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MULTIFACETED INVESTIGATION OF CARDIOVASCULAR RISK PERCEPTION FROM A HEALTH PSYCHOLOGICAL PERSPECTIVE IN A HUNGARIAN COMMUNITY SAMPLE: THE BUDAKALÁSZ EPIDEMIOLOGY STUDY

PhD thesis

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List of Abbreviations

ABCD: Attitudes and Beliefs about Cardiovascular Disease

ADHD: Attention Deficit Hyperactivity Disorder

AMI: Acute Myocardial Infarction

BA: Bachelor of Arts

BDI-9: Beck Depression Inventory- Short form

BES: Budakalasz Epidemiology Study

BMI: Body Mass Index

CAD: Coronary Artery Disease

CFA: Confirmatory Factor Analyses

CFI Comparative Fit Indexes

CVD: Cardiovascular diseases

DALYs: Disability-adjusted life years

Direct Memory Recall (DMR)

EBS: Extended Budakalász Research

EFA Exploratory factor analyses

EHIS: European Health Interview Surveys

ESC: European Society of Cardiology

FRS: Framingham Risk Score

HAI: Health Awareness Index

HbA1c: Haemoglobin A1c

KMO:Kaiser-Meyer-Olkin

HCSS: Hungarian Center of Social Sciences

HDL-C: High-density Lipoprotein Cholesterol

LDL-C: Low-Density Lipoprotein Cholesterol

MA: Master of Arts

MPSS: Multidimensional Perceived Social Support Scale

MPSSH: Multidimensional Perceived Social Support Scale for Health

PSS10: Perceived stress

PTSD: Post-Traumatic Stress Disorder

RMSEA: Root Mean Square Error of Approximation

SEM: Structural Equation Model

SF-36: Short Form Health Survey

SFS: Subjective Financial Situation

SRCS: Self-Reported Cardiovascular Status

SRH: Self-Rated Health

TLI: Tucker- Lewis Index

SRPcvd: Subjective Risk Perception of Cardiovascular Diseases

TC: Total Cholesterol

WHO: World Health Organization

WHO-WB: WHO Well-Being Scale

1. Introduction

1. 1. Introduction and Rationale

Cardiovascular diseases (CVD) represent a significant burden worldwide on economies, healthcare, and quality of life. According to the European Society of Cardiology (ESC), 11 million new cases have been registered worldwide, resulting in a total of 3.9 million deaths per year (1). Despite significant improvements in mortality rates over recent decades, CVDs are still responsible for more than half of all deaths, significantly affecting life expectancy. Most cases of CVD are due to coronary artery disease (CAD), with a rate of 73.6 deaths per 100,000 persons (2), showing an increase worldwide. CAD accounts for more than 50% of deaths among those with CVD (3). European statistics show that over 34 million disability-adjusted life years (DALYs) are associated with this group of diseases, accounting for 25% of all DALYs (4). In 2016, CVD was responsible for 45% of total mortality, resulting in 4 million deaths annually. Coronary heart disease caused 1.8 million deaths, and 1.4 million cases occurred before the age of 75 years (4). Since the 1970s, there has been a significant decline in mortality rates in Western Europe, but this tendency has been slower in Central and Eastern Europe. As a result, the difference between the regions is almost double (e.g. Bulgaria 62% vs. France 26%) (5).

In Hungary the number of deaths from acute myocardial infarction decreased between 1990 and 2017 from 14,000 to 5,700 per annum, despite an increase in the average age of the population (6). The primary reasons for this decline include reducing traditional risk factors (attributable to modern pharmacological treatments for hypertension, dyslipidemia and diabetes) and more effective and faster care (the spread of invasive coronary catheterisation and the quick availability of catheter labs). The importance of a healthy lifestyle, public awareness on the topic, newspaper articles and social media influencers, as well as anti-smoking campaigns, have also played a role in the reduction of deaths from heart attacks (7). Despite the improving results, the mortality rate due to CAD in Hungary is still more than twice that of the EU28 (European Union 28 countries) average (8). Traditional risk factors—such as high cholesterol, high blood pressure, obesity and diabetes—mostly originating in risky behaviours must be considered within the paradigm of health behaviour and not as independent entities. The role of psychosocial and psychological factors in the development of cardiovascular disease is a well-documented phenomenon (9-11). These factors influence and shape behaviour and health-related decisions, perceptions, and attitudes regarding the emergence of CVDs (and other diseases) in the form of psychological malformations and illnesses. The behavioural manifestations of these influences are significantly affected by various clinical and subclinical psychological factors, such as self-esteem, a sensation-seeking personality (i.e. risk-seeking characteristic) and, through them, self-care abilities, chemical and behavioural dependencies, and coping strategies. Microculture, family norms, related health representations and attitudes toward life as a value play significant roles in shaping individual psychological and socioeconomic status alongside inherited factors.

Over the past decades, numerous research groups have investigated these aspects, providing substantial literature on the direct and indirect effects of psychological states affecting health behaviours. Affective and anxiety disorders have direct effects on cardiovascular disease and worsen its outcome (12-14). Typical manifestation of these states, including rumination, negative affectivity, and anger leads to adverse health outcomes (15-17).

Using health psychology models we can better understand disease-related decision-making and effective preventive interventions can be planned based on these (18-19). According to the Health Beliefs Model, change is most likely to occur if an individual is aware of his or her vulnerability to the disease and its seriousness and believes that the proposed preventive action has more benefits than harms (18, 20-21). Carpenter's meta-analysis shows that perceived benefits and drawbacks are the strongest predictors in forecasting health behaviour (22).

1.2 Cardiovascular Risk Factors

"Classic" risk factors are those non-modifiable (age, gender, heredity) and modifiable influencing factors that predict an individual's likelihood of developing a disease. A more accurate risk assessment and stratification are essential in planning effective medical interventions. In most cases, risk factors do not exist in isolation; their multiplicative effects accumulate. Therefore, interventions should be personalised after assessing the objective risks and targeting all risk factors (22).

1.2.1. Modifiable Risk Factors

Traditional modifiable risk factors include hypertension, diabetes, dyslipidemia, obesity and smoking. The range of risk factors continually expands with the accumulation of relevant research data. Risk markers are indicators of target organ damage that can be used to estimate risk in asymptomatic individuals for primary prevention (23).

High blood pressure is the condition with the strongest evidence as an independent risk and causal factor for CVD (23-25). Worldwide, an estimated 1.28 billion adults aged 30-79 years have hypertension, two-thirds of them live in low- and middle-income countries, and approximately 46% are unaware of their condition and therefore do not receive treatment (26).

Among the diabetic population, the most common cause of mortality and morbidity is CVD. The incidence of both types of diabetes is increasing worldwide. From 1985 to 2014, the prevalence rose by 352 million, creating a significant health and economic burden. Optimal management of diabetes can reduce the risk of cardiovascular disease by more than 50%.

Dyslipidemia is defined by elevated levels of serum total cholesterol (TC), triglycerides (TG) and low-density lipoprotein cholesterol (LDL-C). In contrast, high-density lipoprotein cholesterol (HDL-C) is present in reduced concentrations in the blood. Increased LDL levels lead to atherosclerotic deposits through oxidation processes, resulting in cardiovascular diseases. Pharmacological reduction of LDL levels is the standard atherosclerosis treatment, especially in familial hypercholesterolemia cases. LDL levels can be influenced by proper diet and exercise, leveraging their combined effect.

Obesity is a multifactorial disease that increases CVD risk and is remarkably independent of other risk factors (27). The standard indicator for assessing the extent of obesity is the Body Mass Index (BMI). A BMI of 18-24.99 is considered normal, 25-29.99 is overweight, and individuals with a BMI over 30 are obese, while a BMI over 40 indicates severe obesity. Recent research, however, considers abdominal obesity or body fat composition (visceral obesity) as a more significant risk factor. According to a World Health Organization (WHO) report, in 2022, 1 in 8 people was obese, and the number of obese individuals has doubled since 1990, with this rate quadrupling among teenagers

(28). Obesity is a direct trigger for the development of cardiovascular risk factors such as type 2 diabetes, high blood pressure and dyslipidemia. Treatment primarily involves weight reduction (which may include bariatric surgery, pharmacotherapy, and behavioural therapy, depending on the degree of obesity) (29-30).

1.2.2 Factors Influencing Risk Markers: Protective and Harmful factors as research framework

Harmful Factors

Several protective and harmful factors directly or indirectly affect the onset and outcome of CVD.

Such harmful factors are:

1. Lack of social support, social isolation, loneliness (see 1.4.2 in details)

2. Psychiatric comorbidites

Several studies link leading psychiatric disorders to CVD. Shen and colleagues confirmed that these associations are independent of other familial factors in their study published in *The Lancet*, using large Danish, Swedish, and Lithuanian samples (31). The study identified hypertension, angina pectoris, ischemic heart disease, stroke and venous thromboembolism as the most commonly occurring CVDs in the group with psychiatric disorders. Among the conditions, the strength of the association is particularly notable in anorexia nervosa. Other psychiatric disorders that showed associations with CVD are Attention Deficit Hyperactivity Disorder (ADHD), intellectual disability, affective and non-affective psychotic disorders, personality disorders, substance misuse, non-psychotic mood disorder, anxiety and stress-related disorders.

3. Sub-Clinical Disorders

Other subclinical psychological conditions can also contribute to the development of CVD or worsen its course and outcome. Stress-related illnesses and depression, even in their mild to moderate forms, leave their mark on behaviour and self-care, leading to vital exhaustion, which has been proven to be a significant risk factor (32).

These conditions contribute significantly to the development and maintenance of cognitive distortion. In the end, biased cognition might result in a misperception of illness, including CVD, and as a result unhealthy behaviour.

4. Unhealthy Lifestyle

Smoking is a cause of numerous diseases and is a significant contributor to all causes mortality, as well as an independent factor for cardiovascular disease. Both active and passive smoking are responsible for 30% of CVD deaths, primarily due to the deterioration of endothelial functions (33-34). Smoking can raise triglycerides, lower HDL levels, damage and thicken blood vessels, and increase plaque formation and deposition (35). In Hungary, the number of male smokers significantly decreased between 2000 and 2019 (38% vs. 27.2%); however, no significant decrease was observed among women (23% vs. 22%) (36).

A sedentary lifestyle, primarily through obesity and related metabolic processes, also contributes to the development of many diseases. In contrast, with physical activity, there is a noticeable decrease in blood lipid and glucose levels (37). A sedentary lifestyle is generally accompanied by poor nutrition, which increases blood lipids and sugar levels in the body and contributes to obesity. This lifestyle has physiological and significant psychological components as a starting point and outcome.

Protective Psychosocial Factors

In contrast, there are numerous factors that are associated with a reduced risk of cardiovascular disease and mortality.

Such protective factors are:

1. Social support as discussed in 1.4.2 in detail.

2. Psychological well-being

3. Positive psychological states

The latter include, but are not limited to, happiness, optimism, gratitude, purpose, life satisfaction, and mindfulness (38-40). The role of positive psychological states in reducing the risk of myocardial infarction, stroke, and other cardiovascular events is highlighted in one of the largest and most comprehensive systematic reviews on this topic to date (41). The American Heart Association position statement synthesises the evidence on the impact of psychological factors and emotional states on CVD (42). It highlights that positive psychological traits, such as optimism, positive outlook, and having a purpose in life, significantly reduce the risk of myocardial infarction by 38%, 32%, and 38%, respectively.

All these protective conditions might contribute to a correct cognitive process with less distortions, thus additionally aiding with correct illness perception, which results in self-protective behaviour manifesting in a healthy lifestyle. For the correction of the CVD misperception as optimised risk, communication is needed (see Figure 1. Research Framework)

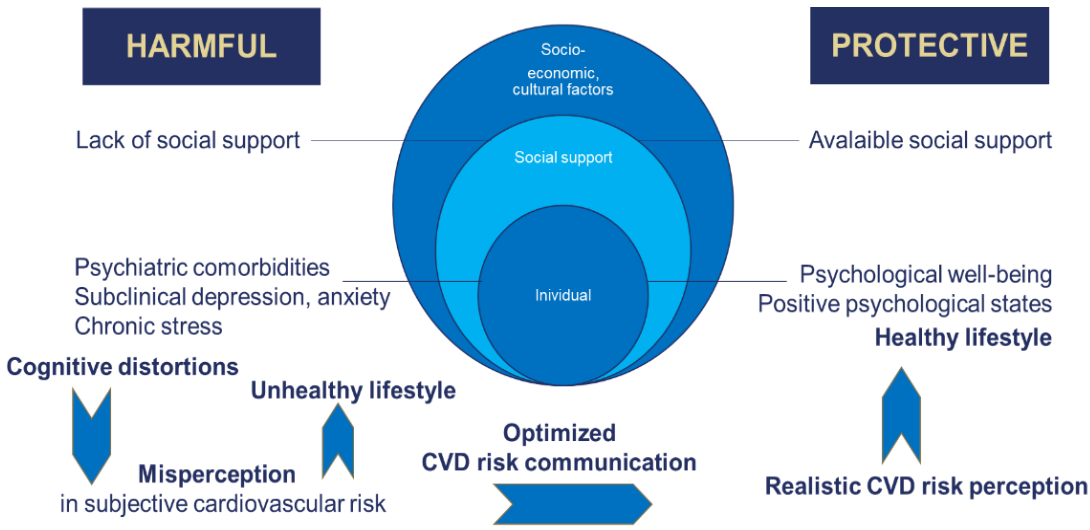


Figure 1: Research Framework

1.3 Health and Illness Perception

Subjective perception of the presence or absence of a disease fundamentally determines our health behaviour. It can motivate or hinder change, and this way plays a pivotal role in health-related decision-making (e.g. participation in screening tests, acceptance of treatments, and adherence to preventive measures). Disease perception is shaped by cultural, social, and individual factors, becoming part of our identity and contributing to our self-perception. Literature data indicate a close relationship between self-perceived health and the perception of a disease or its risk (43-45). A realistic health/disease perception can predict proactive health behaviour. Furthermore, appropriate perception of a disease's risk factors or symptoms significantly impacts the treatment of chronic diseases and the rehabilitation process, considering that an individual's willingness to change is closely linked to their interpretation of their health status.

