factors among adolescents but also provides CVD education in a simple, entertaining way through contemporary digital means.

I used a mixed methods study, starting with a quantitative survey. The survey showed that Nepalese adolescents had limited CVD knowledge. Qualitative study with FGDs revealed that adolescents perceived CVD as a preventable, serious disease and showed adolescents' positive attitudes towards digital cardiovascular health education. Based on the findings of these studies, a serious game called *Happy Heart* was developed.

Implementation of *Happy Heart* among adolescents for two weeks improved knowledge on cardiovascular health and the game was well accepted by the adolescents. However, the engagement with the game was moderate. Therefore, this thesis concluded that targeted and customised digital health education is useful for improving knowledge about cardiovascular health among adolescents. Further research focusing on implementation of the game and strategies for completion of the game by adolescents is necessary to ensure adequate dissemination of knowledge for primordial CVD prevention.

9 FUTURE PERSPECTIVES

Digital health education efforts such as *Happy Heart* can reach a large population of adolescents simultaneously. This type of media is especially important in resource-limited LMICs. Based on the important insights produced by the pilot study described in this thesis, a full-fledged community project can inform the effectiveness and feasibility of serious games. Moreover, perspectives from parents and teachers can play a vital role in effectively integrating *Happy Heart* into adolescents' daily lives. FGDs with parents and teachers about using *Happy Heart* to educate adolescents about cardiovascular health and their role in enhancing adolescents' learning can maximise the game's benefits.

Although adolescents perceive serious games as less entertaining compared to commercially available fast-paced games [105], integrating gameplay into the curriculum to augment the specific topics taught by the curriculum can enhance adolescents' participation in serious games, providing opportunities for effective learning. To make the game interesting, *Happy Heart* can be further developed by upgrading its technology and design. Furthermore, AI technologies can be incorporated to make *Happy Heart* more visually and auditorily engaging. Although multiple ethical issues may need to be considered while using advanced technologies among adolescents, controlled play in a supervised environment such as a school can be beneficial to adolescents in terms of improving their cardiovascular health.

Happy Heart has the potential for scaling up as a primordial CVD prevention strategy by the Nepalese government. This can promote a healthy lifestyle related to diet and physical activity among adolescents, who are the future of the country.

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