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To my family—the treasures of my life

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SÄDE STENLUND: Bidirectional Relationship Between Health Behavior and Subjective Well-being in Adults
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ABSTRACT

Unhealthy behavior increases the unsustainable burden of chronic diseases on health care and changing health behavior is often personally challenging. The present thesis provides a new, positive perspective to investigating health behavior changes by exploring their association with subjective well-being. So far, their mutual associations have been studied in cross-sectional settings. Longitudinal studies are sparse, usually unidirectional, have focused on only one health behavior, and have commonly been based on follow-up times of only a few years. The aim of the present thesis is to explore this bidirectional relationship and to determine whether health behavior better predicts subsequent subjective well-being than vice versa in a longitudinal setting.

The HeSSup (Health and Social Support) study represented a population-based random sample (n = 11,927) of the Finnish working-age population. The longitudinal and reciprocal relationships between health behavior and subjective well-being among the participants were explored using linear regression and structural equation modeling in a nine-year follow-up (2003–2012). The sum score of self-reported dichotomized health behaviors included physical activity during leisure time and commuting, dietary habits based on ten food items, alcohol consumption below the risk use level, and smoking status. The four-item life satisfaction scale including three life assessments (i.e., happiness, interestingness, and easiness) and perceived loneliness was used as an indicator of subjective well-being.

In the nine-year follow-up based on observational results, a higher number of beneficial health behaviors and positive changes in these behaviors predicted improved subjective well-being in both linear regression and structural equation modeling. Subjective well-being and positive changes in this well-being predicted subsequent health behavior in linear regression modeling and potentially through an alternative pathway, but not directly, in structural equation modeling. Health behavior appears to be a stronger predictor of subjective well-being than vice versa.

Improved subjective well-being could serve as a motivator for health behavior change, and on the other hand, targeting subjective well-being could support a positive health behavior change, especially on an everyday level. In conclusion, including subjective well-being perspectives in health care and policies could help support health behavior changes.

KEYWORDS: health behavior, health behavior change, subjective well-being, life satisfaction, bidirectional, follow-up, health promotion

TURUN YLIOPISTO
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TIIVISTELMÄ

Huonot elintavat kasvattavat kroonisten sairauksien kestämätöntä terveydenhuollon taakkaa, ja elintapamuutokset ovat usein yksilölle haastavia. Tämä väitöskirja elintapojen ja subjektiivisen hyvinvoinnin yhteydestä tarjoaa uuden ja positiivisen näkökulman elintapamuutosten tukemiseen. Yhteys on todennettu poikkileikkaustutkimuksissa, mutta seurantatutkimuksia on vähän, ja niissä on monia rajoituksia. Seuranta-ajat ovat useimmiten lyhyitä ja tarkastelu yhdensuuntainen keskittyen yhteen elintapaan. Väitöskirjan tavoite on syventää ymmärrystä tästä kahdensuuntaisesta yhteydestä ja tarkastella ennustavatko elintavat subjektiivista hyvinvointia vahvemmin kuin päinvastoin yhdeksän vuoden seurannassa.

HeSSup-tutkimus (Health and Social Support, terveys ja sosiaalinen tuki) perustuu satunnaiseen väestönotantaan työikäisistä suomalaisista (n = 11,927). Heidän elintapojen ja subjektiivisen hyvinvoinnin keskinäisiä vaikutuksia tarkastellaan pitkittäisasetelmassa (2003–2012) sekä lineaarisin mallein että rakenneyhtälömallinnuksella. Itseraportoitujen kaksiluokkaisten elintapojen summamuuttuja kattaa neljä keskeisintä kroonisiin sairauksiin vaikuttavaa elintapaa: vapaa-ajan ja työmatkojen liikunnan, ruokavalion kymmenen ruoka-ainekategorian perusteella, kohtuullisen alkoholin käytön ja tupakoimattomuuden. Neljän muuttujan elämään tyytyväisyyden mittari sisältää kolme elämän arviota elämän onnellisuudesta, kiinnostavuudesta ja helppoudesta sekä koetun yksinäisyyden. Mittaria käytetään kuvaamaan subjektiivista hyvinvointia.

Yhdeksän vuoden seurannassa useampi suotuisa elintapa ja niiden positiiviset muutokset ennustivat subjektiivista hyvinvointia niin lineaarisissa kuin rakenneyhtälömalleissa havainnoivassa tutkimusasetelmassa. Sen sijaan subjektiivinen hyvinvointi ja sen positiiviset muutokset ennustivat parempia elintapoja lineaarisissa malleissa sekä vaihtoehtoista reittiä mutta eivät suoraan rakenneyhtälömallinnuksessa. Elintavat vaikuttivat ennustavan subjektiivista hyvinvointia vahvemmin kuin subjektiivinen hyvinvointi ennusti elintapoja.

Elintapojen positiiviset vaikutukset subjektiiviseen hyvinvointiin voisivat motivoida elintapamuutoksiin. Subjektiiviseen hyvinvointiin vaikuttaminen voisi myös tukea elintapamuutosten onnistumista päivittäistasolla. Subjektiivisen hyvinvoinnin huomioiminen terveydenhuollossa sekä poliittisessa päätöksenteossa voisi auttaa elintapamuutosten tukemisessa.

AVAINSANAT: elintavat, elintapamuutos, terveyskäyttäytyminen, subjektiivinen hyvinvointi, seurantatutkimus, terveyden edistäminen

Table of Contents

Abbreviations

AIC	Akaike information criterion
CFI	comparative fit index
HB	health behavior
HBSS	health behavior sum score
HeSSup	Health and Social Support (Study)
MET	metabolic equivalent task
ns	non-significant
OECD	Organisation for Economic Co-operation and Development
p	p-value
RMSEA	root mean square error of approximation
SD	standard deviation
SE	standard error
SEM	structural equation modeling
SWB	subjective well-being
TLI	Tucker-Lewis index
UK	United Kingdom
US	United States
WHO	World Health Organization
WLSMV	weighted least squares estimator

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals I–IV:

I Stenlund, S., Koivumaa-Honkanen, H., Sillanmäki, L., Lagström, H., Rautava, P., & Suominen, S. Health behavior of working-aged Finns predicts self-reported life satisfaction in a population-based 9-years follow-up. *BMC Public Health*, 2021. doi: 10.1186/s12889-021-11796-4

II Stenlund, S., Koivumaa-Honkanen, H., Sillanmäki, L., Lagström, H., Rautava, P., & Suominen, S. Subjective well-being predicts health behavior in a population-based 9-years follow-up of working-aged Finns. *Preventive Medicine Reports,* 2021. doi: 10.1016/j.pmedr.2021.101635

III Stenlund, S., Koivumaa-Honkanen, H., Sillanmäki, L., Lagström, H., Rautava, P., & Suominen, S. Changed health behavior improves subjective well-being and vice versa in a follow-up of nine years. Manuscript.

IV Stenlund, S., Junttila, N., Koivumaa-Honkanen, H., Sillanmäki, L., Stenlund, D., Suominen, S., Lagström, H., & Rautava, P. Longitudinal stability and interrelations between health behavior and subjective well-being in a follow-up of nine years. *PLOS ONE*, 2021. doi: 10.1371/journal.pone.0259280

1 Introduction

Health, happiness, and longevity are the characteristics of a good life that individuals typically list as the most important (Diener & Chan, 2011). Maximizing these outcomes, i.e. maximizing well-being using finite resources, is one of the fundamental goals of individuals (Veenhoven, 2017b), politicians, and governments (Ngamaba et al., 2017). However, despite well-established knowledge that unfavorable behavior weakens health and longevity, unhealthy behavior continues to persist, and the burden of chronic diseases is increasingly alarming, and is causing an unsustainable situation in health care (OECD, 2019). Treating, rather than preventing, disease has long been the central goal of medicine (Marcum, 2008), even though graduating medical doctors proclaim that "prevention [is] preferable to cure" (Hajar, 2017) and despite prevention holding the potential to both avoid the occurrence of diseases and delay their onset and progress (WHO, 1998). Chronic diseases account for 75% of health care costs, whereas only 1% to 3% of these costs is spent on prevention (Woolf, 2008). Therefore, new, innovative strategies for disease prevention and health promotion are seriously needed (OECD, 2019). A new perspective could be provided by research on positive outcomes, in line with the salutogenic view on health (Antonovsky, 1979, 1987), which focuses on resources, coping, and the aspects that create health (salutogenesis vs. pathogenesis). If the use of various strategies can prevent chronic diseases, delay their onset, and reduce their severity, they may also be able to reduce the unsustainable burden on health care.