The perception of a disease is part of the self-regulation process in facing an illness. This suggests that the more accurate and realistic the perception, the more likely it is to encourage action towards restoring or maintaining health. However, this notion does not consider the emotional burdens of recognising an illness. Emotional distress can lead to logical thinking errors, resulting in misconceptions as individuals avoid confronting reality, thus reducing the associated anxiety and distress (46). One such cognitive distortion is the attribution of the disease's cause to reduce self-blame stemming from inappropriate health behaviours, which would impose a significant emotional burden. This aspect is essential concerning the perception of risk regarding cardiovascular diseases. Research has shown that after myocardial infarction, patients tend to focus more on uncontrollable factors (especially stress) when searching for the cause of their illness and overlook the presence of other emphasised modifiable factors (e.g., smoking) (47). At the same time, they perceive previously uncontrolled factors as controllable in the future. However, these distortions are not necessarily maladaptive. The depression that develops after a myocardial infarction is proven to result in worse survival rates; thus, the distortion made to reduce anxiety and distress can also be interpreted as a protective barrier against depression as an attempt at normalisation (48-49). Perceptions regarding the timing and severity of an illness (which can also be distorted elements) predict the speed of re-adaptation regarding the resumption of work and other social roles (50).

Extensive literature data is available regarding the perception of other chronic diseases, indicating how physical and emotional conditions influence it more than the actual status of the disease (51-53). The level of self-rated health (SRH) status can be assessed using a single question standardised by the WHO, which is also part of the European Health Interview Surveys (EHIS): "How is your health in general? Is it..." Very good / Good / Fair / Bad / Very bad). Numerous studies have been conducted using this scale or its partially modified version, which De Salvo et al. summarised in a meta-analysis (54). The analysis, which included 20 scientific publications, found that mortality from any cause (over a span of 2.5 - 21 years) was twice as high among those who rated their health as poor. Previous studies have shown that self-perceived poor health has a negative impact on the effect of risk factor burden in the prediction of acute myocardial infarction (AMI) and stroke (55-56). The associations of SRH in predicting mortality are well established in previous studies (57-58). Jylhä designed a unified conceptual model to understand this phenomenon (59).

Guma created decision trees using a classification methodology and learning algorithms to identify the cognitive and decision-making processes through which we assess our health status (60). According to his findings, the presence/absence of chronic disease was the starting node for both men and women, followed by the ability to perform daily activities, household chores, self-care skills and depressive symptoms as decision nodes leading to the final decision. Gender and age differences were also evident in his research, which serves as a cautionary note regarding using and assessing the question as an independent construct. Huisman and Deeg (61) reached a similar conclusion, emphasising that self-perception of health is a process heavily influenced by psychological factors, whose complex process leads to worse outcomes, as individuals with greater conviction in their health are less likely to seek medical assistance or engage in preventive lifestyle changes.

1.4 Factors Influencing the Subjective Perception of Cardiovascular Risk in Healthy Individuals

The scientific framework outlined above provides a solid basis for understanding the thoughts of a target population, which is classified as primordial and primary prevention in the context of disease perception (i.e. "Patients-In-Waiting”). Examining the attitudes of individuals at high risk for illnesses is critically important from an epidemiological perspective when planning effective interventions. As previously described, the foundation of disease perception is rooted in knowledge, personal context and cultural context, and psychological status, all of which influence the interpretation of health risks (46).

1.4.1 Knowledge About the Disease and Cultural Context

Knowledge about a disease is an essential component of its subjective perception. The manifestations and recognition of symptoms, awareness of risk factors and knowledge about possible ways to prevent the disease contribute cumulatively to the perception. The threat posed by cardiovascular diseases has become almost a part of daily public discourse through informational materials, campaigns, signage and advertisements. However, these often contain unchecked content and suggestions encouraging the reader to use or purchase a particular product. Nonetheless, the information overload makes users feel they have accurate knowledge about the disease and its prevention. Mapping this information can provide interesting and important insights for healthcare providers, as it can highlight misconceptions, fallacies and false beliefs that obstruct adherence or lifestyle changes.

Cultural perceptions regarding health and illness provide fundamental perspectives for members of a society in interpreting disease. In Western medicine, the thinking is fundamentally based on a biomedical perspective. This significantly differs from the moral approach of Eastern countries regarding the possible explanations for diseases and healing. Embedded within culture and religion, identity and self-image establish feelings of resilience or vulnerability (46). In addition, beliefs about human dignity and self-worth play an important role in self-care and self-regulation ("Am I, as an individual, worthy of taking care of me?").

1.4.2. The Role of Social Support in Health and Illness

Human beings are inherently social creatures. From birth, we rely on others for survival. A significant body of literature indicates that social support is essential in our adult lives for health behaviours, maintaining health, and overall well-being (62). Social relationships can positively influence health through stress reduction and primary effect models. According to the stress reduction models, social relationships provide psychological and material resources that help individuals cope with stress. A crucial factor for those receiving help is the feeling that assistance is available during stressful situations. The belief that support can be accessed when needed can reduce emotional and physiological burdens or maladaptive behaviours in response to specific events. Social relationships can positively influence an individual's health behaviours, encouraging regular exercise, healthy eating and quitting smoking. Maintaining contact with others positively impacts emotional regulation, increases the likelihood of positive emotions and decreases intense and prolonged negative emotions (63).

Studies focusing on the positive effects of social relationships have examined two types of social influences (which affect our health and well-being): social integration and social support. Social integration covers participation in a wide range of social relationships, characterised by the number of relationships, frequency of interaction and structure (e.g. size, density) (64). Social support is the experience of being loved, respected, and valued by others, and of being part of a social network that is based on mutual help and obligation (64-65). It has been shown that those with strong social connections are 50% more likely to survive compared to those with weaker connections, and the latter group is also more likely to die from cardiovascular causes (66-67). Holt-Lunstad, Smith and Layton also report in their meta-analysis that individuals with stronger social connections have a 50% higher chance of survival than their lonely or poorly connected peers (68). Interestingly, this was predominantly not determined by the spousal relationship (or cohabitation) but rather by social embedding, the presence or absence of diverse and multifaceted social connections. Furthermore, the meta-analysis also showed that low levels of social support and social integration impact the onset, progression, and mortality of cardiovascular diseases, as well as increase the risk of developing hypertension and high pulse rates (63,69-70).

The absence or shallow level of social support indicates social isolation. This includes unmarried individuals who live alone and have a minimal quantity and quality of relationships with relatives, friends, or other external individuals. Loneliness and a lack of social connections can lead to long-term allostatic overload, initiating inflammatory processes in our bodies and resulting in various diseases, such as cardiovascular conditions (71-74).

Adult social isolation and loneliness are well-known sources of chronic stress, and they present a 1.5 times higher risk of ischemic heart disease and mortality in healthy individuals (75). Poor social support and social isolation make people more likely to be depressed, have high blood pressure, be overweight, and suffer from CVD (76-80).
Moreover, despite technological advancements and globalisation, which theoretically expand social connections, social isolation is increasing. Therefore, examining the socially embedded nature of relationships and their effects on health should be prioritised for future research.

1.4.3 Attempts to Cope with Danger-Induced Distress: Heuristics and Cognitive Biases

Classical health psychological models help us to understand the subjective disease risk estimation process (81-82). The final result of risk estimation is significantly influenced by cognitive biases intertwined with emotions. Due to unrealistic "optimistic" or "pessimistic" bias, individuals tend to conclude that they are less or higher at risk than others, which affects human behaviour and attitudes toward managing health problems. "Pessimistic" bias is influenced by anxiety and fears, which can hinder health actions and behaviour change (83-85). Both models describe subjective disease risk assessment as critical to personal health decision-making towards protective health behaviour actions. As an essential aspect of risk estimation and communication, some valuable research studying the effects of this process found that no long-term psychological consequences were observed after CVD screenings (86-89). Earlier studies have investigated personal health decision-making based on subjective disease risk perception and assessment (82-83, 90).

1.5 Cardiovascular Risk Communication and Education

The 2021 Cardiovascular Disease Prevention Guide of the ESC classifies systematic CVD risk assessment as class I, level of evidence C for men over the age of 40 and women over the age of 50 years when risk factors are present. 10-year fatal and nonfatal CVD risk assessment in apparently healthy individuals under the age of 70 years as class I, level B evidence. This guide describes the importance of individual risk assessment followed by appropriate communication, considering, among others, patients' educational level and numeracy skills, by highlighting the role of subjective risk perception (91). However, optimal communication of CVD has its difficulties, as understanding one's own disease risk is influenced by convictions and beliefs about oneself, resulting in self-perception as introduced above.

The goal of risk communication is to enable patients to estimate their cardiovascular risk as closely as possible to the objective risk using information and communication materials. that the patient a) can easily understand (corresponding to their intellectual abilities, text comprehension and numerical skills), b) go beyond mere information transfer, c) can relate to personally, d) reduce cognitive biases and e) do not increase the patient's anxiety.

Accurate risk perception, thus well-targeted risk communication, can be beneficial in initiating change; however, later on, other factors play a more significant role in the self-regulation process. This experience shows a growing need for increasingly complex health psychology interventions (92). Knowing how disease is perceived can also provide a good foundation for planning interventions. However, we cannot create individually tailored programs; optimised preventive interventions can be designed by clustering (93).

The first step in optimal cardiovascular risk communication is assessing objective risk which is a medical task. Online calculators (Heart Age, Vascular Age, Framingham, ASCVD) provide an excellent basis and offer valuable assistance. However, relevant research indicates that merely communicating risk (e.g. in ratio, or categorised as "low, middle, high") does not yield significant changes without appropriate education (94).

1.6 Evidence-based psychological interventions for behavioural change

Meta-analyses revealed that cognitive-based techniques can effectively increase self-efficacy and physical activity (95-96). Specific techniques associated with higher self-efficacy and physical activity levels include action planning, providing instruction, and reinforcing (96). For medication adherence, interventions using motivational interviewing and other cognitive techniques showed significant improvements (97). The effectiveness of these interventions appears consistent across different populations and delivery methods (97). Self-determination theory (SDT)-based interventions have shown promise in promoting health behavior change. Meta-analyses have found that these interventions produce small-to-medium positive effects on SDT constructs, health behaviors, and physical and psychological health outcomes (98). Computer-tailored and online interventions, which are cost-effective and have wide reach, can also be effective in facilitating health behavior change (99-100). Key strategies in SDT interventions include providing autonomy support, fostering need satisfaction, and enhancing autonomous motivation (101). Factors influencing intervention effectiveness include delivery format (one-on-one vs. group), participant age, intervention duration, and the number of behavior change techniques used (100-101). While the overall effects of SDT-based health interventions are modest and heterogeneous, they demonstrate the potential of this approach in promoting positive health outcomes (98).

2. Objectives

Conceptual framework

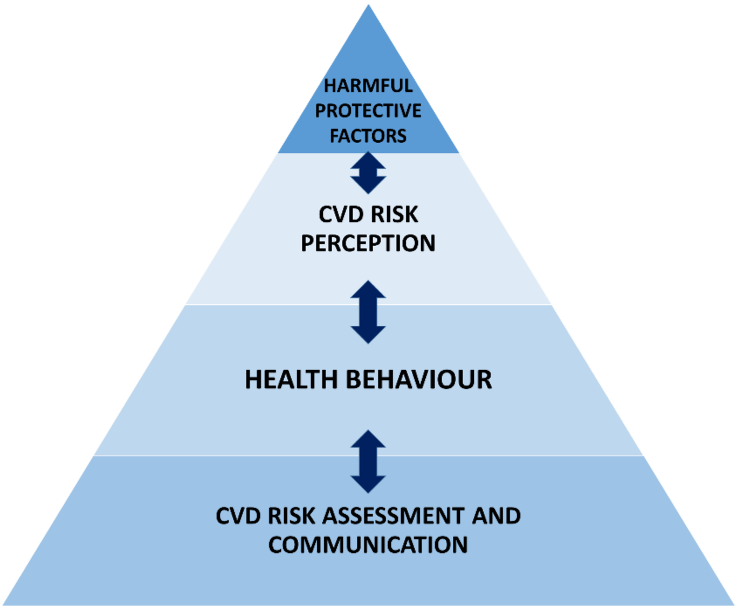


Figure 2. Schematic representation of the conceptual framework

So far, to the best of our knowledge, no multifaceted insight into the Hungarian population has been conducted regarding cardiovascular risk. There is a high need for research results in the Hungarian population for well-planned and evidence-based interventional programs. Thus, our main objective was a multifaceted investigation of our Hungarian sample from a health-psychological perspective, involving the most relevant aspects from a cardioprotective view.

This dissertation aims to explore, on one hand, the protective and harmful psychosocial factors contributing to cardiovascular risk perception and awareness as well as health behaviour, and on the other hand, to explore the different types of cardiovascular risk perception and the effect of cardiovascular risk communication to the change of health behaviour (Figure 2. Schematic representation of the conceptual framework).

Over the course of the several years this research took place, we revised and validated a social support questionnaire to measure health-related social support more accurately. Additionally, we validated another psychological measurement tool, the Attitudes and Beliefs about Cardiovascular Disease (ABDC) questionnaire, within a healthy Hungarian sample to ensure the use of more precise instruments in relevant research.

Study 1. <u>Protective psychological factors</u>: "Effect of health-related social support on health behaviour and psychological status" (validation of a new questionnaire) explores the associations of health-related social support with health behaviour and psychological factors related to cardiovascular diseases. Furthermore, the Multidimensional Perceived Social Support Scale (MPSS) was modified and validated in the health domain (MPSSH).