Subjective well-being (SWB) is described as an individual's evaluation and appraisal of their own life as a whole (Diener, 1984) and is often described as happiness when communicated to the general public (Diener, Lucas, et al., 2018). Health behavior (HB), on the other hand, refers to actions taken to improve or maintain health (WHO, 1998). As SWB is of central importance to an individual (López Ulloa et al., 2013), deeper understanding of the cross-sectional relationship between SWB and HB (e.g. Grant et al., 2009; Kushlev et al., 2019) could provide a new, positive perspective of HB change and health promotion. Until now, longitudinal studies on this relationship have been sparse and have mainly focused on one HB, with rather short follow-ups. Studies with follow-ups longer than a few years, including multiple HB,

and comparisons with the opposite direction of effects could provide further explanations for the link between HB and SWB (Diener et al., 2017).

HB and SWB have been widely studied. They represent complex phenomena and are affected by numerous external and internal factors. Understanding and improving HB have been stated as the most complex tasks ever confronted by science (Glanz et al., 2015; McGinnis, 1994), whereas SWB has been the topic in more than 170,000 articles and books (Diener, Lucas, et al., 2018). Furthermore, a variety of terminology and concepts are used without a uniform consensus.

The focus of the present thesis is on the four major HBs accounting for chronic disease (WHO, 2020): 1) physical activity, 2) dietary habits, 3) alcohol consumption, and 4) smoking status. The study also uses the conceptualization of SWB as a personal evaluation of life comprising cognitive and affective components (Diener, 1984), but discusses various concepts related to SWB either as reflections or indicators of SWB. The term *predict* is frequently used to describe the temporal direction of the association, i.e., a variable predicting the level of a subsequent outcome even though causal effect cannot be determined due to the observational nature of the study. The focus is on the working-age population, excluding the most dynamic phases of personal growth in early life as well as older age when daily life can be increasingly affected by ageing and diseases. The thesis is multidisciplinary and has implications for multiple fields, including medicine, sociology, and econometrics. Medical research provides the concepts for HB research and underlines the importance of HB change for health. Psychology provides both theoretical and practical insights into the study of HB and SWB. Econometrics in turn emphasize the importance of HB changes for economic sustainability in health care and society.

The thesis was driven by the need for new perspectives of health promotion. Its underlying aim was to determine ways to promote health, well-being, and human flourishing. Finland has been ranked the happiest nation in the world for four consecutive years, based on life evaluation (Helliwell et al., 2021) and is also in a top position when societal factors are taken to reflect well-being (OECD, 2020). Therefore, many confounders that globally reduce happiness have minor effects and studying Finnish working-aged people could provide new knowledge on the potential of SWB for improving HB and vice versa.

2 Review of Literature

2.1 Health Behavior

2.1.1 Historical and Current Perspectives

HB is defined as:

> Any activity undertaken by an individual, regardless of actual or perceived health status, for the purpose of promoting, protecting or maintaining health, whether or not such behaviour is objectively effective towards that end. (WHO, 1998)

Unhealthy behavior refers to both the absence of healthy behavior, such as a lack of consumption of fruit and vegetables, and a lack of physical activity and risk behavior, such as excessive alcohol consumption and smoking, which have proven to be associated with specific diseases or ill health (WHO, 1998). Behavior can impact health in three ways: through direct biological changes, by conveying health risks or protecting against them, and by leading to early detection or treatment of disease (Conner, 2015). The four major modifiable HBs that account for chronic diseases are physical activity, dietary habits, alcohol consumption, and smoking (WHO, 2020). It has also been suggested that sleep is relevant for health outcomes (Ding et al., 2014). Other behaviors relevant to health include brushing one's teeth, protection from the sun, using a seatbelt, sexual behavior, sedentary behavior, medical adherence, and attending health screenings. Thus, HB covers a wide variety of actions but the focus in the present thesis is on the four major modifiable HBs.

The concept of HB to improve health is historically novel. In the past few centuries, the understanding of diseases has increased significantly, and measures have been taken to affect HB. In Finland, district doctors began spreading knowledge on hygiene to prevent communicable diseases in the 19th century (Hakosalo, 2010). The globally acknowledged Finnish maternity clinics started to support, inform, and visit families at the beginning of the 20th century (Kouvalainen, 1995). Furthermore, the famous *North Karelia Project,* a comprehensive community project, succeeded in reducing mortality caused by coronary heart disease in a highly disadvantaged region

in Finland in the late 1960s and early 1970s. Importantly, similar results have later been reached in other parts of Finland (Jauho, 2020). In general, HB as a medical concern has developed rapidly since the 1970s (Armstrong, 2009), and the benefits of common HBs have become well established.

It has been observed that better HB can reduce the incidence of chronic diseases by around 75% (Ford et al., 2009) and the risk of mortality related to these conditions by 66% (Loef & Walach, 2012). Thus, HB is relevant for individuals, society, and health care. *Physical activity* and *dietary habits* have numerous beneficial effects, ranging from reduced cardiovascular morbidity and mortality to reduced life stress and anxiety (Conner, 2015). However, many adults in Western countries fail to meet physical activity and nutritional recommendations (Conner, 2015; Haack & Byker, 2014; Valsta et al., 2018). Moderate *alcohol consumption* shows an association with positive health outcomes, and long-term excessive alcohol consumption is associated with, for example, heart disease and cirrhosis of the liver, as well as social problems such as accidents, domestic violence, and unsafe sex (Conner, 2015). *Smoking* is linked to the most negative outcomes, including increased incidence, morbidity, and mortality caused by both coronary heart disease and cancer. However, some smokers report positive mood effects from smoking, using it as a way to alleviate stress (Conner, 2015). Smoking rates have steadily declined, and presently about 18% of adults smoke regularly (OECD, 2019).

In general, people's HB patterns have shown stability over time (Burgard et al., 2020). HB changes, however, have gained major interest among individuals, policy-makers, and researchers, due to their impact on chronic diseases (Hilliard et al., 2018). Changes in HB can be either voluntary or involuntary and be caused by internal or external factors. Nevertheless, unhealthy behavior continues to persist, and it has become evident that knowledge of the benefits of HB for combating diseases is not sufficient to motivate change.

Several theories have sought to explain and predict health-related decisions. Over 80 theories have been identified, but only a handful of these have shown to have a major impact, and no single theory or conceptual framework alone dominates the field (Glanz et al., 2015). The theories share constructs and are usually rational, assuming that individuals wish to maximize positive health outcomes (Noar & Zimmerman, 2005). The five central theories (Janevic & Conell, 2018) are the *Health Belief Model* (Becker, 1974) and the *Theory of Planned Behavior* (Ajzen, 1991, 2011), which emphasize one's personal beliefs of being able to perform an action as well as the probability and desirability of an outcome; the *Social Cognitive Theory* (Bandura, 1977), according to which these beliefs derive from personal experience, observation of others, verbal encouragement, and physiological states; the *Transtheoretical Model* (Prochaska & Velicer, 1997), one of the most prominent

theories in HB research focusing on HB change in six stages; and the *Relapse Prevention Model* (Janevic & Conell, 2018), which has been highly influential in building coping skills to deal with situations that carry a high risk of relapse.

2.1.2 Measuring Health Behavior

The techniques and measures for capturing HB vary considerably, even within studies of a single HB (Geller et al., 2017). Both subjective and objective techniques are used, including paper-and-pencil rating forms, in vivo observations, biomarker assays, or electronically collected objective measurements. The results are frequently compared with guidelines and recommendations for specific HBs (Becker et al., 2004; Duodecim, 2016, 2018).

Physical activity refers to energy-consuming movement produced by skeletal muscles and includes occupational, sports, conditioning, household, or other activities. Physical exercise in turn represents physical activity that is planned, structured, and repetitive, with a goal to improve physical fitness (Caspersen et al., 1985). Physical activity can be measured by self-reporting or objectively by accelerometers, pedometers, and actigraphy. Self-reporting has shown higher levels of physical activity than accelerometer results, especially in less active groups (Colley et al., 2018; Downs et al., 2014). As a self-reporting technique, describing a typical week is appropriate for population-level studies, whereas a recall method over a short period of time may better capture variations in behavior (Wasserman & Hilliard, 2018). A wide variety of techniques can be used to measure *dietary habits*, including self-reported consumption of fruit and vegetables, broader food-frequency questionnaires, food diaries that can be computer-analyzed for nutritional content, biomarkers, and a remote food photography method. Self-reporting is recommended for capturing large-scale population-level eating trends, but can be subject to under-reporting unhealthy food intake (Wasserman & Hilliard, 2018).

Alcohol consumption is frequently measured by self-reports of, for example, the amount of alcohol consumed or heavy drinking occasions, which can be complemented by objective measures such as blood alcohol concentration or the mean corpuscular volume (MCV) of red blood cells (Gmel & Rehm, 2004). According to Gmel and Rehm, self-reports have shown consistency over-time and between different measures. Surveys, however, have shown to underestimate alcohol consumption per capita, which may be systematic in all participants or specific groups, or may be due to selective non-response. *Smoking status* is most commonly measured by self-reports of, for example, the number of cigarettes smoked, dependence, feeling a prisoner to cigarettes, succeeding in quitting, or relapse. Self-reporting has, however,

been criticized as underestimating smoking behavior. Alternative objective measurements have been explored but not necessarily found to be better indicators of smoking than self-reports (Haller, 2016; Tennekoon & Rosenman, 2013).

Beneficial and unhealthy behaviors both tend to cluster. Therefore the study of multiple HBs is encouraged (Geller et al., 2017). Two distinct approaches have been used. Co-occurrence refers to the prevalence of multiple HBs. It is usually studied by a sum score index of the four major HBs, i.e., physical activity, dietary habits, alcohol consumption, and smoking status (McAloney et al., 2013). Further according to McAloney, each major HB is often dichotomized into unhealthy (0 points) and beneficial (1 point), resulting in a sum score ranging from 0 to 4. However, no consensus has been established on cut-off points. The study of clustering, on the other hand, explores the underlying mechanisms that observe or identify the prevalence of combinations of HB.

2.1.3 Factors Related to Health Behavior

Health behavior is affected by numerous internal and external factors, as shown in Figure 1.

Figure 1. Visual grouping of various factors related to health behavior: Graphical overview of multiple dimensions that might affect HB.

Many stable characteristics can affect HB. *Genes* have been identified that affect exercise habits (Stubbe & Geus, 2009), and that code the receptors affecting dependence on smoking (Loukola et al., 2014) and alcohol (Rietschel & Treutlein, 2013). Of the Big Five *personality traits*—conscientiousness, agreeableness, extraversion, openness, and neuroticism—the two first have shown associations with favorable HB (Bogg & Roberts, 2004; Booth-Kewley & Vickers, 1994). *Early life experiences* and *circumstances* can raise HB trajectories that last into adulthood (Umberson et al., 2010). For example, adverse childhood experiences (Daines et al., 2021), and social learning (Berrigan et al., 2003) have been identified as associating with HB in adulthood. Concerning *gender,* women show better HB than men but engage less in regular physical activity (Conner, 2015; Waldron, 1976). As *age* increases, HB appears to improve (Berrigan et al., 2003; Conner, 2015; Ocean et al., 2019). *Sense of coherence* is described as a stable but flexible individual perception of life as comprehensible, manageable, and meaningful (Antonovsky, 1987; Honkinen et al., 2008; Lindström & Eriksson, 2005). This too has been associated with better HB (Wainwright et al., 2007).

Dynamic personal characteristics can affect HB, sometimes in a bidirectional relationship. It is widely documented that individuals with higher *education* (Cowell, 2006) and higher *socioeconomic status* (Conner, 2015) tend to engage in healthier behaviors. This could be the result of better *health literacy* (Squiers et al., 2012), resulting in favorable *health beliefs,* but also better resources. Good *physical and mental health* enable individuals to perform HBs and avoid risk behavior, whereas diseases can hamper HB or increase unhealthy behavior. On the other hand, a new diagnosis can elevate a person's sense of vulnerability, resulting in an HB change (Zanjani et al., 2006). *Self-compassion* (Kumlander et al., 2018; Neff, 2003) has been associated with beneficial dietary habits, physical activity (Sirois et al., 2015), increased positive motivation to exercise (Magnus et al., 2010), and successful self-regulation of HB (Terry & Leary, 2011). *Time-management* can challenge HB, if time is scarce (Hamermesh, 2019): It can result in, for example, skipping physical exercise, taking the car instead of walking, or consuming unhealthy fast food.

In the network of factors related to HB, external effect is also important. *Social relationships* can show beneficial supportive effects on HB through, for example, better mental health and reducing the effect of stress, but they can also increase certain unhealthy behaviors (Umberson et al., 2010). *Life events* might exert positive outcomes such as lower alcohol consumption among new parents (Nomaguchi & Milkie, 2020) or better HB for men after getting married (Umberson, 1992), whereas stress and stressful life events can have a negative impact on HB (Wasserman & Hilliard, 2018). *Culture* can provide norms for HB (Kagawa Singer et al., 2016), for example, either encouraging or discouraging alcohol consumption (Quah, 2007). Similarly, *religion* can result in specific dietary choices (Enstrom, 1989; Hunt et al.,

1988) and reduced alcohol consumption (Richard et al., 2000). *Society* affects HB context, possibilities, and resources. In the Third World, dietary habits have been characterized by undernutrition, whereas in the First World, the primary problem is the overconsumption of food (Conner, 2015). Political decisions can also substantially support HB by, for example, promoting active commuting, increasing the availability of exercising facilities, or by the taxation of unhealthy foods, alcohol, and cigarettes (Glanz et al., 2015; Matson-Koffman et al., 2005). The impact of the *surrounding environment* on HB has been demonstrated by nudging—placing food items in shops and restaurants in an order that promotes healthier choices—increasing their consumption (Marchiori et al., 2017).

2.1.4 Summary of Health Behavior

HB is a complex, multifaceted, and diversely studied phenomenon that has a substantial impact on the risk of chronic diseases and their burden on health care. Therefore, understanding HBs and successful HB changes is important on individual, health care, and society levels. The present thesis focuses on the four major modifiable HBs that account for chronic diseases: physical activity, dietary habits, alcohol consumption, and smoking status.

2.2 Subjective Well-being

2.2.1 Historical and Current Perspectives

From the beginning of human history, humans have sought pleasure and happiness. Earlier, the principles of a good life were explored and defined within philosophy and religion by notable figures such as Aristotle, Confucius, Jesus, and Buddha (Diener, Oishi, et al., 2018). In Europe during the middle-ages, happiness was seen as something lost in paradise, and life was characterized by suffering, whereas the Enlightenment era turned happiness into an achievable and desirable goal (Veenhoven, 2017a).

In the 1950s, SWB emerged as a side topic in research on successful aging and mental health. It became a main topic in social indicator research in the 1970s, and since 2000 has been studied in the field of happiness economics (Buettner et al., 2020) when *Positive Psychology* was also introduced as the study of human flourishing (Seligman & Csikszentmihalyi, 2000). For a long time, psychiatry and psychology, like the other medical sciences, focused on defining and treating diseases instead of considering positive outcomes (Froh, 2004; Vaillant, 2003). This was challenged by the growing interest in exploring the arguably innate human tendency

to strive for continuous growth and development as well as positive phenomena such as love, courage, and happiness (Froh, 2004).

Even though the scientific understanding of mental health has grown immensely, overall happiness levels increased (Veenhoven, 2017a), and suicide rates decreased (OECD, 2019), the burden caused by mental health problems persists (Kessler et al., 2009). Half of all people experience a mental health problem during their lifetimes (OECD, 2019), mental disorders being the leading cause of disease burden worldwide in terms of years lived with a disability (James et al., 2018).