Study 2. **Effect of risk assessment and risk communication:** "Cardiovascular Risk Assessment and Health Behavior Over a 7-Year Period" is a follow-up study of the Budakalasz Epidemiology Study (BES) population (see Methods section for details). We aimed to explore the health status change of the participants after seven years of their cardiovascular risk assessment and risk communication.

Study 3. Harmful psychological states: "The Association of Cardiovascular Risk Perception with Depression and Subjective Stress". This study was designed to provide a reliable and valid assessment of subjective risk perception as an important part of preventing and rehabilitating CVD. The present study aimed to examine the psychometric properties of the Hungarian version of the ABCD Risk Questionnaire, as this recently developed questionnaire fulfils these requirements. We also investigated psychological status in relation to cardiovascular attitudes and beliefs.

Study 4. Risk perception: "Perception Gap: Differences and Associated Factors Between Objective Risk and Subjective Risk Perception" aimed to investigate the discrepancy between objective and subjective cardiovascular risk assessments and their possible consequences on health behaviours.

Study 5. Protective psychological factors and health behavior: "Structural Equation Modelling: Examining Long-term Sustained Health Behavior' focuses on the role of psychological states in the development of cardiovascular disease, exploring the potential of positive psychological factors to reduce the risk of cardiovascular disease. Psychological well-being is also associated with the improvement and long-term sustainability of health behaviours that prevent CVD and thus serves as a starting point for preventive interventions. Based on this approach, in our follow-up study, we aim to examine the contribution of psychological well-being to long-term health awareness in an SEM (Structural Equation Model).

3. Methods

3.1 Sample and procedure: a comprehensive overview

The study is a longitudinal, three-step research conducted with mixed methods (cross-sectional and longitudinal). The detailed description of the sample is introduced in the Sample and Procedure section for the individual studies. The research is based on the BES conducted between 2012 and 2014 (102). The BES was a comprehensive, voluntary participation-based cardiovascular screening program targeting the adult population of Budakalász, which included a health questionnaire, non-invasive measurements (anthropometry, echocardiogram, carotid artery ultrasound, blood pressure, ankle-brachial index), as well as venous blood sampling and laboratory tests. By January 2014, 2420 individuals (30% of the population, 41.2% male (n=996; average age: 54,0±15,0), 58,8% women (n=1424, average age:55,3±14,6) average age 54.8±14,8 years) were examined, and their cardiovascular risk was assessed using the Framingham risk scoring system. The result was communicated in written feedback. The implementation of this study was not part of this thesis; however, data retrieved were partially used in Study 3 and Study 5 (Step 1).

In 2019, as a follow-up to the BES conducted between 2012 and 2014, a questionnaire survey (n = 502) was carried out within the framework of the National Heart Program (Step 2/a). In 2018, a study was conducted (n=507) to validate two new psychological questionnaires for social support in the health domain (MPSSH, ABCD) (Step 2/b.). Step 1. and Step 2. are represented in Figure 3.

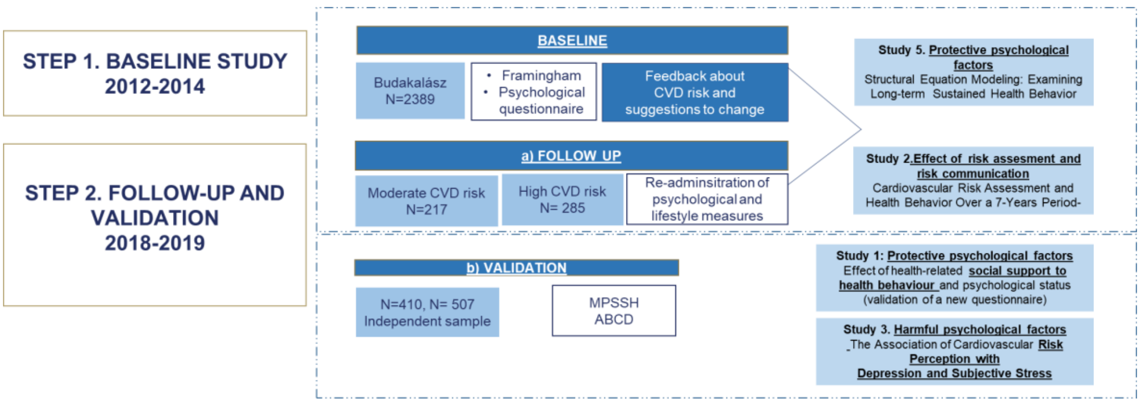


Figure 3. Step 1. and Step 2. of the Budakalász Study

The Expanded Budakalász Study 2023-2024 (EBS) involved following up on the BES and expanding the study sample with two additional populations (residents of the 9th district and employees of Semmelweis University) (Step 3., see Figure 4).

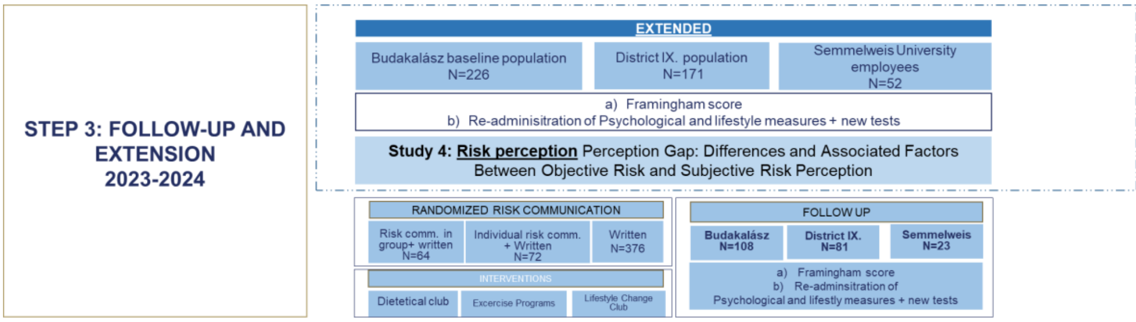


Figure 4. Step 3. of the Budakalász Study

3.2 Measures

This section will list the measurement tools used for the entire research. When describing the methods of each study, I will only mention the measurement tool and present the relevant psychometric indicators. The internal consistency of psychological tests for this population was checked with a reliability test, and the value was reported in Cronbach's Alpha (0.60 - 0.70 and above is acceptable, 0.80 and above considered as good and 0.90 and above is excellent).

Medical Measures

Framingham Risk Score (FRS)

The Framingham Heart Study is a continuous cardiovascular study that resulted in a prediction tool developed to estimate a person's 10-year cardiovascular risk (103). Participants were categorised into three risk groups: low-risk (<10%), middle-risk (10–20%), and high-risk (>20%). Although there are other new tools, even those designed for European populations (SCORE2), we have decided to use the Framingham method, on the one hand, because the participants of the BES baseline study received their cardiovascular risk classification based on the Framingham assessment, so they were familiar with its results. On the other hand, the Framingham score is the preferred tool for risk communication (104-105).

Laboratory Examination

During the blood tests, samples were analysed for blood lipids, including TC, LDL, HDL, triglycerides, glucose, and Haemoglobin A1c (HbA1c). In the absence of an LDL determination, a calculated LDL value was used.

Blood Pressure

Blood pressure was measured in a supine (BES) and sitting (EBS) position during the primary examination and in a seated position for subsequent tests approximately 30 minutes after arrival at the location. The results of three consecutive measurements were recorded, and their average values were used for the analyses.

Body Composition Measurement

Body composition measurements were taken during all subsequent examinations, except for the basic examination, within 20-25 minutes after arrival. The InBody 270 device was used for the measurement (106). A trained dietitian or a dietitian student conducted the assessment. After the examination, the report generated by the device was printed, and the interpretation and communication of the results were carried out by the person performing the measurement, after which the report was provided to the participant.
The following outcome data were recorded in the database: InBody score, lean body mass, muscle mass, body fat mass, visceral fat level, risk of obesity (%), and BMI.

Psychological Measures

Hungarian Center of Social Sciences (HCSS) Questionnaire: The HCSS questionnaire is a 128-item measurement tool based on the questionnaire used by the Central Statistical Office during the EHIS. The items in the questionnaire cover the following main topics: 1) socioeconomic status; 2) encounters and connections with healthcare; 3) lifestyle (training, eating, alcohol, smoking); 4) psychological factors; 5) factors influencing quality of life. Unchanged questionnaire was administered during BES and selected items were used during EBS.

Short Form Health Survey (SF-36) shortened version: The Short Form Health Survey is a 36-item, patient-reported survey of patient health (107). As part of the HCSS questionnaire, it was administered as a baseline. Four of the eight mental health/psychological well-being scale items were selected based on a preliminary scale analysis of the BES dataset to measure psychological well-being. Items were prompted as follows: "In the past 2-4 weeks, how often did you feel (1) calm and peaceful, (2) energetic, (3) happy, (4) tired?" Items were rated on a 5-point scale ranging from 1 = never to 5=always, the "tired" with reversed scoring.

World Health Organization (WHO) Well-Being Scale (WHO-WB): The 5-item shortened WHO Well-Being Scale is one of the most frequently used self-report instruments to measure subjective mental well-being (108-109). Participants used a four-point Likert scale to answer questions (0 = not at all applicable, to 3 = fully applicable). Higher total score indicates better mental well-being.

Perceived stress (PSS10): PSS10 is a ten-item questionnaire which captures how individuals perceive stress (110). Respondents rated the statements on a 5-point Likert scale. The higher the total score, the higher the perceived stress. We used a shortened 4-item version of this scale.

Beck Depression- Short form (BDI-9): The shortened and validated version of the Beck's Depression Inventory consists of 9 items (111-112). This scale identifies depressive symptoms and their severity and is widely used in research.

Multidimensional Perceived Social Support Scale for Health (MPSSH): The original MPSS is a brief, self-report, self-administered questionnaire developed for the subjective measurement of perceived social support (113). This version was further developed and validated by Ocsovszky et al. (114) to measure health-related social support.

Attitudes and Beliefs of Cardiovascular Disease (ABCD): The ABCD Risk Questionnaire has 18 items. Eight items measure CVD risk perceptions, seven relate to perceived benefits of healthy lifestyles, and three assess healthy eating intentions. The response options are presented on a 4-point scale and range from 1 "strongly disagree" to 4 "strongly agree." The knowledge scale consists of eight statements on CVD risk (for

example, "Walk and gardening are considered types of exercise that may lower the risk of myocardial infarction") with the answer options 0 = false and 1 = true, which indicates whether the participant agrees or disagrees with the statement.
Our research group validated and adapted this measure to Hungarian language (115). The original questionnaire was developed by Woringer et al. to create a validated and reliable measurement tool regarding the population's knowledge of cardiovascular risk for the National Health Service Health Check Program (116).

Direct Memory Recall (DMR): We administered a short questionnaire to assess how participants remembered their cardiovascular risk after completing their CVD assessment during the BES 2012-14. The items included in this study can be found in Appendix 1.

Self-Rated Health (SRH): Subjective Health Status: A single question developed and approved by WHO measured the respondent's evaluation of their own health: "Overall, how would you rate your health?" The five response options ranged from very poor to excellent.

Subjective Risk Perception of Cardiovascular Diseases (SRPcvd): We also asked a single question about subjective CVD-related risk routinely used in CVD-related studies (117-118). The question read, 'What do you think the risk of you getting any kind of CVD within the next 10 years is?' 0=low risk, 1=medium risk and 3=high risk answers can be given.

Subjective Financial Situation (SFS): The respondent's assessment of their own financial situation was measured on a ten-point scale, with endpoints: 1 = very poor, 10 = very good.

Satisfaction with Life Scale (SWLS): A single-item questionnaire was used. Respondents provided ratings on a 10-point Likert scale, with higher scores indicating greater satisfaction. The psychometric evaluations of single-item measures have been shown to converge with multi-item scales, demonstrating adequate performance (119).

Health Awareness Index (HAI)*:* HAI was developed in our previous research (120) to measure overall health behaviour. The items for the index were selected from the HCSS questionnaire. We have administered it during our two data collection processes (2012–2014- baseline; 2019- follow-up). Items used for HAI: (1) How would you generally describe your health? (very bad, bad, satisfying, good, and very good) (2) How much do you think you can do for your health? (nothing, not too much, much, and very much) (3) How many days have you engaged in intense physical activity in the past seven days? (4) How often do you consume vegetables and fruits? (less frequently than once a week, at least once a week, at least four times a week, daily, multiple times a day).

3.3 Sample and Measures

3.3.1 Study 1: Protective psychological factors: Health behaviours and social support as important factors from a cardioprotective perspective

3.3.1.1. Sample and procedure

The data was conducted using convenience sampling in the fall of 2018 as part of the National Heart Program. The research questionnaire was administered online through the LimeSurvey platform developed by Carsten Schmitz, which was hosted on the secure server of the University of Szeged. We received prior ethical approval from the ETT TUKEB for the research (TUKEB approval number: 53056-2/2018/EKU). The inclusion criterion was an age over 35 years and not being under treatment with a psychiatric disorder.

Regarding sampling, our goal was to achieve maximum heterogeneity. Before beginning the questionnaire, participants who wished to participate were given comprehensive information indicating that their involvement in the study was voluntary and anonymous. Respondents could start the questionnaire only after providing their informed consent.

In total, 1,393 potential respondents accessed the online survey site and presumably read the information sheet, of whom 766 voluntarily provided informed consent and began the assessment. Of those, 559 completed the online survey, meaning 207 quit the assessment, the great majority shortly after starting. During data processing, 48 respondents under 35 had to be excluded since the online questionnaire system accepted respondents under 35. In addition, four participants had missing responses that could not be imputed (e.g., health status responses). The data of 507 participants were analysed.

28.0% of the participants, 142 persons were men, 70.8%, 359 were women; six of the 507 did not give their gender. The average age was 50.01± 8.14 years. 58.8% (n= 298) of the sample had higher education, 25.0% (n=127) had secondary education, and 16.2% (n=82) had a basic education.