SWB represents one dimension of quality of life, defined as "individuals' perceptions of their position in life in the context of the culture and value system where they live, and in relation to their goals, expectations, standards, and concerns" (WHO, 1998). Research on well-being, referring here to a wider field exploring the various aspects of happiness and SWB, has been characterized by duality. Hedonic tradition has focused on pleasure and pain avoidance as sources of happiness, whereas the eudaimonic tradition emphasizes meaning and self-realization (Ryan & Deci, 2001). SWB represents a subjective quality of life dimension, leaning towards the eudaimonic direction of well-being but not including all its constructs (Diener, Diener, et al., 2018).

Research on well-being has been diverse in its concepts and perspectives. The research field has grown exponentially, with the works of 15,000 researchers (Buettner et al., 2020) and 40,000 research findings (Veenhoven, 2017c) presented in the World Database of Happiness (Veenhoven, 2017c). SWB can cover phenomena from optimism to low-level anger or work satisfaction (Diener & Chan, 2011). Diener's (1984) major conceptualization outlined SWB as an individual's evaluations and appraisals of their own life as a whole, including both cognitive judgement and emotional responses to life (Diener, Oishi, et al., 2018). The components of cognitive evaluation and affect are distinct and are highly affected by the standards an individual sets for a good life. The cognitive component is a personal evaluation of one's life and includes life satisfaction and domain satisfaction (Diener, Lucas, et al., 2018). The emotional dimension is further divided into positive and negative affects which correlate with each other in spite of being separate constructs that can co-occur (Diener, Oishi, et al., 2018). The term happiness has been used in the scientific field to refer to emotions, feelings, and mood (Ngamaba et al., 2017), but also life satisfaction. In the latter case, happiness has referred to the subjective enjoyment of one's life as a whole (Buettner et al., 2020; Veenhoven, 1984), with both affective and cognitive components (Veenhoven, 2017b), thus resembling the concept of SWB. The term is, however, best used for communicating constructs related to SWB to the public (Diener, Lucas, et al., 2018). Table 1 presents an overview of the different terms and their definitions.

Table 1. Definitions of key concepts (Diener, et al., 2018b; reprint with permission from the publisher).

CONCEPT	DEFINITION
WELL-BEING	The most general term covering how well individuals are doing in life, including social, health, material, and subjective dimensions of well-being.
PSYCHOLOGICAL WELL-BEING	A term that has come to be equated with Eudaimonic Well-Being (see below). Thus, it is often used in a way that does not refer to all possible types of psychological well-being, but only to one form of well-being.
QUALITY OF LIFE	A term usually referring to a person's overall life circumstances, including environmental, social, societal, material, and other aspects of their life that would affect how desirable and positive his or her life is.
SUBJECTIVE WELL-BEING	General term referring to the various types of subjective evaluations of one's life, including both cognitive evaluations and affective feelings.
LIFE SATISFACTION	People's explicit and conscious evaluations of their lives, often based on factors that the individual deems relevant.
DOMAIN SATISFACTION	Narrower than life satisfaction, domain satisfactions refer to evaluations of various domains in life such as health, work, and relationships.
POSITIVE AFFECT	Positive, pleasant, and desirable emotional feelings and moods.
NEGATIVE AFFECT	Negative, unpleasant, and undesirable emotional feelings and moods.
HEDONIC WELL-BEING	A person's well-being derived from pleasure, and lowered by pain. Often scholars will include physical pleasures, pleasures of the mind, and emotions.
EMOTIONAL WELL-BEING	People's positive moods and emotions and low levels of negative moods and emotions, and reflects not only momentary enjoyment, but also movement toward goals that are congruent with a person's motives. In addition, Emotional Well-Being is thought to include resilience after bad events, and the ability to express various emotions that are functional and appropriate to the situation.
EUDAIMONIC WELL-BEING	In contrast to Subjective Well-Being, this refers to well-being defined as desirable psychological characteristics such as meaning and purpose, positive social relationships, mastery, autonomy, virtues, and so forth, which can enhance effective functioning and Subjective Well-Being. Eudaimonic refers to Aristotle's notions of well-being based on the good functioning person.
HAPPY OR HAPPINESS	This popular word can be confusing because it means different things in different contexts and to different people. It may mean positive feelings at the moment, long-term life satisfaction, all forms of well- being, or even the causes of subjective well-being. This word is helpful at times communicating with the public, but can be confusing in a scientific context.

Three categories of constantly evolving and complementary theories explaining SWB are described here according to Diener, Oishi, et al. (2018). The *biological theories* focus on biology and genetics to explain the differences between individuals' happiness. These theories suggest that individuals have a baseline level, i.e., a set-point, to which they return after momentary fluctuations in SWB. The set-point view has been questioned by research findings, but individuals nevertheless appear to have various propensities towards better or worse SWB. According to the *Satisfaction of goals theory,* the satisfaction of personal needs, desires, and goals results in higher levels of SWB, which may potentially explain the unexpectedly low difference between the SWB of extreme socioeconomic groups, for example. *Mental-state theories* concentrate on cognitive and attentional processes in which, for example, comparison to others or interpretation of the situation substantially impact the SWB experience.

In the Nordic Countries, Eric Allardt (1976) developed welfare studies from quality of life studies (Andrews F, 1976; Campbell A, Converse P, 1976). Based on Maslow's fulfillment of needs theory (Maslow, 1968), Allardt outlined three dimensions of personal needs resulting in welfare: 1) having (material and impersonal resources), 2) loving (love, companionship, and solidarity), and 3) being (self-actualization and the obverse of alienation) (Allardt, 1976).

SWB has been outlined as a fairly stable characteristic if life circumstances remain unchanged (Diener, Oishi, et al., 2018). However, permanent SWB changes are also possible (Easterlin, 2003). A consensus of happiness experts states that intentional actions on both the individual and societal level can lead to greater sustainable well-being, but not in the stereotypical way of becoming rich and owning the best material possessions (Buettner et al., 2020; Sheldon & Lyubomirsky, 2006). Interventions aiming to raise long-term SWB levels, such as mindfulness, counting one's blessings, employing personal strengths, and savoring experiences, have also shown some success in improving SWB in randomized settings and according to biological markers (Steptoe, 2019).

SWB has shown a wide range of positive associations for individuals and society, in the areas of health, longevity, income, and productivity as well as organizational, individual and social behavior (De Neve et al., 2013). For *individuals*, SWB has been associated with, for example, better overall and disease-specific health (e.g. cardiovascular health), longevity, better sociability, networks, and better financial and cognitive performance (De Neve et al., 2013). In addition, individuals with high SWB generally have better resilience and bounce back from setbacks and recover from stress more rapidly (Fredrickson et al., 2003). On the *societal level*, cross-sectional studies have associated higher SWB with higher productivity (Isham et al., 2020), higher national income, and higher GDP per capita (Deaton, 2008). The effect also seems to apply longitudinally, particularly if economic advances result in fulfilment

of citizens' needs (Jebb et al., 2018). The positive associations between SWB and *work* lead to greater productivity and lower absenteeism, creative and cognitive flexibility, and better co-operation and collaboration (De Neve et al., 2013). In addition, happier individuals also help others, and do more than that required for their company (Borman et al., 2001; Jebb et al., 2018). The issue of causality has also been raised. It seems likely that the causal effect works in both directions, i.e., SWB predicts a positive outcome, which also enhances SWB. However, evidence of this is still limited (Diener, Oishi, et al., 2018).

The pursuit and experience of happiness is generally seen as a hallmark of psychological health (Gruber et al., 2011), and in many situations it is beneficial for an individual to experience mostly pleasant feelings (Diener, Oishi, et al., 2018). However, in some aspects, the highest SWB may not be the most beneficial and SWB can be pursued in adverse times, situations or ways (for review, see Gruber et al., 2011). Furthermore, a moderately high level of SWB compared to the highest level has been found to be more beneficial for income, education, and political participation (Oishi et al., 2007). High levels of positive affect can also have some specific negative influences on health through, for example, underestimating potential threats or adopting inappropriate coping strategies (Pressman & Cohen, 2005). In contrast, openness to some temporary unpleasant feelings in certain situations can be beneficial (Diener, Oishi, et al., 2018). Therefore, even though a high level of SWB is mostly beneficial, this issue is not straightforward in all situations.

2.2.2 Measuring Subjective Well-being

Rather than seeking to define a good life, behavioral scientists have turned their interest towards attempting to understand the factors that lead individuals to perceive their lives as worth living and as rewarding, which is referred to as SWB (Diener, Oishi, et al., 2018). Further, according to Diener et al. (2018), researchers rely on the belief that the personal evaluation and experience of how good life is lets the individual decide what constitutes a good life. Because of its subjective nature, self-reporting is the primary method for measuring SWB and has shown good reliability: Consistency in reporting has been observed over short periods of time (with no major changes in life circumstances), with evaluation from others (including family and friends), and with numerous momentary assessments. Objective measures of SWB include smile intensity, number of good versus bad life events recalled, positive or negative words used on social media, text analysis, cortisol level measurements, and neuroimaging, the three first of which have shown convergence with self-reporting. Self-reporting is more feasible in large populations but advances in technology mean objective measures can be scaled. Both subjective and objective measures can be

influenced by momentary bias caused by, for example, the weather or the day of the week.

Self-reported SWB has been measured by both single and multiple items (Veenhoven, 2017b), the latter being seen as having better psychometric properties (Ngamaba et al., 2017). Furthermore, of the two SWB components, affect has commonly been the focus, and mood or feelings of positive affect are typically measured on various scales (Diener, 2009). Single items measuring SWB have asked, for example, "How do you feel about your life as a whole…". The *Satisfaction with Life Scale* (Diener et al., 1985) is a composite measure that evaluates overall satisfaction, i.e. the cognitive component of SWB, and contains five items: experiences of life being close to the personal ideal, experiences of conditions in life, satisfaction with life, achievements, and regrets (Diener, 2009).

The *Four-item Life Satisfaction Scale* was modified by Eric Allardt for welfare studies in the Nordic countries (Allardt, 1976) and measures happiness, interestingness, and easiness of life, as well as perceived loneliness (Koivumaa-Honkanen et al., 2000). The scale has shown a strong long-term predictive ability concerning various long-term health outcomes (Koivumaa-Honkanen et al., 2000; Koivumaa-Honkanen et al., 2004; Rauma et al., 2014) and predictive power concerning depression in samples of both patients samples (Koivumaa-Honkanen et al., 2008; Rissanen et al., 2011) and the general population (Koivumaa-Honkanen et al., 2004).

2.2.3 Factors Related to Subjective Well-being

Numerous factors related to SWB have been identified, as shown in Figure 2. Many of the findings are derived from cross-sectional studies, which cannot determine causality (Diener et al., 2017). The correlates might also have differing relationships with the components of SWB. For example, income is more strongly associated with evaluative well-being than affective well-being (Steptoe, 2019).

A growing body of studies have identified a u-shaped curve for SWB by *age* in the working-age population. The lowest point observed is between the mid 30s and early 50s, but other patterns have also been reported (Dolan et al., 2008; Graham & Ruiz Pozuelo, 2017; Maher et al., 2015). In some cases, age can act as a moderator towards SWB: For example, social relationships appear more important for SWB among older than younger adults (Steptoe, 2019).

The most consistent finding in terms of *gender* and SWB is that men have slightly higher life satisfaction than women, whereas findings concerning positive affect have shown inconsistencies (Batz-Barbarich & Tay, 2018). Gender minorities might also experience lower SWB, mediated by discrimination and moderated by self-esteem and stigma consciousness (Douglass et al., 2017). *Race* might also affect

SWB, but due to a lack of studies, we can make no firm conclusions regarding this issue (Diener, 1984; Diener et al., 2017).

Genes guide stable characteristics that can account for about 30–40% of the variance of non-specified SWB measures (Diener, Oishi, et al., 2018). Genetics also account for top-down influences which represent internal factors that cause individuals to react in specific ways (Diener, 1984). Furthermore, genes that regulate expression in the *central nervous system* as well as in the adrenal and pancreatic tissues have also shown associations with SWB (Bartels, 2015; Okbay et al., 2016).

Figure 2. Visual grouping of various factors related to subjective well-being: Graphical overview of multiple dimensions that might affect SWB (modified from Steptoe, 2019).

Of the Big Five *personality traits*—extraversion, agreeableness, openness, conscientiousness, and neuroticism—neuroticism was the strongest predictor of low life satisfaction, a low level of happiness, and negative affect. Positive affect was equally predicted by extraversion and agreeableness (Deneve & Copper, 1998). Furthermore, of the 137 distinct personality constructs, an association was observed between SWB and repressive-defensiveness, trust, emotional stability, change in locus of control, desire for control, hardiness, positive affectivity, private collective self-esteem, and tension. Personal characteristics that are determined by both genetics and life experiences can improve SWB through a strong s*ense of coherence* (Nilsson et

al., 2010), *self-compassion* (Hollis-Walker & Colosimo, 2011; Neff et al., 2007), and *personal values* (Diener, Oishi, et al., 2018).

Higher education appears to be associated with SWB through non-monetary benefits (Yakovlev & Leguizamon, 2012) and through its association with socioeconomic status, which enables the fulfilment of basic and psychological needs (Diener, Oishi, et al., 2018). The effect of socioeconomic status varies between countries but appears stronger for life evaluation that reaches a plateau at an annual income of US$ 95,000, whereas emotional well-being is more associated with fulfilment of psychological needs, showing rising levels until US$ 60,000–75,000 (Diener et al., 2010; Jebb et al., 2018). *Purpose in life* has been suggested as one aspect of the golden triangle of happiness, together with feelings of satisfaction with income and relationships (Cummins, 2018). The *fulfilment of needs* has shown a positive correlation with SWB in 123 nations (Tay & Diener, 2011). Fulfilment of basic needs such as food and shelter is additive and most strongly associated with life evaluations, whereas social needs being met and experiencing respect is associated with positive feelings (Diener, Oishi, et al., 2018). A good *health status* has also shown a positive association with SWB (Ngamaba et al., 2017). Initial results even suggest that the *brain-gut-microbiome* axis is associated with SWB through certain patterns of the microbiome linkage to emotional well-being (Lee et al., 2020).

Environmental effects have been estimated to account for 60–70% of SWB, based on various SWB measures (Diener, Oishi, et al., 2018), and represent bottom-up influences, i.e., dynamic events that affect SWB (Diener, 1984). Specific *life events* and personal circumstances can also affect SWB, although adaptation occurs in many cases (Luhmann et al., 2012). Adverse *childhood experiences*, however, have long-lasting effects into adulthood and higher odds of physical and mental health problems reducing SWB (Corcoran & McNulty, 2018). *Unemployment* has consistently been associated with lower SWB through lowered income as well as through social and psychological factors (Dolan et al., 2008).

Positive *relationships* contribute substantially to SWB, and socializing with friends and especially family has been positively associated with life satisfaction (Dolan et al., 2008). However, relationships can also have detrimental effects through, for example, social comparison, reducing the effect of material goods on SWB (Easterlin, 2003). *Marital status* and stable cohabitation (Dolan et al., 2008) have been consistently associated with higher SWB, where selection bias accounts for part of the effect, and the boost to SWB of getting married typically lasts for a few years (Lucas et al., 2003). Divorce and widowhood, on the other hand, are associated with lower SWB (Lucas et al., 2003). *Parenthood* has shown various associations with SWB: insignificant (Diener, Oishi, et al., 2018), positive or detrimental

(Nelson et al., 2014), as well as moderation by sociodemographic variables and differing associations with SWB according to a child's age (Nomaguchi & Milkie, 2020).

Habits can impact SWB in both the short and long term. HB has been identified as one potential habit. Other specific habits, such as practicing mindfulness (Brown & Ryan, 2003) and savoring (Szczygieł & Mikolajczak, 2017), have increased positive emotional and decreased negative experiences. *Time use* can improve SWB if individuals can choose how they use their time, which has been observed in both rich and poor nations (Diener, Oishi, et al., 2018). On the other hand, factors that occupy time in an unpleasant way, for example, long commutes to work, can reduce SWB (Stutzer & Frey, 2008). SWB might also be affected negatively by individuals allocating disproportionate amounts of time to pursuing pecuniary, i.e., material or monetary goals instead of pursuing non-pecuniary goals such as family life and health (Easterlin, 2003). The evidence of the association between SWB and working hours has been mixed, with results suggesting that life satisfaction increases as working-hours increase, no difference, or a reversed u-shaped curve (Dolan et al., 2008). Further, according to Dolan, caring for others, especially within the family, associates with lower SWB if it results in a loss of autonomy. Being part of a non-religious community or volunteering could improve SWB but controlling for personal factors significantly affected this association; and even opposite effects have been observed.