3.3.1.2 Measures

1) Multidimensional Perceived Social Support Scale for Health (MPSSH). Cronbach's alpha: 0.907.
2) Subjective Health Status (SRH)
3) Subjective Financial Situation (SFS)
4) World Health Organization (WHO) Well-Being Scale (WHO-WB). Cronbach's alpha: 0.856.
5) Perceived stress (PSS10). Cronbach's alpha: 0.805.
6) Beck Depression Short Form (BDI-9) Cronbach's alpha: 0.835.

3.3.2 Study 2: Risk assessment and risk communication: Cardiovascular Risk Assessment and Health Behavior Over a 7-Year Period

3.3.2.1. Sample and procedure

In the follow-up to the baseline survey conducted in Budakalász from 2012 to 2014, additional data was collected in 2019 as part of the National Heart Program. The present sample (n = 502) was drawn from the initial sample (n = 2400). The inclusion criterion was defined as having a medium or high cardiovascular risk. Framingham risk scores were available for 2389 individuals from BES collected during 2012–2014. Based on these scores, 995 individuals were classified as having low risk, 611 as having medium risk and 783 as having high cardiovascular risk. A professional data collection company reached out to a list of 1394 individuals initially characterised as having medium or high cardiovascular risk. The study's objective was to conduct a follow-up with a minimum of 500 randomly selected individuals in a maximum of 60 a 40% women-to-men ratio. Of the originally included 507 participants, 5 had to be excluded due to missing responses. During data cleaning, personal information gathered in 2012–2014 was matched with data collected in 2019. The study received ethical approval from the ETT TUKEB (TUKEB approval number: 53056-2/2018/EKU). Among them, 217 individuals (43%)

had medium, and 285 individuals (57%) had high cardiovascular risk. Based on gender distribution, the study included 225 men (45%) and 277 women (55%), aged between 45 and 98 years. The average age is 71±8.57 years. The majority of the population was single (n = 277; 55.17%) and had a basic level of education (n = 178; 35.45%).

3.3.2.2 Measures

1) Institute for Social Research (HCSS) Questionnaire.
2) World Health Organization (WHO) Well-Being Scale (WHO-WB). Cronbach's alpha: 0.829.
3) Perceived stress (PSS10). Cronbach's alpha: 0.777.
4) Beck Depression- Short form (BDI-9). Cronbach's alpha: 0.900.
5) Attitudes and Beliefs of Cardiovascular Disease (ABCD). Perceived Cardiovascular Risk Cronbach's alpha: 0.870, Perceived Benefits of Change and Willingness to Change Cronbach's alpha: 0.664, Healthy Eating Intentions Cronbach's alpha: 0.698.
6) Multidimensional Perceived Social Support Scale for Health (MPSSH). Cronbach's alpha: 0.865.
7) Direct Memory Recall (DMR)

3.3.3 Study 3: Harmful psychological states: The Association of Cardiovascular Risk Perception with Depression and Subjective Stress (ABCD validation)

3.3.3.1. Sample and procedure

The sample was collected between October and December 2018 using the online survey tool LimeSurvey. The approval of the Ethics Committee of the Council of Health Sciences (ETT- TUKEB, 53056-2/2018/EKU) was obtained prior to the study. BA (Bachelor of Arts) and MA (Master of Arts) psychology students of the University of Szeged disseminated the online research form in their online social networks (mainly via Facebook posts and personal email lists) as part of their student research. The inclusion criteria were being a Hungarian citizen over the age of 35 and not being treated for a psychiatric disorder. During the screening process, participants were adequately informed about the general topic of the study and they gave their informed consent according to the

Declaration of Helsinki before starting the online questionnaire form. In total, 1,393 potential respondents accessed the online survey site and read the information sheet, of whom 766 signed the informed consent and began the assessment. In sum, 559 participants completed the online survey, and 207 of them quit the assessment, with most of them doing so shortly after the start. During the data processing, we had to exclude 48 respondents who were below 35, since the online questionnaire system also accepted respondents who were younger than 35 years. Additionally, 101 participants had missing responses that could not be imputed (e.g., health status responses). In total, 410 participants could be included in the present analyses. They were 35 years of age or older and had complete data for the variables in the analyses.

Participants who were included had a mean age of around 50 years (49.53±8.09) with a range from 35 to 76 years. About two-thirds of the respondents were female (67.6 %, n=277). The largest part of the sample consisted of respondents with college or university- level education (60.2%, n=247), followed by high school graduates (25.4%, n=104) and participants with elementary- level education (14.4%, n=59).

3.3.3.2. Measures

1) World Health Organization (WHO) Well-Being Scale (WHO-WB). Cronbach's alpha: 0.845.
2) Perceived stress (PSS10). Cronbach's alpha: 0.806.
3) Beck Depression – Short form (BDI-9). Cronbach's alpha: 0.849.
4) Attitudes and Beliefs of Cardiovascular Disease (ABCD). Perceived Cardiovascular Risk Cronbach's alpha: 0.945, Perceived Benefits of Change and Willingness to Change Cronbach's alpha: 0.822, Healthy Eating Intentions Cronbach's alpha: 0.756.
5) Subjective Risk Perception of CVD (SRPcvd).

3.3.4. Study 4: Risk perception: Perception Gap: Differences and Associated Factors Between Objective Risk and Subjective Risk Perception

3.3.4.1. Sample and procedure

As a continuation of BES, a new research phase (Extended Budakalász Study) started in 2023, and new data collection was conducted. This investigation does not use data from the previous stages of the research. Participants (N=376) were recruited from three populations (Budakalász, IX. district and Semmelweis employees) based on the inclusion criteria (age 45–65 years. All participants underwent blood sampling and physical examination. Laboratory screening (TC, triglycerides, LDL, HDL, blood glucose levels, and HbA1c obtained within the last 4 months) were done by general practitioners. Written and oral information was provided to the participants during the first visit, and informed consent was obtained. Physical examinations included blood pressure and weight measurements and InBody analysis. Concurrently, a questionnaire was administered in two parts: 1) administered by the examiner during the physical examination and 2) self-completed by the participants before the physical examination.

Of the 393 participants included in data analysis, 17 were excluded due to missing laboratory parameters (13 participants) and missing answers to the subjective risk question (4 participants). Among the remaining 376 participants, 132 were female and 244 were male, with an average age of 54.36±6.34 years. The majority were in a relationship (82%) and had a higher education degree (64.6%).

3.3.4.2 Measures

1) World Health Organization (WHO) Well-Being Scale (WHO-WB). Cronbach's alpha: 0.837.
2) Perceived stress (PSS10). Cronbach's alpha: 0.75.
3) Beck Depression- Short form (BDI-9). Cronbach's alpha: 0,839.
4) Subjective Risk Perception of CVD (SRPcvd).
5) Satisfaction with Life Scale (SWLS).

3.3.5 Study 5: **Protective psychological factors** and health behaviour: Structural Equation Modeling: Examining Long-term Sustained Health Behavior

3.3.5.1. Sample and Procedure

The current analysis used data from the baseline study (BES) and the follow-up study (Study 2). The same sample was used as in Study 2. In the follow-up to the baseline survey conducted in Budakalász from 2012 to 2014, follow-up data were collected in 2019 as part of the National Heart Program. The present sample (n = 502) was selected from the initial sample (n = 2400). The inclusion criteria were: having a medium or high cardiovascular risk. Framingham risk scores were available for 2389 individuals from the baseline study (BES). The study's objective was to conduct a follow-up with a minimum of 500 randomly selected individuals in a maximum of 60 a 40% women-to-men ratio. During data cleaning, personal information gathered in 2012–2014 was matched with data collected in 2019.

995 individuals were categorised as low risk, 611 as medium risk and 783 as high risk. A professional data collection company reached out to a list of 1394 individuals initially characterised as having medium or high cardiovascular risk. Of the originally included 507 participants, 5 had to be excluded due to missing responses.

Out of the 502 participants, 217 individuals (43%) had medium, and 285 individuals (57%) had high cardiovascular risk. Based on gender distribution, the study included 225 men (45%) and 277 women (55%), aged between 45 and 98 years. The average age is 71±8.57 years. The majority of the population was single (n = 277; 55.17%) and had a basic level of education (n = 178; 35.45%).

3.3.5.2 Measures

1.) Short Form Health Survey (SF-36) shortened version (Cronbach's alpha of 2012/2019: 0.624/0.782)

2.) Health Awareness Index (HAI).

3.4. Statistical analysis

3.4.1. Study 1: **Protective psychological factors:** Health behaviours and social support as important factors from a cardioprotective perspective

Statistical analysis was performed using IBM SPSS 25.0 Windows (IBM Corp., Armonk, NY, USA). To validate the scale of MSPSSH, we conducted a confirmatory factor analysis (CFA), defining the model with three intercorrelated latent factors. These factors represented four items, each measuring support received in relation to health from family members, friends, and people in general. Following this, we employed multiple logistic and linear regression models to examine how health-related social support predicts the amount of intensive physical activity and mental health indicators.

3.4.2 Study 2: **Risk assessment and risk communication:** Cardiovascular Risk Assessment and Health Behavior Over a 7-Year Period

Statistical analysis was performed using IBM SPSS 25.0 Windows (IBM Corp., Armonk, NY, USA) and ROPstat 2.0 statistical software (http://ropstat.com). To analyse and describe the relationships between variables, we conducted Spearman correlation analyses, Welch's t-test, Mann–Whitney U-test, independent samples t-test, paired samples t-test (Wilcoxon signed-rank test), chi-squared test, and analysis of variance with partial eta-squared and its corrected version. The internal consistency of the psychological tests for the current population was verified in SPSS using a reliability test, with the value reported as Cronbach's alpha. We accepted or rejected the use of items based on the expected correlation between them.

We created HAI indices using factor analysis to examine changes in health behaviours. The possible variables for the analysis were selected based on professional considerations, with the primary aim of investigating the health-related questions from 2012 and 2019 and exploring the organising principles of variable clustering within this specific sample. We examined the shifts in these indices from 2019 in relation to their status in 2012, categorising the subjects of the sample into groups (deteriorating, stagnant, improving) based on this analysis. The categories were then compared to the Framingham risk determined in 2012 (medium, high) to assess how classification influenced the movement of the indices.

3.4.3 Study 3: Harmful psychological states: The Association of Cardiovascular Risk Perception with Depression and Subjective Stress

Exploratory and confirmatory factor analyses (EFA and CFA) were conducted by the freeware statistical package Jamovi 1.0.5 (https://www.jamovi.org). Model fit of the CFA was evaluated based on a series of indices; the X2 test (non-significant results indicating adequate fit), the Tucker- Lewis and Comparative Fit Indexes (TLI and CFI, respectively; values between 0.90 and 0.95 indicate acceptable fit, while values greater than 0.95 suggest good fit) and the root mean square error of approximation (RMSEA); values below 0.08 indicate an acceptable fit, while values below 0.05 indicate a good fit). All other statistical computations, including bivariate Pearson correlation coefficients and group comparisons (t-tests and one-way analysis of variances), were carried out using the software package IBM SPSS 23.0 Windows (IBM Corp., Armonk, NY, USA).

3.4.4 Study 4: Risk perception: Perception Gap: Differences and Associated Factors Between Objective Risk and Subjective Risk Perception

For our analysis, we created groups labelled as "realistic," "optimistic," and "pessimistic" based on the concordance and discrepancies between FRS (low, medium, high risk) and SRPcvd (low, medium, high). Statistical analyses were performed using IBM SPSS 25.0 Windows (IBM Corp., Armonk, NY, USA.) software package. Chi-square and Kruskal-Wallis non-parametric tests were employed because our variables did not show a normal distribution. To determine the differences among the three groups, we performed Dunn-Bonferroni *post hoc* analyses. Binary logistic regression was performed to analyse the predictors of over and underestimation of CVD risk.

3.4.5 Study 5: Protective psychological factors and health behavior: Structural Equation Modeling: Examining Long-term Sustained Health Behavior

We have used Structural Equation Modelling (SEM), which encompasses a set of various methods. SEM includes building a model, an informative representation of an observable or theoretical phenomenon. In this model, different aspects of a phenomenon are theoretically constructed to be interconnected with a structure (121-122). SEM is comparable yet more potent than regression analyses; this method investigates linear causal connections between variables while also considering measurement error. SEM offers a fresh viewpoint for data analysis and the potential to enhance medical and health science research (123). We also aimed to use power analysis to ensure sufficient sample size to create a stable model. The statistical analyses were performed using JAMOVI 2.4.11 (https://www.jamovi.org) statistical software and semPower (https://cran.r-project.org/). For an integrated analysis of health behaviour, we created HAI and applied discrete-time structural equation modelling, with a particular emphasis on cross-lagged relationships. Based on our previous results, we aimed to investigate the changes in factors constituting health awareness and their relationship with psychological characteristics and a more thorough analysis of the cardiovascular risk assessment and the health awareness factor (124).

4. Results

4.1 Study 1: Protective psychological factors: Health behaviours and social support as important factors from a cardioprotective perspective

Descriptive

A total of 559 respondents were recruited. However, only the data of 507 participants were used for the present analysis; 52 participants were excluded due to age and significant filling gaps. 28.0% of the participants, 142 persons were men, 70.8%, 359 were women; six of the 507 did not give their gender. The average age was 50.01 ±8.14 years. 58.8% (n= 298) of the sample had higher education, 25.0% (n=127) had secondary education, and 16.2% (n=82) had a basic education.

In terms of marital status, 140 people (27.6%) lived alone, while 365 people (72.0%) lived with a spouse, partner or other family member, and two people who participated in the study did not provide an answer. We also explored the presence of cardiovascular diseases in the respondents. In their responses to the detailed, self-reported health status questionnaire, a total of 183 people (36.1%) indicated that they had one or more of the following symptoms: irregular heartbeat, cardiac arrhythmia, atrial fibrillation, any other heart disease, hypertension. The respondents also indicated whether they currently smoked (376 people, i.e. 74.2% no, 129 people, i.e. 25.4% yes, and 2 people did not respond).