Culture can affect what individuals believe is the source of happiness (Diener, Oishi, et al., 2018). Cultural values and norms affect the relationship between self-esteem, income, financial satisfaction, friendships, family satisfaction, and SWB (Diener & Diener, 1995). *Society* can also have a substantial impact on SWB. There is consensus that the wealth of a nation is closely associated with the degree to which citizens can live their lives according to their personal ideals (Diener, Oishi, et al., 2018). Furthermore, positive associations have been observed between societal SWB and lower income inequality (Oishi et al., 2018), a higher degree of political freedom (Inglehart et al., 2008), and lower corruption (Tay et al., 2014). Engagement in regular *religious activities* has fairly consistently been associated with higher SWB (Dolan et al., 2008), which is especially observable in religious nations (Garssen et al., 2016). The *external environment* has also shown associations with SWB; for example, higher SWB is linked to living in urban areas with more green spaces (White et al., 2013), and spending time in greener environment (MacKerron & Mourato, 2013).

2.2.4 Summary of Subjective Well-being

The longing for SWB is deeply innate in all humans. The study of SWB is characterized by a variety of formulations and methods. The present thesis follows Diener's conceptualization that SWB refers to the personal experience of how well life is going. SWB can be affected by numerous internal and external factors but is stable if no major changes occur. Experts agree that intentional actions by individuals or in policymaking can improve SWB.

2.3 Relationship Between Health Behavior and Subjective Well-being

2.3.1 Health and Subjective Well-being

Longitudinal studies have long focused on the negative rather than positive outcomes of mental health. Before 2005, 20 times more publications explored depression and health than happiness and health (Pressman & Cohen, 2005). However, the positive dimension has gained more attention in recent decades, and now hundreds of studies have shown an association between health and positive SWB (Diener et al., 2017; Ngamaba et al., 2017): Medium-sized associations have been found in both patient and general populations ($r = 0.347$, 95% CI = 0.309–0.385) (Ngamaba et al., 2017). It has been proposed that the relationship is bidirectional, i.e. SWB improves health, and health and illness contribute to SWB (Diener, Oishi, et al., 2018; Kushlev et al., 2019), but not many studies have explored this. In a 20-year follow-up, positive and negative affect simultaneously predicted subsequent health, and health predicted subsequent affect, but neither direction was stronger than the other (Wiese et al., 2019). In unidirectional settings, SWB has predicted later health and longevity in long-term prospective studies, in animal studies, and in experimental interventions (Diener & Chan, 2011). It has been suggested that HB is an important and even a major pathway for this to occur, but that SWB also affects the immune and cardiovascular system and plays a buffering role in challenging life events (Diener et al., 2017; Ong, 2010; Pressman & Cohen, 2005; Sin et al., 2015; Wiese et al., 2019). Good mental and physical health have also predicted greater SWB (Koivumaa-Honkanen et al., 2008; Kushlev et al., 2019; Maher et al., 2015; Wiese et al., 2019), but this pathway seems to be reported less than that of the opposite direction, from SWB to health. Therefore, although an association between health and SWB has been shown in both cross-sectional and longitudinal settings, bidirectional evidence and insights into the pathways are limited.

2.3.2 Pathways Between Health Behavior and Subjective Well-being

Various mechanisms may exist between HB and SWB (Mujcic & Oswald, 2016; Ocean et al., 2019; Sin et al., 2015). The pathway can also be affected by confounding and moderating factors. Although the growing literature on the link between HB and SWB has provided some answers, it has raised almost as many questions (Kushlev et al., 2019).

HB improving health and thus also SWB is a natural hypothesis for the association in the long term, but more specific mechanisms have also been proposed. It has been suggested that HB affects biological and neural processes. On a daily basis, physical activity seems to reduce the levels of proinflammatory cytokines and amygdala reactivity (Sin et al., 2015) and to activate several cortical regions in the brain and the modulations in the central nervous system's neurotransmitters (Portugal et al., 2013). Furthermore, according to Portugal, HB has potentially favorable long-term effects on SWB through hormonal and physiological effects. For example, sustained levels of physical activity result in neurogenesis and angiogenesis, which can enhance SWB through improved behavioral and cognitive function. Potential pathways from a healthy diet to better SWB include vitamin B12 and a carbohydrate-rich diet enhancing serotonin production, microbiota modulating brain chemistry, and antioxidants lowering the proinflammatory markers associated with the onset of depressive moods (Mujcic & Oswald, 2016; Ocean et al., 2019). In more practical terms, physical activity could increase feelings of energy, reduce feelings of fatigue, and enhance pleasant affect on a day-to-day basis (Maher et al., 2015).

Various pathways have been suggested for SWB enhancing HB. According to Sin et al. (2015), the following may be potential mediators between SWB and HB: enhanced motivation, self-efficacy, paying more attention to and carefully processing health risk information, and better adjustment to health-relevant goals. Positive affect has been linked to self-regulation through the confidence and favorable expectations that are produced when one progresses towards personal goals. Positive affect might also facilitate acceptance and the processing of health risk information by reducing self-defensiveness towards such information.

Confounding and moderation might affect the nature of the pathways. As described in Sections 2.1.3 and 2.2.3, both HB and SWB are affected by a wide range of common factors that can function as confounders. However, in a panel-setting, many stable factors such as personality or genetics stay constant or change very slowly, meaning that confounding is partly controlled for. Moderating factors can also alter the effect of the predictor on the outcome. For example, age appeared to moderate the effect of physical activity on daily SWB when the association was observed among middle-aged and older but not emerging adults (Maher et al., 2015). Further according to Maher, goals to maintain health and enable functional capacity

and independence become increasingly important throughout adulthood, and therefore achieving these goals through HB may be more rewarding later in life. The type of physical activity has also shown to be a moderating factor: Moderately intensive physical activity has improved life satisfaction, but vigorous activity has not (Wicker & Frick, 2015). Relationship status is another potential moderator, in which social control has been proposed as a mediator (Umberson, 1992).

2.3.3 Cross-sectional Evidence

The cross-sectional association between HB and SWB has been investigated in very large population-based studies; for example, studies of 2.5 million Americans (Kushlev et al., 2019), 700,000 British women (Liu et al., 2016), 19,000 multicultural students (Grant et al., 2009), 12,000 Danish adults (Schnohr et al., 2005), 7,900 German adults (Velten et al., 2014), and 80,000 British adults (Blanchflower et al., 2013). Further, different beneficial HBs have had an additive effect on life satisfaction, i.e. when the number of beneficial HBs increases, life satisfaction also improves (Velten et al., 2014). Cross-sectional studies, however, can only point to the existence of a relationship; longitudinal studies are needed to reveal more about its nature (Diener et al., 2017).

2.3.4 Unidirectional Longitudinal Evidence

Since the lack of longitudinal studies on the association between HB and SWB was addressed in 2012 (Boehm & Kubzansky, 2012), some research has explored positive longitudinal perspectives, although mainly in unidirectional settings. These studies have examined day-to-day effects but have also had follow-ups ranging from weeks to years. Commonly, they have focused on one HB, but a number have controlled for other HBs at baseline.

On a day-to-day basis, healthy dietary patterns among young adults (Conner et al., 2015; White et al., 2013) and physical activity among middle-aged and older people (Maher et al., 2015) has been associated with better SWB, but the results concerning the carry-over effect to the next day have been mixed. In a dose-response fashion, fruit and vegetable consumption predicted better life satisfaction in a representative sample of 45,000 adults in the five-year follow-up of the UK Household Longitudinal Study (Ocean et al., 2019) and in a two-year follow-up of randomly selected Australians (Mujcic & Oswald, 2016).

A few studies have explored the effect of baseline SWB measures on subsequent HB. Among inactive men but not among women, happiness and optimism at baseline were associated with a greater increase in physical activity in follow-ups ranging from six months to ten years (Baruth et al., 2011). Among adults older than 50, better

SWB was associated with high levels of physical activity in an 11-year follow-up (Kim et al., 2017) and slower decline of fruit and vegetable consumption in a six-year follow-up (Boehm et al., 2018). SWB measures predicted a reduction in smoking, less relapses, and higher cessation rates in a four-week website survey (Haller, 2016) and in an up to 26-week smoking cessation trial among heavy alcohol consumers (Leventhal et al., 2008).

Covariance of HB and SWB was observed in three major Socio-Economic Panels in Germany, Britain, and Australia, (Headey et al., 2012). It was also observed among cardiovascular patients in physical activity and SWB measures (Sin et al., 2015). Furthermore, congestive cardiac failure patients experiencing more positive affect reported more perceived positive HB changes (Chaves & Park, 2016).

2.3.5 Bidirectional Evidence

The bidirectional relationship between HB and SWB has not been studied widely. In a 15-year follow-up, moderate alcohol consumption in the Finnish adult population predicted better SWB in logistic regression modeling than heavy alcohol consumption at baseline and vice versa (Koivumaa-Honkanen et al., 2012). In this study, high consumption seemed to more strongly predict worse SWB than vice versa, and the scale of SWB was identical to that in our study—individuals with major health conditions were excluded, and the models were adjusted for social class, physical activity, smoking status, sex, and marital status.

In a two-year follow-up, fruit and vegetable consumption predicted subsequent life satisfaction, analyzed using fixed-effect regression models and adjusted for sociodemographic factors and other HBs. However, the opposite direction of influence was not statistically significant (Mujcic & Oswald, 2016). In a day-to-day analysis of young adults, fruit and vegetable consumption predicted positive affect the following day but positive affect did not predict fruit and vegetable consumption the following day (White et al., 2013).

A four-year follow-up studied the association between different aspects of SWB and smoking among older adults (mean age, 64 years) using structural equation modeling (SEM) (Lappan et al., 2018). Smoking predicted subsequent SWB, and SWB predicted subsequent smoking, the first association being stronger. The strongest effect, however, was seen between baseline and subsequent smoking and between baseline and subsequent SWB. The cross-sectional associations between smoking and SWB were also statistically significant.

2.3.6 Intervention Studies

Intervention studies have the best potential to indicate whether an action results in a specific outcome and provides the strongest argument for causality (Diener et al., 2017). A few interventions have aimed to improve SWB in patient populations in which increases in positive affect and reductions in negative affect have resulted in better HB (Peterson et al., 2012). In a non-clinical population, an intervention among 171 young adults provided two additional servings of fruit and vegetables per day for participants with low fruit and vegetable consumption. This resulted in elevated levels of vitality, flourishing, and motivation, but not elevated mood (T. S. Conner et al., 2017). Further, an extensive campaign promoting fruit and vegetable consumption in various states of Australia resulted in both their increased consumption and improvements in SWB in the general population (Mujcic & Oswald, 2016). According to a meta-analysis, physical activity has also shown a small positive effect on SWB in experimental settings (Buecker et al., 2020). A practically oriented Blue Zones project promoted healthy living and health-supportive environments in various cities in the US, and led to improved SWB (Buettner, 2017). Adding the target of improved SWB to HB interventions has also been suggested (Leventhal et al., 2008). A significant body of research among patient populations has shown that lifestyle interventions improve the quality of life, which is a more general measure than SWB and is often described through the effect of health on everyday life, i.e. health-related quality of life (e.g. Danielsen et al., 2014; Govil et al., 2009; Lidin et al., 2018; Wadden, 2014).

2.3.7 Theoretical Perspectives

The present thesis is more constructivist or epidemiological than theoretical, as it explores the phenomena of HB and SWB rather than their theories. Neither is it practically focused, as it does not test a specific HB or SWB change approach or strategy. However, the SWB theories described in Section 2.2.1 provide various perspectives of how HB may or may not predict SWB. According to the traditional *biological theories*, SWB is caused by internal factors and therefore would not be altered by HB, whereas SWB could influence HB. Furthermore, HB and SWB would assumably share common determinants, explaining their association. However, the newer understanding of, for example, the physiological effects of physical activity has led to refinements in biological theories on SWB. *Satisfaction of goals theories* could explain why HB predicts SWB through improved health, which in turn enables the pursuit of personal goals. HB change could also represent a personal goal, meaning that its attainment would increase SWB. *Mental theories* suggest that SWB might alter how an individual perceives HB and therefore affect HB. On the other hand,

the hypothesis that SWB could enhance HB is supported by the HB theories in Section 2.1.1, in that SWB might serve as a resource that increases self-efficacy towards HB change, which would be in line with the *Social Cognitive theory* (Bandura, 1977)*, The Health Belief* Model (M. H. Becker, 1974), and the *Theory of Reasoned Action* (Ajzen, 1991, 2011).

2.3.8 Summary of the Bidirectional Association

Based on the above, it seems relatively certain that SWB affects health, and that HB is the potentially most important pathway in this process. A few studies have also shown that HB predicts SWB measures. However, not many studies have explored the longitudinal associations between HB and SWB in follow-ups longer than a few years. Usually, these associations have been explored in respect to only one HB domain. No study has used an extensive follow-up with multiple HBs to explore this bidirectional relationship.

2.4 Summary of Literature Review and Need for Further Research

HB and SWB have been studied widely, and the focus has been on negative outcomes. Positive perspectives of the two phenomena and their mutual relationship have gained growing attention in recent decades. A wide variety of concepts and measures have been used for SWB especially, but also for HB. Both are complex phenomena with a wide range of internal and external correlates and predictors, many of which may be common to them both.

SWB predicts subsequent health. HB may have an important, potentially even the most important role in this relationship, but this needs further study. A few studies have also found that HB predicts SWB. Longitudinal evidence of the relationships between HB and SWB is, however, limited. Only a handful of studies have explored their potentially bidirectional relationship, and none have included multiple HBs in an extensive follow-up of such a relationship.

A better understanding of this relationship could provide new, positive perspectives of HB changes, which are seriously needed to decrease the burden of chronic disease. The need to gain a broader understanding of this bidirectional relationship formed the basis of the main aim of the present thesis.

3 Aims

The main aim of the present thesis was to gain a better understanding of the bidirectional relationship between multiple HBs and SWB. The main research question was whether HB is a stronger predictor of SWB or vice versa in an observational longitudinal setting. The objectives of the thesis were:

1. To explore how a composite measure of HB is associated with a composite measure of SWB in a nine-year follow-up (Study I).
2. To explore how a composite measure of SWB is associated with a composite measure of HB in a nine-year follow-up (Study II).
3. To analyze the bidirectional relationship between multiple HBs and SWB in a nine-year follow-up (Studies II and IV).
4. To evaluate the effect of change in multiple HBs on subsequent SWB and vice versa (Study III).
5. To utilize two separate statistical methods to deepen the understanding of the bidirectional relationship between HB and SWB (Studies I, II, and IV).

4 Materials and Methods

4.1 Study Population

4.1.1 Health and Social Support Study

Health and Social Support (HeSSup) is a prospective cohort study of the psychosocial health of the working-age population in Finland (Sumanen, n.d.). The study originated from the concern that chronic diseases are the most common cause of illness and premature mortality in Western countries. Thus, it was important to learn to understand the effects of possible etiological factors (i.e. biological, social, environmental, and lifestyle) on the occurrence of chronic conditions. HeSSup also aimed to seek potentially effective prevention and treatment of these conditions (Salakari, 2020). Data from the HeSSup study has been used in several doctoral dissertations and in over 115 studies published as international peer-reviewed original articles.

The HeSSup study began in 1998 with a random sample (n = 64,797) drawn from the national population register. This sample represented four age groups: 20–24 years (Group 1), 30–34 years (Group 2), 40–44 years (Group 3), and 50–54 years (Group 4). The Finland Proper population and Swedish-speaking Finns were slightly overrepresented in comparison to the general Finnish population. Postal enquiries were sent in 1998 (Time 1), 2003 (Time 2) and 2012 (Time 3). Each time, the enquiry was reposted after 10 weeks if no response was received in the first round.