Correlations

Regarding the subjective perception of social support, support from family and friends is the most important. However, to a non-significant degree, age weakly and negatively correlates, indicating that the perceived support somewhat decreases with age. The same negative trend is observed concerning depression and perceived stress: the higher the score achieved, the lower the level of perceived support. However, intensive physical activity ($\rho = 0.097$, $p < 0.05$), SRH ($\rho = 0.270$, $p < 0.001$), and well-being ($r = 0.322$, $p < 0.001$) show positive associations (stronger with support from friends), meaning that respondents report more physical activity when perceiving higher levels of support. There is no significant difference in the level of social support regarding gender and educational attainment; in terms of social status, those living with family report higher support from both family ($t = -3.87$, $p < 0.001$) and other individuals ($t = -2.72$, $p < 0.01$). The social support of smokers does not significantly differ from that of non-smokers (See Table1:

Correlations between different types of health-related social support and socio-demographic, health characteristics, and mental health indicators).

Table 1. Correlations between different types of health-related social support and socio-demographic, health characteristics, and mental health indicators

	MPSSH		
Correlations	family	friends	others
MPSSH family			
MPSSH friend	$0,591^{***}$		
MPSSH others	$0,816^{***}$	$0,670^{***}$	
Age	-0.005	-0.023	-0.047
SRH	$0,244^{***}$	$0,272^{***}$	$0,218^{***}$
Intensive physical activity	$0,135^{**}$	$0,097^{*}$	0.084
BDI-9	$-0,343^{***}$	$-0,316^{**}$	$-0,297^{***}$
PSS10	$-0,347^{***}$	$-0,306^{***}$	$-0,303^{***}$
WHO-WB	$0,372^{***}$	$0,322^{***}$	$0,311^{***}$
Group comparision			
men m (SD)	4,39 (0,86)	3,96 (0,99)	4,42 (0,75)
women m (SD)	4,24 (0,91)	4,05 (0,99)	4,33 (0,83)
t	1.69	-0.88	1.12
basic level m (SD)	4,45 (0,79)	4,05 (0,96)	4,44 (0,75)
intermediate level m (SD)	4,20 (0,93)	4,02 (1,00)	4,31 (0,77)
upper m (SD)	4,28 (0,90)	4,03 (1,00)	4,36 (0,84)
F	2.07	0.02	0.67
single m (SD)	4,04 (1)	3,93 (1)	4,2 (0,89)
married/lives in family m (SD)	4,38 (0,83)	4,06 (0,99)	4,42 (0,77)
t	$-3,87^{**}$	-1.34	$-2,72^{**}$
not smoking m (SD)	4,31 (0,87)	4,02 (0,98)	4,38 (0,78)
smoking m (SD)	4,23 (0,95)	4,05 (1,02)	4,29 (0,89)
t	0.91	-0.3	1.15

Abbreviation: MPSSH: Multidimensional Perceived Social Support Scale for Health. ; SRH= Self-Rated Health; BDI-9: Beck Depression Inventory- Short; PSS10= Perceived Subjective Stress; WHO-WB: WHO Well-Being Scale; For SRH and intensive physical activity, Spearman's rho was used, while other correlation coefficients were calculated using Pearson's r.
p < 0.05, ** p < 0.01, *** p < 0.001; for unmarked statistical values, p > 0.05.

Regression models

Intensive physical activity

The results of the regression model (Table 2. Prediction of Intensive Physical Activity in a Multiple Hierarchical Regression Model) indicate that social support received from friends and family concerning health (controlling for gender, age, education, marital status, and SRCS is not statistically significant (Delta R2=.008; F=1.06; p=0.348). However, social support from friends concerning health tends to be positively associated with the amount of intense physical activity (B = 0.205, beta = 0.096, p = 0.093) after controlling for the respondent's gender, age, educational attainment, marital status, and self-reported cardiovascular disease status.

Table 2. Prediction of Intensive Physical Activity in a Multiple Hierarchical Regression Model

	Intensive physical activity		
	B	beta	p
Sex	-0.520	-0.113	0.015
Age	0.024	0.092	0.048
Education basic	-0.869	-0.181	0.005
Education higher	-1.707	-0.402	< 0.001
Married (vs. single)	0.050	0.011	0.821
SRCS	-0.374	-0.088	0.058
MPSSH family	0.033	0.014	0.810
MPSSH friends	0.205	0.096	0.093
Model Summary			
Delta R2 (MPSSH)	0.008	Model R2	0.108
F	1.06	F	4.309
p	0.348	p	< 0.001

Abbreviations: SRCS: Self-Reported CVD status, MPSSH: Multidimensional Perceived Social Support Scale for Health

Smoking

Analysis of the results presented in Table 3. indicates that social support from family members and friends regarding health does not correlate with smoking when controlling for the respondent's gender, age, educational attainment, marital status, and self-reported cardiovascular disease status. Among these variables, only educational attainment demonstrated a significant relationship with smoking; specifically, individuals with higher levels of education are less likely to smoke (B = –1.284, OR = 0.277, p = < 0.001).

Table 3. Prediction of Smoking in a Logistic Regression Model

	Smoking				
	B	OR	95% CI		p
Sex	0.118	1.125	0.672	1.883	0.653
Age	0.001	1.001	0.973	1.031	0.922
Education- basic	-0.559	0.572	0.300	1.088	0.089
Education- higher	-1.284	0.277	0.153	0.500	<0.001
Married (vs. single)	-0.310	0.733	0.440	1.221	0.233
SRCS	-0.321	0.725	0.450	1.167	0.186
MPSSH family	-0.163	0.850	0.609	1.186	0.338
MPSSH friends	0.243	1.275	0.936	1.736	0.123

Model Summary			
Delta R2 (MPSSH)		Model R2	
Cox Snell	0.005	Cox Snell	0.057
Nagelkerke	0.008	Nagelkerke	0.085
Khi2	2.214	Khi2	26.229
p	0.331	p	0.001

Abbreviations: SRCS: Self-Reported CVD status, MPSSH: Multidimensional Perceived Social Support Scale for Health

Psychological status

The social support and psychological indicators revealed (Table 4.) that social support received from family members concerning health is negatively associated with the number of depressive symptoms and perceived stress levels (depression: B = –0.943, beta = –0.219, p = < 0.001; perceived stress: B = –0.172, beta = –0.213, p = < 0.001). Similarly, social support from friends also demonstrated a negative association with depressive symptoms and perceived stress levels (depression: B = –0.599, beta = –0.155, p = 0.005; perceived stress: B = –0.109, beta = –0.150, p = 0.007), controlling for the respondent's gender, age, educational attainment, marital status, and SRCS. Thus, both family and friend support significantly negatively correlated with an individual's depression and perceived stress levels. The stronger the social support experienced, the higher the level of well-being reported. Additionally, social support from family (B = 0.771, beta = 0.236, p = < 0.001) and friends (B = 0.438, beta = 0.152, p = 0.006) also positively associated with well-being.

Table 4. Prediction of Mental Health Indicators in a Multiple Hierarchical Regression Model

	BDI9			**PSS-10**			**WHO-WB**		
	B	beta	p	B	beta	p	B	beta	p
Sex	0.600	0.072	0.104	0.085	0.054	0.228	-0.233	-0.038	0.406
Age	-0.075	-0.160	<0.001	-0.008	-0.088	0.052	0.037	0.106	0.020
Education-basic	-1.726	-0.198	0.001	-0.383	-0.235	<0.001	1.073	0.166	0.008
Education-Higher	-1.101	-0.143	0.018	-0.250	-0.173	0.005	0.490	0.086	0.169
Married (vs. single)	-0.170	-0.020	0.656	-0.051	-0.031	0.486	0.119	0.019	0.680
CVD yes (vs. none)	1.703	0.221	<0.001	0.250	0.173	<0.001	-1.088	-0.191	<0.001
MPSSH family	-0.943	-0.219	<0.001	-0.172	-0.213	<0.001	0.771	0.236	<0.001
MPSSH friends	-0.599	-0.155	0.005	-0.109	-0.150	0.007	0.438	0.152	0.006

Model Summary			
	BDI-9	PSS-10	WHO-WB
Delta R2 (MPSSH)	0.108	0.102	0.116
F	29.187	26.573	29.859
p	<0.001	<0.001	<0.001
Model R2	0.212	0.18	0.191
F	14.362	11.737	12.34
p	<0.001	<0.001	<0.001

Abbreviations: SRCS: Self-Reported CVD status, MPSSH: Multidimensional Perceived Social Support Scale for Health, BDI-9: Beck Depression Inventory- Short; PSS10= Perceived Subjective Stress; WHO-WB: WHO Well-Being Scale

4.2 Study 2: Risk assessment and risk communication: Cardiovascular Risk Assessment and Health Behavior Over a 7-Year Period

Descriptive

The current sample consists of 502 individuals with medium and high cardiovascular risk, assessed using the Framingham estimation tool. Among them, 217 individuals (43%) had medium, and 285 individuals (57%) had high cardiovascular risk. Based on gender distribution, the study included 225 men (45%) and 277 women (55%), aged between 45 and 98 years. The average age is 71 ±8.57 years. The majority of the population was single (n = 277; 55.17%) and had a basic level of education (n = 178; 35.45%).

HAI Index

Regarding HAI, a significant difference was defined as at least one standard deviation from the average. By subtracting the 2012 indices from the 2019 indices, we calculated the value of the change in the HAI. Based on the magnitude of this change, respondents were further categorised according to the standard deviation of the index change observed in the sample: respondents characterised by a value within ±1.0 standard deviation from the sample mean were placed in the "stagnant" category, while those with values beyond this range were considered to show a "deteriorating" (below –1.0 standard deviation) or "improving" (above 1.0 standard deviation) trend in health behaviour change.

The paired sample t-test (Wilcoxon signed-rank test) indicated a significant difference ($p < 0.001$) in the changes of health behaviour indices for all three indices, suggesting that a significant improvement occurred between the 2012 and 2019 surveys across all factors of the health behaviour index (see Table 5. Change of HAI Between 2012 and 2019).

Table 5. Change of HAI Between 2012 and 2019

Results of Health Behavior Index Changes with Paired Sample Testing

	Deterioration (n)	Improvement (n)	Stagnation (n)
Health awareness	23 (75,72)	466 (254,24)	0
Risk behaviour	16 (50,13)	472 (251,09)	10
Medication	86 (185,17)	380 (244,44)	26

Results of Health Behavior Index Changes with One Standard Deviation Difference

	Deterioration (n)	Improvement (n)	Stagnation (n)
Health awareness	23	369	117
Risk behaviour	2	369	127
Medication	11	366	115

n= the frequency of individuals belonging to each category (with the rank average of the Wilcoxon signed-rank test in parentheses).

The association between recalling the results received seven years ago and changes in health behaviour

The analysis produced a Chi-Square statistic (χ^2) of 509.807, with 8 degrees of freedom. The corresponding p-value was <0.001, indicating a statistically significant association between the groups (those who remembered their results and those who did not). Individuals who could recall their examination results took action at a higher ratio regarding lifestyle changes to improve their cardiovascular health. Furthermore, an effect size was calculated using Cramer's V, resulting in a value of 0.7. This effect size is statistically significant and indicates a high magnitude of association (See Table 6: Crosstabulation: Frequency distribution table and Table 7. Chi square test and effect size).

Table 6. Crosstabulation: Frequency distribution table

		DMR Q2			Total
		NA	Action	No action	
DMR Q1	NA	22	-	-	22
	I don't remember at all	79	-	-	79
	Somewhat remember		**49**	70	119
	I remember more or less		**90**	107	197
	I remember exactly		**50**	34	84
Total		101	189	211	501

Abbreviation: DMR: Direct Memory Recall Q1): How well do you remember the level of cardiovascular risk that was reported to you? DMR Q2: Please recall whether you took any action in response to the feedback regarding your cardiovascular risks! (Action/No action)

Table 7. Chi square test and effect size

	action	χ 2	φc
remember	189	509.807	0.713

χ2: Chi-square test, φc: Cramer-V effect size (0.60-0.80, very strong)

4.3 Study 3: Harmful psychological states: The Association of Cardiovascular Risk Perception with Depression and Subjective Stress

Descriptive

In sum, 1393 potential gave informed consent and started the assessment. 207 respondents quit the assessment; thus, 559 participants completed the online survey. 48 respondents below the age of 35 had to be excluded. 101 participants had missing responses that could not be imputed. In sum, 410 entries could be included in the present analyses. The average age was 49.53±8.09.

67.6 % (n=277) pf the participants were female. The most significant part of the sample possessed college or university-level education (60.2%, n=247), followed by high school graduates (25.4%, n=104) and participants with elementary-level education (14.4%, n=59).

Bivariate correlations

The bivariate correlations were predominantly significant and ranged from low to medium. Specifically, higher risk perception was linked to lower self-rated health and well-being, as well as a greater prevalence of depressive symptoms and perceived stress.

Conversely, a contrasting relationship was observed for the Perceived Benefits and Healthy Eating Intentions subscales, although the association strength was generally lower for the latter. Knowledge scores did not correlate significantly with any of the examined characteristics. The patterns of associations presented suggest that the cardiovascular disease-related perceptions, as measured by the ABCD Risk Questionnaire, represent distinct constructs that can be differentiated from mental health indices despite demonstrating some relational connections. See Table 8. Bivariate associations of the subscales).

Table 8. Bivariate associations of the subscales

	ABCD Risk Questionnaire			
	Risk	*Benefits*	*Eating*	*Knowledge*
ABDC Benefits	-0.125***			
ABCD Eating	-0.070	0.336***		
ABCD Knowledge	0.053	0.224***	0.143**	
Age	0.011	-0.042	0.014	-0.073
SRH	-0.451***	0.204***	0.059	0.049
Intense physical Activity	-0.103*	0.204***	0.147***	-0.046
BDI-9	0.409***	-0.219***	-0.129**	-0.085
PSS-10	0.317***	-0.207***	-0.131***	-0.066
WHO-WB	-0.365***	0.228***	0.195***	0.027

**P<0.05, **P<0.01, ***P<0.001*

Abbreviations: ABCD: Attitudes and Beliefs About Cardiovascular Disease; BDI-9: Beck Depression Inventory-Short, SRH: Self-rated Health; WHO-WB: WHO Well-Being Scale

4.4. Study 4: Risk perception: Perception Gap: Differences and Associated Factors Between Objective Risk and Subjective Risk Perception

Descriptive analysis of FRS

A significant proportion of the high-risk group was male (N=44; 78.6%). The age distribution was: 60.05±4.70 years for high-risk, 56.94±5.54 years for medium-risk, and 51.53±5.47 years for low-risk individuals. In the high-risk group, 53.6% (N=30) were nonsmokers, and 46.4% (N=26) were smokers. The high-risk group had the highest BMI values (30.19±5.77 vs. 28.96±4.54 in the medium-risk and 26.95±5.79 in the low-risk group). The psychological measures revealed worse mood (5.07±2.99) and higher reported stress levels (1.89±2.99) in the high-risk group (see Table 9. Basic characteristics of the sample according to Framingham Risk).

Table 9. Basic characteristics of the sample according to Framingham Risk

N=376	**FRS**		
Variable	Low Risk	Middle Risk	High Risk
Age,yr (mean)	52.53±5.47	56.95±5.54	60.05±4.70
Male sex (N)	38 (18%)	50 (45.9%)	44 (78.6%)
Female sex (N)	173 (82%)	59 (54.1%)	12 (24.1%)
Education Primary (N)	8 (3.8%)	9 (8.3%)	8 (14.3%)
Education Upper-secondary (N)	51 (24.2%)	34 (31.2%)	23 (41.1%)
Education Higher (N)	152 (72.0%)	66 (60.6%)	25 (44.6%)
Marital status: Married (N)	147 (69.7%)	77 (70.6%)	45 (80.4%)
Marital Status: Single (N)	64 (30.3%)	32 (29.4%)	11 (19.6%)
TC (mmol/L) (mean)	5.367±0.98	5.76±1.21	5.53±1.20
Tryglicerid (mmol/L) (mean)	1.24±0.65	1.68±0.98	2.14±1.67
HDL (mmol/L) (mean)	1.67±0.48	1.43±0.30	1.28±0.35
LDL (mmol/L) (mean)	3.45±0.65	3.82±1.11	3.54±1.26
Glucose(mmol/L)(mean	4.78±0.76	5.04±0.95	5.74±2.07
BPsys_avg (mean)	116.80±12.59	128.36±11.17	140.71±16.29
BPdia_avg (mean)	78.30±8.70	82.48±7.95	87.34±9.43
BMI (mean)	26.95±7.79	28.95±4.54	30.19±5.77
FRS (mean)	4.73±2.50	13.53±2.51	28.09±7.57
BDI-9 (mean)	4.04±3.49	3.45±3.51	4.58±5.24
PSS-10 (mean)	4.73±2.50	4.50±2.37	5.07±2.99
WHO-WB (mean)	9.24±2.54	9.31±2.60	8.63±3.14
SWLS (mean)	7.75±1.37	8.02±1.41	7.45±1.98

Abbreviations: FRS: Framingham Risk Score, TC: Total Cholesterol, HDL: High-Density Lipoprotein, LDL: Low-Density Lipoprotein, BPsys_avg: Average systolic blood pressure, BPdia_avg: Average diastolic blood pressure, BMI: Body Mass Index, FRS: Framingham Risk Score, WHO-WB: WHO Well-Being Scale, PSS-10: Perceived stress, BDI-9:Beck Depression Inventory-Short form, SWLS: Satisfaction with Life Scale

Discrepancy of objective vs. perceived risk

The discrepancies and concordances of objective versus subjective cardiovascular risk among participants and sex differences are: "Realistic" (N=145 [38.6%]; 38.5% men, 38.6% women out of 145); FRS 10.27±7.95. “Pessimistic” (N=163 [43.10%]; 25.8% male, 52.5% female out of 163), FRS 6.41±4.10. “Optimistic” (N=69[18.4%]; 35.6% male, 9% female out of 69), FRS 22.01±10.02. The lowest Framingham score was found in the “pessimistic” group, and the highest values were revealed among “optimistic” group members.

Group Comparison

Associations with Cardiovascular Risk Assessment Inaccuracy

The differences among the "realistic," "optimistic," and "pessimistic" groups in relation to demographic, medical, and psychological characteristics were analysed using the Kruskal-Wallis test (see Table 10. Results of Kruskal-Wallis test between realistic, optimistic and pessimistic groups).

The most important results are:

Demographics

Age

Significant differences between the three groups were observed ($\chi 2=47.982$, $p<0.001$). *Post hoc* tests indicated that the age of the “optimistic” group (58.84±5.56) was significantly higher compared to the “realistic” (54.39±6.07) group ($p<0.001$) and “pessimistic” (52.44±5.94 groups ($p<0.001$). A further significant difference on age was found between the “pessimistic” (52.44±5.94) and “realistic” (54.39±6.07) groups ($p=0.018$).

Education

Significant differences across the three groups were observed ($\chi 2=11.976$, $p=0.003$). *Post hoc* comparisons revealed that the “optimistic” group had a significantly lower educational level than the “realistic” (2.36±.66 and 2.61±.63, respectively; $p=0.006$) and “pessimistic” groups (2.64±.56; $p=0.003$).

Psychological status

Depression

Significant differences between the groups were identified regarding depression ($\chi 2$=14.913, *p*=0.001). *Post hoc* analysis revealed that the "pessimistic" group had significantly higher depression scores than the "realistic" (4.80±4.09 and 3.37±3.21 respectively, *p*=0.006) and "optimistic" (3.26±4.06 *p*=0.003) groups.

Perceived stress

Significant differences were found across the groups regarding perceived stress ($\chi 2$=10.699, *p*=0.005). The *post hoc* analysis indicated the "pessimistic" group to be more stressful compared to the "realistic" group (5.13±2.41 and 4.43±2.72 respectively, *p*=0.007), although no significant difference was revealed with the "optimistic" group.

WHO well-being

The statistical analysis showed a significant difference between the groups ($\chi 2$=16.553, *p*<0.001). The results of the post-hoc analysis indicated that the “optimistic” group rated their well-being significantly higher compared to the “pessimistic” and “realistic” groups (9.65±2.54, 8.65±2.54; and 9.5±2.76, respectively, *p*=0.002 and *p*=0.002).

Life satisfaction

Significant differences were found across the groups ($\chi 2$=9.676, *p*=0.008). *Post hoc* analysis showed the "optimistic" group as having higher life satisfaction compared to the "pessimistic" group (8.12±1.36 and 7.61±1.39, respectively, *p*=0.012). Still, no significance was found with the "realistic" group (7.82±1.65 *p*=0.781), nor between the “pessimistic” and the “realistic” group (*p*=0.089).

Health Behaviour

Alcohol consumption – frequency

Significant differences between the groups were revealed ($\chi 2$=10.041, *p*=0.007). According to the *post hoc* analysis, the “optimistic” group showed significantly worse results regarding the frequency of alcohol consumption in the last 12 months compared to the “realistic” and “pessimistic” groups (3.26±1.52, 2.70±1.19, and 2.59±1.19, respectively, *p*=0.046 and *p*=0.005).

Alcohol consumption-amount consumed

Significant differences were found across the groups ($\chi 2$=11.165, *p*=0.0004). According to the *post hoc* test, the "optimistic" group consumed significantly more units of alcoholic beverages during one occasion compared to the "realistic" and "pessimistic" groups (.62±.96, .29±.65, and .25±.56 respectively, *p*=.013 and *p*=0.004).

Table 10. Results of Kruskal-Wallis test between realistic, optimistic and pessimistic groups

			Mean rank				
Variable	χ Stat (effect size)	N	Realistic	Pessimist	Optimist	H-statisics	P-value
Age		376	189.61	155.52	263.59	47.982	<0.001
Education		376	195.49	196.88	154.14	11.976	0.003
Female sex	47.177 (0.354)						<0.001
BPsys_avg		376	178.05	160.74	275.63	56.281	<0.001
BPdia_avg		376	181.09	169.77	248.05	26.238	<0.001
BMI		375	165.81	200.89	204.55	9.966	0.007
Alcohol c. (12 M)		375	185.72	175.5	222.65	10.041	0.007
≥ 6 alc. un./ event		364	178.2	174.31	211.17	11.165	0.004
Smoking	19.994 (0.231)						<0.001
BDI-9		336	155.6	192.01	143.85	14.913	0.001
PSS-10		376	171.99	209.39	174.14	10.699	0.005
WHO-WB		372	202.46	160.83	212.34	16.553	0.000
SWLS		374	195.52	169.53	212.69	9.676	0.008
SRH		376	204.29	172.12	193.76	8.671	0.013

Abbreviations: BPsys_avg: Average systolic blood pressure, BPdia_avg: Average diastolic blood pressure, BMI: Body Mass Index, Alcohol C: Alcohol consumption in the last 12 months, ≥ 6 alc. un./ event: six or more units of alcohol consumption per occasion, WHO-WB: WHO Well-Being Scale, PSS-10: Perceived stress, BDI-9:Beck Depression Inventory- Short form, SRH: Self-rated Health, SWLS: Satisfaction with Life Scale; χ Stat: effect size, H- statistic: Kruskal- Wallis test

Regression: Predictors of underestimated and overestimated cardiovascular risk

The logistic regression model's goodness-of-fit was assessed using a likelihood ratio test, yielding a significant chi-square statistic of $\chi 2(8)$=3.359, *p*=0.910. Additionally, the pseudo-R2 value of 0.752 suggests that the model accounts for approximately 75.2% of the variability in the "pessimistic" assessment outcomes. Of the variables included, the female sex was the strongest predictor of "pessimistic" group membership with an OR = 15.013: 95% CI, 3.998-56.378, *p* <0.001; hence, the male sex itself predicts the optimism in cardiovascular self-assessment. Further listed variables were also predictors of optimism all with 95% CI: higher blood pressure (OR=0.913, *p*<0.001), higher age (OR=0.716, *p*<0.001), and higher well-being (OR=0.652, *p*=0.003) were the strongest predictors of "optimistic" bias in cardiovascular risk. Smoking status (OR=0.043, *p*<0.001) and poor SRH status (OR=0.399, *p*=0.035) were also significant risk factors. Table 11 presents the results of the binary logistic regression.

Table 11. Significant variables to predict optimistic bias in a binary logistic model

Variables	B(SE)	Wald	OR	95% C.I. (LL-UL)	P value
Female gender	2.708 (0.675)	16.100	15.013	(3.997.56.378)	<0.001
Age	-0.333 (0.073)	21.159	0.716	(0.621-0.826)	<0.001
WHO-WB	-0.427 (0.141)	9.136	0.652	(0.494-0.860)	0.003
Smoking	-3.146 (0.842)	13.980	0.043	(0.008-0.224)	<0.001
BPSsys_avg	-0.090 (0.025)	12.821	0.913	(0.869-0.960)	<0.001
SRH	-0.919 (0.435)	4.463	0.399	(0.169-0.936)	0.035

Abbreviations: BPsys_avg: Average systolic blood pressure, SRH: Self-rated Health

4.5. Study 5: Protective psychological factors and health behavior: Structural Equation Modelling: Examining Long-term Sustained Health Behavior

Descriptive

From the BES database, 1394 people were selected in the sample, which includes 892 unfollowed cases and 502 followed cases. When comparing them, we found no significant differences in socio-demographics, health behaviours and indicators, except marital status. For the SEM model, the sample consisted of 502 followed people with medium and high cardiovascular risk. The risk was assessed using the Framingham assessment tool. Two hundred and seventeen people (43%) have a medium, and 285 people (57%)

have a high cardiovascular risk. Based on the gender distribution, 225 men (45%) and 277 (55%) women between the ages of 45 and 98 were included in the study. The average age was 71 ±8.57 years. The majority of the population was single (n = 277; 55.17%) and had primary (n = 178; 35.45%) and secondary (n = 174; 34.66%) education.

SEM Model

Model Settings

Path Model

As the variables did not adhere to a normal distribution, statistical analysis was conducted using robust methods. Robust method is a statistic that retain their properties even when the underlying distributional assumptions are incorrect. We created a linear regression model connecting the HAI2019 and 2012 and psychological well-being (Psych) in 2012. Similarly, we conjectured a relationship involving Psych in 2019, HAI in 2012, and Psych 2012. Furthermore, we determined a covariance relationship between the HAI in 2012 and Psych2012 latent variables and between the HAI 2019 and Psych 2019 latent variables. The model is depicted in Figure 5.

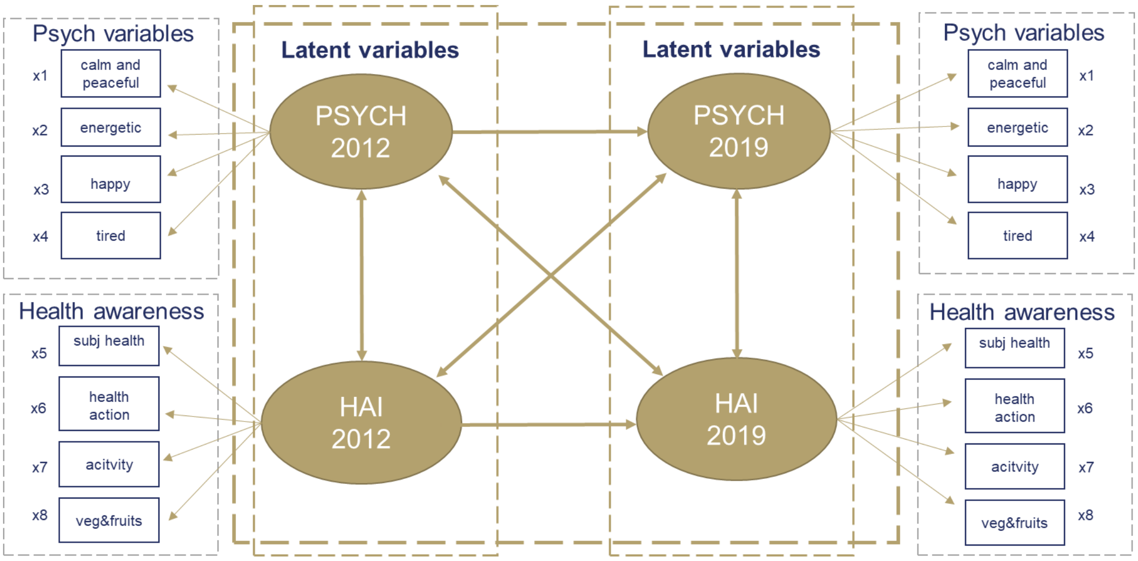


Figure 5. SEM Path Model

Model evaluation: Goodness-of-fit index

The Fit of the model was evaluated with the following indices and indicators (the limit values of the good indicators are given in parentheses). Comparative Fit Index (CFI >0.90), TLI >0.90, Root Mean Square Error of Approximation (RMSEA>0.10), Standardised Root Mean Squared Residual (SRMR >0.08), Goodness of fit (GFI >0.90) (42). The Chi-square test ($\chi 2$ (984) = 286 p <0.05) indicates a significant difference, but this value is disregarded for the estimation of model fit, as it is difficult to achieve a good fit in a large sample using $\chi 2$ (43). Based on the fit indicators, the model has an adequate fit: CFI = 0.936, TLI = 0.921, RMSEA = 0.064, SRMR = 0.050, GFI = 0.985.

Measurement model

Table 12. presents the main results of the measurement model. Estimates, standardised estimates, Beta Coefficients, and p-values for the measurement model are reported with regard the observed variables. According to the significance levels, all the observed variables have a significant role in the given latent variable. Beta Coefficients point out how strong the effect of the given variable is. Standardised Beta or Beta refers to the coefficients representing the relationships between model variables. These coefficients are crucial in SEM as they indicate the strength and direction of the effects of observed variables on latent variables in the model. All observed variables explained a significant proportion of variance in the given latent variable and standardised coefficients (i.e., betas) with absolute values less than 0.10 may indicate a “small” effect, values around 0.30, a “medium” effect, values >0.50, a “large” effect. Bivariate correlations (standardised covariance estimates) of the latent variables are reported in Table 13. We found highly significant (p <0.001) positive associations between all latent constructs, ranging from 0.47 to 0.84, indicating their multiple interconnectedness.

Table 12. Main results of the measurement model

Latent	Observed	t	z	β	p
Psych2019	X1	1		0.563	
	X2	1.555	15.12	0.876	< 0.001
	X3	1.216	18	0.685	< 0.001
	X4	1.236	13.84	0.696	< 0.001
Psych2012	X1	1		0.458	
	X2	1.461	11.16	0.67	< 0.001
	X3	1.324	12.05	0.607	< 0.001
	X4	1.262	10.63	0.578	< 0.001
HAI2019	X5	1		0.705	
	X6	0.754	14.14	0.531	< 0.001
	X7	0.656	14.08	0.462	< 0.001
	X8	0.431	9.92	0.304	< 0.001
HAI2012	X5	1		0.759	
	X6	0.492	11.14	0.373	< 0.001
	X7	0.277	6.96	0.21	< 0.001
	X8	0.562	10.68	0.427	< 0.001

Abbreviations: HAI: Health Awareness Index; Psych: Psychological measure; Note: Estimates (t), Standardised estimates (z), Standardised Beta Coefficient (β), Significance (p); Standardised path coefficients with absolute values less than 0.10 may indicate a "small" effect, values around 0.30, a "medium" effect, values greater than 0.50, a "large" effect

Table 13. Parameter estimates

Predictor	Dependent	t	z	β	p
HAI2012	HAI2019	1.29141	1.3528	1.3915	0.176
Psych2012	HAI2019	-1.1844	-0.7904	-0.7704	0.429
HAI2012	Psych2019	0.00996	0.0403	0.0134	0.968
Psych2012	Psych2019	0.68046	1.6425	0.5537	0.1

Abbreviations: HAI: Health Awareness Index; Psych: Psychological measure; Note: Estimates (t) Standardized estimates (z), Standardized Beta Coefficient (β), Significance (p)

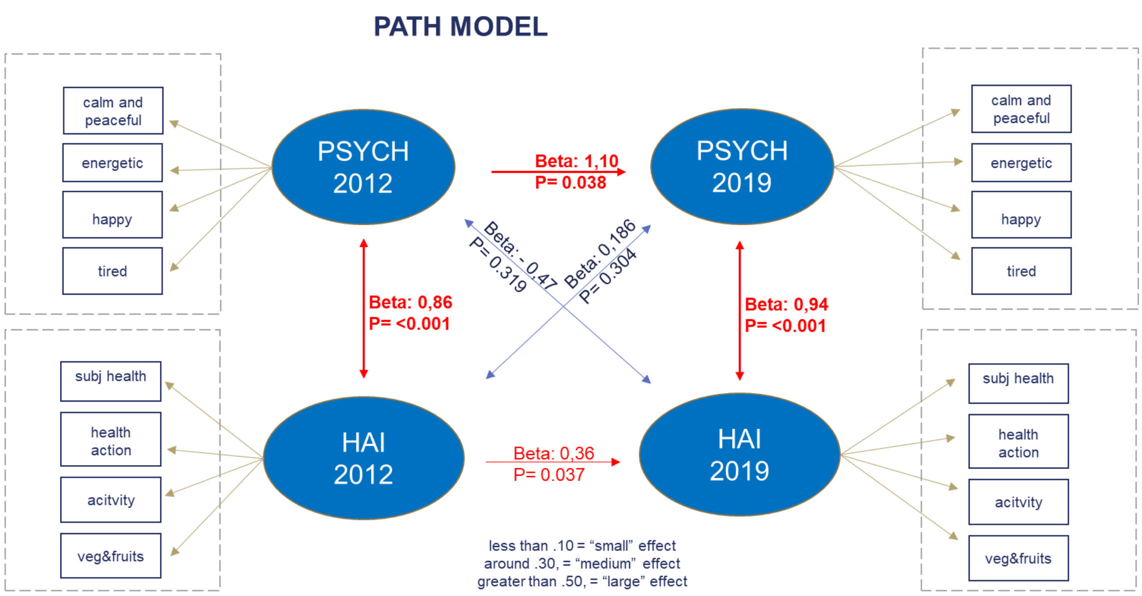
Path Model

We tested the predictive associations between the psychological and health awareness constructs from 2012 to 2019 in a cross-lagged panel model. Path coefficient estimates, standardised estimates, and p-values in the final path model are reported in Table 14. Based on the significance values, it can be concluded that the latent factor of HAI in 2012 directly predicts the HAI in 2019 (beta = 1.10, *p*=0.038), and the Psychological Measure 2012 directly predicts the Psychological Measure 2019 (beta=0.36, *p*=0.037) (Table 14). The cross-lagged predictions did not reach significance (Figure 6: Path Model with beta and p values).

Table 14. Model-implied Covariences for Latent Variables

	Psych2012	**Psych2019**	**HAw2012**
Psych2012	0.21		
Psych2019	0.146	0.317	
HAI2012	0.316	0.22	0.576
HAI2019	0.159	0.342	0.371

Abbreviations: HAI: Health Awareness Index; Psych: Psychological measure



Psych 2012/2019: Psychological latent factor and the variables belong to it

Figure 6. Path Model with beta values and p values.

5. Discussion

Based on the most important findings presented in the current research work, it can be concluded that the observed psychosocial states play pivotal role in the perception of cardiovascular risk. Effective intervention planning is not possible without recognising and addressing these factors. Complex sociodemographic and psychological states underpin the correct perception of risk. However, our research also highlights that the primary focus should not be modifying a personality or a mindset. Instead, as a first step, individuals should be supported in recognising and understanding their own risk through well-targeted communication. Secondly, it is advisable to provide a supportive community by involving a supportive social environment or, in its absence, by creating self-help groups with a common goal. Thirdly, within these groups formed for a common goal, teaching and reinforcing self-care skills can enhance a person's mood, positive feelings, and self-confidence.

In **Study 1** we have investigated the role of social support in health-related behaviour, as there is increasing research evidence that cardiovascular disease development, progression and mortality are linked to social relationships. Although the data in the literature are mixed, most evidence suggests that low social support (regardless of type) represents 1.5–2.1 times higher risk for both the healthy population and patients with coronary heart disease (62-63, 79). Low levels of social support have adverse effects through health-damaging behaviours, negative psychological processes and direct physiological mechanisms (63).

Our findings indicate that social support from friends is positively associated with regular intense physical exercise, which may have a protective effect against cardiovascular diseases. This supports the findings of Fisher, Aggarwal, and colleagues, who reported that greater social support (both instrumental and emotional) positively correlates with the amount of time spent with physical activity each week (125). One interpretation of their result is that higher emotional and social support was associated with higher HDL levels and greater physical activity, which can significantly contribute to reducing cardiovascular risk.

Our further findings suggest that social support from family and friends is negatively associated with the level of depression, which aligns with previous research

(126-127). Additionally, our results indicate a positive association with perceived stress levels and well-being. Therefore, social support from family and friends is inversely related to the development of depressive symptoms and higher stress levels and positively related to higher levels of personal well-being. Since these environmental factors are associated with the development of cardiovascular diseases, the role of social support seems unavoidable when examining the onset of the disease. Low social support and depression are independent risk factors for the development and prognosis of heart diseases. However, depression can also result from low social support and existing depressive symptoms may worsen.

In **Study 2**, we followed up on part of the BES population sample seven years after their cardiovascular risk assessment. Our goal was to investigate if they remember their results and it affects their health behaviour. For this purpose, we have created the HAI. According to our study the established HAI changes over the seven years showed significant lifestyle changes in both risk groups. Our study demonstrated significant positive correlations between the extent of health behaviour change and subjective well-being, perceived health status, social support, and willingness to make further changes. Additionally, a negative correlation was found between perceived stress, hopelessness and the perception of cardiovascular risk.

Few studies have been published so far examining the relationship between the assessment of cardiovascular risk and its outcomes related to healthy lifestyle, the manifestation of cardiovascular diseases, and mortality, particularly considering psychosocial factors. Van den Brekel-Dijkstra and colleagues investigated, in their pilot study in 2016, the usability of a personalised program for assessing cardiovascular risk (128). In their research, 230 individuals participated in completing a web-based questionnaire, which was followed up six months later. Among the participants, 39% had high cardiovascular risk and, overall, one-third of the participants changed their health behaviours after the program. Widén and colleagues used a web-based assessment program to examine the impact of risk assessment on health behaviour. During an average follow-up period of 17 months, they found that 42.6% of high-risk individuals (>10%) changed one or more of their behavioural patterns in a favourable direction (129).

The rate of health behaviour change measured in these studies corresponds to our present research results, as more than one-third of the participants (37.6%) made some changes following the risk assessment in 2012. Moreover, regarding health indices, 73.5% of the participants improved their health awareness and medication-related behaviours and the level of risk behaviour decreased. In another web-based study that provided personalised consultation, cardiovascular risk was assessed in 176 individuals who were followed up an average of seven months later (130). Among those individuals with a cardiovascular disease risk greater than 20% at the time of the assessment, the relative reduction in risk by the time of the follow-up was 17.9%.

According to the literature, significant change can be achieved by communicating cardiovascular risk. In the current study, the assessment of cardiovascular risk and the communication of the results significantly impacted 30.3% of the participants in the first year, which increased the measured health behaviour change, thereby contributing to risk reduction. Based on the aforementioned studies and our knowledge of the literature, there has not yet been such a long follow-up period following the estimated cardiovascular risk measured within an adult population as in the present study.

A reliable and valid assessment of subjective risk perception is crucial to CVD prevention and rehabilitation. While it has been long-established that effective prevention planning requires the assessment of perceived CVD risk, we could not find any reliable measures that could be applied to this population. Considering that a reliable measurement tool is important for research purposes and patient care, we aimed in **Study 3** to validate a Hungarian version of the ABCD questionnaire developed by Woringer et al. (116)**.** We also tested bivariate associations with a series of background variables. Concerning CVD risk perception, it was significantly higher in respondents with the presence of CVD. At the same time, neither age, gender, nor smoking status was significantly associated with it (male respondents and those who smoked had a marginally significantly higher average). This may be an important warning for CVD prevention, as male gender, age and smoking status are known risk factors for CVD and these factors are also included in objective measures of CVD risk such as the Framingham score. In line with our results, studies assessing the objective and subjective levels of CVD risk consistently show that the two rarely converge (119, 124-131-135). The possibility that the only factor that can increase the level of subjective CVD risk assessment is the presence of CVD symptoms and events may pose a considerable level of health risk to the individual, especially the elderly.

To investigate the nature of the self-perceived cardiovascular risk further, in **Study 4** we have assessed the discrepancies in objective and subjective risk awareness and the possible underlying factors of the erroneous estimation. Our findings partially align with those of previous studies using similar research designs. However, our study consolidates the advantages of earlier studies under the umbrella of a single research project, adding value and providing new results to prior studies. Many previous studies lacked objective risk estimation following clinical assessments, did not cover all risk groups, excluded those that accurately estimated their risk or lacked data on sex differences. In contrast, our observations incorporated subjective and objective risk assessments across all relevant risk groups and analysed the dataset across all created groups.

In our sample, 61.5% of the participants misjudged their cardiovascular risk: 43.1% overestimated and 18.4% underestimated it. Optimism (underestimation) occurred more often in men, whereas pessimism was more common in women. No significant sex differences were found in realistic perceivers. These figures present alarming results in an epidemiological context. Both our findings and the earlier literature suggest that "pessimistic" estimators display more depressive symptoms, higher anxiety levels, lower well-being and life satisfaction. In contrast, "optimistic" estimators tend to be older, have higher systolic blood pressure, smoke, and consume alcohol more frequently and in larger quantities (six units or more per occasion) (134-135).

Similar distribution can be found in the research of Katz et al., who utilised the FRS and lifetime risk assessment (LRS) models to estimate the cardiovascular risk of the study participants (134). Their findings indicated that misperceptions increased when using FRS with a higher objective risk. The overall ratio of "realistic" persons was 56.6%, the "pessimist" 27.3%, and the "optimist" 15%. These results support our findings (61.5%, 43.1%, and 18.4%, respectively). Our results also demonstrated sex differences across the groups. Alwan et al., in Seychelles Heart Study III, found that only half of their participants could even estimate their CVD risk, and only 3.8% underestimated their risk, which was associated with younger age, lower education level, normal BMI, male sex, and frequency of physical activity (135). Overestimation (48%) was associated with cardiovascular medication use, older age and being overweight. Their result concerning the factors of underestimation is similar to ours regarding age. The discrepancy of the ratio of underestimation might come from methodological differences or cultural ones (their study population was African).

Lee et al.'s study assessed the cardiovascular risk using the FRS and compared it with perceived health, depression, and stress scores (136). Their results showed that 54.7% of the participants accurately estimated their risk, 12% overestimated it and 33.3% underestimated it. These results confirm our group ratio results. Furthermore, in Lee et al.'s study, depressive symptoms were associated with overestimation, which is consistent with our findings.

Helou et al. compared under-estimators with accurate estimators, and found that among others, smoking, alcohol consumption, dyslipidemia, and physical activity were associated with underestimation (133). Meanwhile, a higher BMI, more depressive symptoms and higher stress levels reduced the likelihood of underestimation. Our results align with the associations between underestimation ("optimistic") and similar variables.

Profiling and quickly identifying "optimistic" and "pessimistic" distorters could be clinically valuable for personalised prevention management. Our binary regression model, which examined the "optimistic" and "pessimistic" groups, partially supports previous research findings. Members of the "optimistic" group are predominantly older male smokers with higher systolic blood pressure, and they report higher life satisfaction than the "pessimistic" group. Helou et al. found in their regression model that "optimistic" distortion was associated with higher age, higher blood pressure and dyslipidemia, smoking, lower BMI and lower levels of perceived stress or depressive symptoms (133). While our model aligns with some of Helou et al.'s findings, it is essential to note that their study design was retrospective, excluded overestimators (pessimists) and included only 19.9% women. By contrast, our analysis was prospective, included all perception groups and had a female participation rate of 64.9%. These conflicting results may stem from diverse methodologies, study designs, inaccuracies in objective risk assessments and cultural differences.

In our research, our goal was not only investigating the health behaviour change seven years later after a risk assessment, but the underlying factors of sustained health behaviour. In Study 5, we used SEM to comprehensively analyse repeated measures within an extended framework to understand how these variables interact. Our research results are consistent with the recommendations of the American Heart Association

(AHA) statement on psychological health, wellness, and the mind-body relationship (137).

Our hypothesis about the relationship between well-being and sustainable health behaviour could be partially supported by our results in **Study 5**. Although we did not find a significant relationship between all the hypothesised latent factors, the analysis revealed that the Health Awareness Index 2012 influenced the Health Awareness Index 2019. Psychological well-being in 2012 has an impact on psychological well-being in 2019. In addition, there are moderate to strong positive bivariate associations between the latent factors and the goodness of fit of our model was adequate. Our results suggest that the starting point for health behaviour change is a well-founded cardiovascular health awareness and an increase in subjective risk perception.

This awareness and self-direction, together with increased internal control, can enhance psychological well-being, which helps to maintain healthy attitudes and behaviours. Numerous researchers have explored Seligman's positive health concept (138). By examining health behaviour from a positive psychological perspective, we aimed to contribute to this initiative. Most studies in this area have used cross-sectional methods. Few have used SEM methods, and even fewer have used longitudinal studies with repeated measures. In order to better understand the issue and provide further evidence in support of this concept, we aimed to use all possible approaches. In our SEM model, we could not identify the cross-lagged predictive properties of earlier levels of well-being and health behaviour on later levels of the other characteristics, as was the case in Boehm's review, which comprehensively presents numerous studies on this topic (139). There is evidence that fruit and vegetable consumption and physical activity are associated with well-being and reduced levels of risk behaviour (140). These results are evidence of the importance of an individual's psychological state in any preventive intervention. We cannot expect the development of long-term sustainable adaptive health behaviours, which are of primary importance from a CVD perspective, without strengthening, improving and maintaining positive psychological factors. It is important to point out the main difference between these studies and our own investigation. While we employed SEM in a cross-lagged model and longitudinal setting, the studies in Boehm's review used cross-sectional method (139).

As discussed above, most of the evidence is based on cross-sectional methodology, and the underlying research shows a considerable variety of methodologies, but two of them on physical activity, using a longitudinal setting, support our theory and our findings (136, 141). In work by Lee, physical activity, self-rated health and psychological resilience are examined in a repeated measures SEM model with two follow-up points (136). Her results show that exercise and resiliency were positively associated with self-rated health over time, but there were no significant associations between exercise and resiliency.

Our SEM model, by simultaneously representing well-being and health consciousness as separate yet interrelated constructs, has an adequate fit that supports the concept of positive health. This result follows the findings of Stenlund et al. (142). In their research, they applied the same methodology as our team, emphasising the mutual relationship between well-being and health behaviour and confirming our expectations about the predictive power of health behaviour on future well-being. However, we did not find a significant relationship in our model longitudinally. Another difference is that in our research, unlike theirs, HAI is a more complex construct, encompassing health attitudes as well as health practices, which allows for a more dynamic and proactive evaluation.

5.1 Limitations

The weakness of our two studies (validation studies) is that the data collection was done through convenience sampling and the vast majority of participants (70.8%) were female. Hence the generalizability of the results is limited. There was no possibility of a medical examination when the data were collected in the follow-up study, so we could only measure health changes based on self-report. Regarding SEM analysis only a limited number of factors were available for examination in a positive framework. Another limitation is that we have preliminarily focused on people with medium to high CVD risk. We did not include individuals with low risk in the study. All of this determines the linear regression relationships. Study 4 participants were predominantly female and had higher education levels. Second, the cross-sectional nature of the study design did not allow us to observe prospective outcomes. Third, in addition to the FRS, several population-specific estimation scales were used to measure cardiovascular risk (e.g. Score2). Nevertheless, we used FRS because of its good communicability.

6. Conclusion

This doctoral research aimed to explore the protective and harmful psychosocial factors contributing to cardiovascular risk perception and health behaviour change.

Summary of key findings

#1 Health-related social support, perceived especially from friends, positively correlates with intense exercise activity. #2 Even one well-organised written CVD risk communication might trigger a change in cardio-protective health behaviour, thus decreasing CVD risk. #3 Higher CVD risk perception was linked to lower self-rated health and well-being, as well as a greater prevalence of depressive symptoms and perceived stress. #4 CVD perception, similar to other illnesses, is biased. Our research could reveal that men are more "optimistic" in their cardiovascular risk assessment despite having the highest blood pressure, BMI and lifestyle factors such as smoking and alcohol consumption. #5 With a SEM model, our research brought limited but promising results. Health Awareness Index 2012 influenced the Health Awareness Index 2019. Psychological well-being in 2012 has an impact on psychological well-being in 2019. Health awareness and self-direction, together with increased internal control, can enhance psychological well-being, which helps to maintain healthy attitudes and behaviours.

Significance

So far, to the best of our knowledge, no multifaceted insight into the Hungarian population has been conducted regarding cardiovascular risk, and no longitudinal research on cardio-protective health behaviour has been conducted. Identifying biased cardiovascular risk perception has significant social (e.g. equitable health, stigma reduction, empowerment) and practical implications, mainly in risk communication and the design of prevention or intervention programs (e.g. personalised healthcare, improved screening programs.

Recommendation for future research

For the better clinical utilisation of our results, our final goal is to develop a screening package that is easy to use in general practice and clinical settings to identify the patient's harmful factors, and suggestions for short, minimal interventions to correct CVD risk perception. Further research may deepen the knowledge on the Hungarian population regarding the possibilities of CVD risk reduction by further studying the trigger points of health behaviour change.

7. Summary

According to our knowledge, no multifaceted insight into the Hungarian population has happened regarding cardiovascular risk so far. There is a high need for research results in the Hungarian population for well-planned and evidence-based interventional programs. Thus, our main objective was a multifaceted investigation of our Hungarian sample from a health-psychological perspective involving the most relevant aspects from a cardio-protective view.

This dissertation aimed to explore, on one hand, the protective and harmful psychosocial factors contributing to cardiovascular risk perception and awareness as well as health behaviour, and on the other hand, to explore the different types of cardiovascular risk perception and the effect of cardiovascular risk communication to the change of health behaviour. The main results are represented in Figure 7.

Relevant research results found in international studies can be applied to our studied population. Our findings suggest that objective assessment and communication of CVD risk can facilitate change and maintain health behaviour. Correcting misperceptions of CVD in time is especially important. Our results raise the need and question of CVD screenings, as there is currently a lack of comprehensive cardiovascular risk screening in primary care even though simple communication of cardiovascular risk showed a significant change in the involved population even after seven years. Additional studies are required to reinforce these findings.

During the development of preventive interventions targeting cardio-protective health behaviour, it is essential to focus on health-related social support by mobilising existing social networks or creating self-help groups. Levels of depression, perceived stress and well-being can significantly impact appropriate health behaviours both directly and through social support. Psychological states may contribute to erroneous self-assessment of CVD risk, often resulting in pessimistic assessments. These findings suggest that identifying subclinical mood disorders is important for preventing cardiovascular diseases. Their management can be addressed through health psychology approaches and interventions to promote appropriate health behaviours. From a clinical perspective, the identification of optimistic evaluators is also critical. Developing optimal interventions for their treatment requires further research that explores the methods of intervention and how to reach this population effectively.

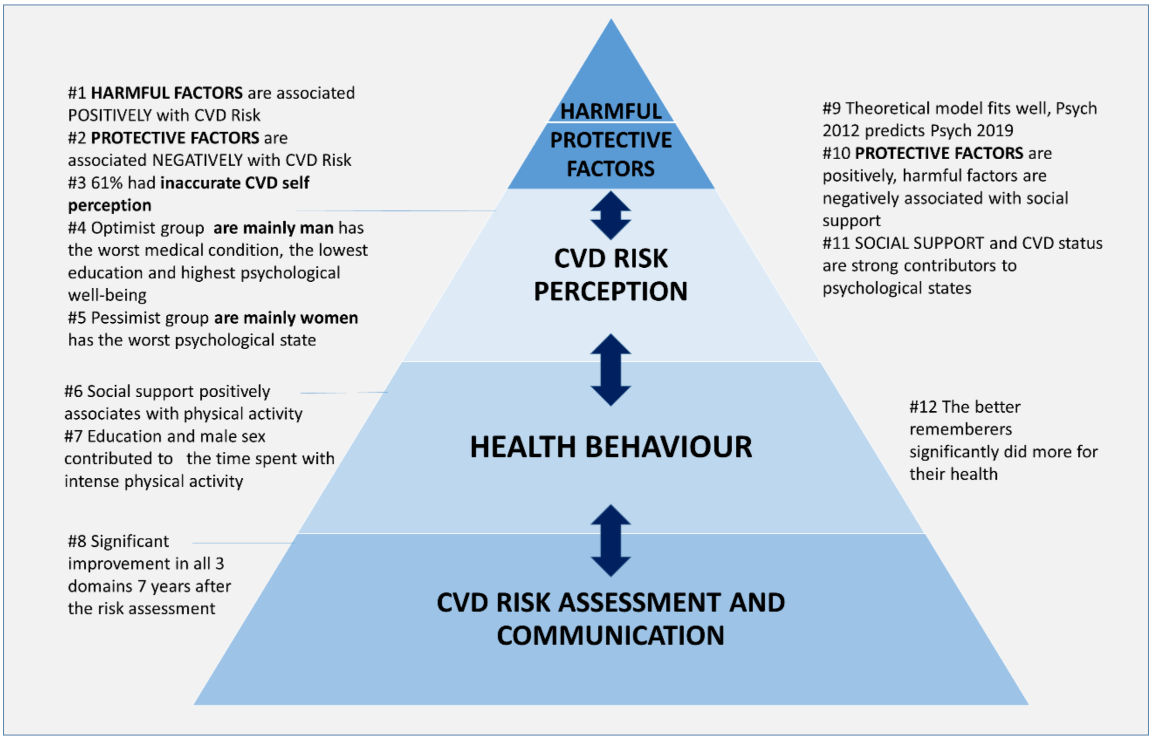


Figure 7. Conceptual framework and connected main results

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9. Bibliography of the candidate's publications

9.2 Publications directly related to the present thesis

1. **Ocsovszky Z,** Ehrenberger B, Berenyi B, Assabiny A, Otohal J, Martos T, Papp-Zipernovszky O, Hegedus F, Merkely B, Csabai M, Bagyura Z. Positive cardiovascular health: longitudinal investigation of sustained health behavior in a cross-lagged model. Front Public Health. 2024 Aug 22;12:1400849. **IF 3.0**

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9.3 Publications not directly related to the present thesis

1. Assabiny A, Otohal J, **Ocsovszky Z,** Nagy AF, Papp-Zipernovszky O, Dénes F, Becker D, Merkely B, Pethesné Dávid B, Sax B. Felnőtt szívtranszplantált betegeket célzó sorstársi mentorprogramok. Orv Hetil. 2024;165(10):379-384. **IF 0,8**
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