The baseline of the studies of the present thesis was Time 2, and Time 3 was the follow-up. Only at these two timepoints were both HB and SWB measures included in the study questionnaire. In 2003 and 2012, postal enquires were sent to the participants who had responded in 1998. The surveys contained 103–112 items (27–30 pages in total), mostly well-validated questions from international studies. They assessed the following areas: social background and support; personal resource factors (such as education); personality factors (including sense of coherence, optimism and pessimism, hostility); stress factors (such as life events and daily stress); life satisfaction; HBs and attitudes; and medical issues (including medications, diagnosed conditions, depressive symptoms, and use of health care services) (Korkeila et al., 2001). The formulation and order of the original items remained identical in these two follow-ups, but a few items were excluded, and new items included. The enquiry

was translated for the Swedish-speaking population, which made up ca 7.5% of the HeSSup population (Volanen et al., 2006) and represented 5% of the general Finnish population (Suominen, 2014).

4.1.2 Ethical Considerations

The participants signed their written consent for a panel-setting and their commitment to data protection. The concurrent joint Ethical Committee of the University of Turku and the Turku University Central Hospital approved the Health and Social Support study. The study was carried out in accordance with the Declaration of Helsinki. Participation was voluntary and individuals could withdraw from the study at any point.

No separate ethics approval was required for the present thesis to use the data of the HeSSup study, but permission was granted by the study group led by the Principal Investigator, Professor Markku Koskenvuo. The study data contained variables of a personal and sensitive nature, and according to present legislation, such data cannot be made openly accessible inside or outside Finland. All shared and analyzed data were pseudonymized before delivery.

4.1.3 Participants

The first postal survey in 1998 (Time 1) (n = 64,797) resulted in a response rate of 40.0% (n = 25,898). The follow-up surveys at Time 2 and Time 3 reached response rates of 80.2% (n = 19,269) and 57.4% (n = 13,050), respectively, calculated from respondents to the Time 1 survey.

For the present Studies I–IV, a longitudinal sample of respondents from Time 2 (2003) and Time 3 (2012) were chosen due to the inclusion of dietary and life satisfaction measures in these waves, as illustrated in Figure 3.

In Studies I, II, and III, individuals with missing information in any HB domain, on covariates, or in more than one item on the four-item life satisfaction scale were excluded. Thus, the final study population was 10,855. In Study IV, respondents with missing information on education or diseases covariates were excluded, resulting in a final study population of 11,806. For further details, see the flow charts in the original publications.

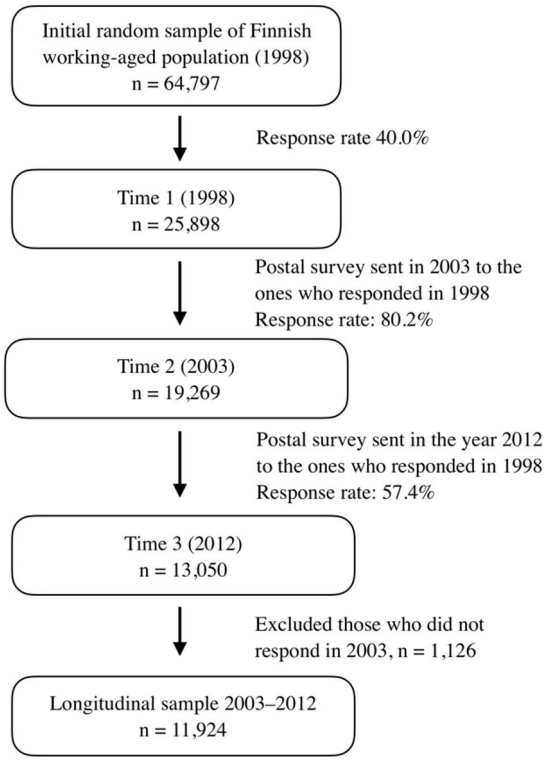

Figure 3. Selection of study population from Health and Social Support study. Modified from Studies I–III.

4.2 Methodological Approach

The present thesis aimed to provide insights into the bidirectional relationship between HB and SWB. Causal evidence would provide the strongest argument for the association in which the most reliable method is randomized controlled trials. Observational studies, however, enable a wider representation of the general population in a cost-effective way, longer follow-up times, and a more natural setting than randomized controlled trials (Diener et al., 2017).

The data used were based on self-reports. For HB this may result in some reporting bias (Wasserman & Hilliard, 2018), but as SWB is a personal evaluation of life, self-reporting is an appropriate measure and has been used most often in SWB studies (Diener, Lucas, et al., 2018).

Studies I, II, and IV explored interindividual differences, but the intraindividual change perspective was added to Study III. Further, insights from different statistical methods were compared to gain a better understanding of the phenomenon in the present thesis.

4.3 Assessment of Health Behavior

HB was assessed on the basis of the four principal HBs accounting for chronic diseases, i.e., physical activity, dietary habits, alcohol consumption, and smoking status (OECD, 2019; WHO, 2020). Each HB was dichotomized into either unhealthy or beneficial (Studies I–IV). An HB sum score (HBSS) was calculated (Studies I–III) as the total number of beneficial HBs. Each unhealthy behavior provided 0 points and each beneficial behavior 1 point, creating a sum score ranging from 0 to 4. In Study IV, the dichotomized HBs were included individually as observed variables in the structural equation model. The supplementary material in Study I shows the HB questionnaire in more detail.

Physical activity during leisure time and commuting was counted as time spent per week (not at all/ less than 0.5 hours/ 1 hour/ 2–3 hours/ 4 hours or more) on each level of the following intensities of activity: comparable to walking/ brisk walking/ jogging/ running. The responses were converted into metabolic equivalent task (MET) units in which a MET value of 2 corresponds to 30 minutes of walking per day and was the cut-off point for beneficial behavior (Kujala et al., 2002).

Dietary habits were assessed using a dietary measure (range 0–100) based on a non-validated food propensity questionnaire (Lagström et al., 2019). Adherence to Nordic nutrition recommendations (Becker et al., 2004) was evaluated using ten of the 23 food items in the survey. A choice that was in line with the recommendations scored 1 dietary score point. The following specific cut-off points were used: dark bread (≥ 2/day); pastries and sweets (≤ 1–2/week); fat-free milk (≥ 1/day); sausages (≤ 1–2/week); red meat (≤ 1–2/week); chicken or turkey (each ≤ 1–2/week); fish (≥ 1–2/week); fresh fruits and berries (≥ 2/day); vegetables (≥ 2/day); alcohol consumption (< 10 g women, 20 g men/day). The dietary score (range: 0–10) was multiplied by 10 to obtain the percentage of compliance with recommendations (Lagström et al., 2019). Dietary habits were dichotomized at the median into beneficial (diet score of ≥ 60) and unhealthy (diet score of ≤ 50).

Alcohol consumption was measured by weekly intake of beer, wine, and other equivalent mild alcoholic beverages, and monthly intake of spirits. Alcohol consumption was converted into grams per week and then dichotomized according to the Finnish guidelines for alcohol consumption, which classes excessive consumption as ≥ 140 g/week for women and ≥ 280 g/week for men (Duodecim, 2018).

Smoking status was measured by the reported number of cigarettes smoked daily. Current smoking was dichotomized as unhealthy, whereas not smoking (including former smokers) was beneficial.

The categories for the four domains of HB were defined as follows; beneficial behavior is presented first:

1) Dietary patterns: sum score of ≥ 60 vs. sum score of ≤ 50
2) Physical activity: active, MET ≥ 2 vs. inactive MET < 2
3) Alcohol consumption: non-drinkers and moderate drinkers vs. heavy drinkers (women ≥ 140 g/week; men ≥ 280 g/week)
4) Smoking status: currently not smoking vs. currently smoking

If any of the HB domains had missing information, the individual was excluded from the analyses (2003, n = 1,069; 2012, n = 1,085).

HB change (Study III) was measured by a change in the HBSS (range 0–4) during follow-up and categorized into three groups as follows: positive, neutral, and negative change.

4.4 Assessment of Subjective Well-Being

In general, SWB comprises both a cognitive component (i.e. life satisfaction) and an affective component (i.e. both positive and negative affect) (Diener, Oishi, et al., 2018). In the present thesis, SWB was measured using the four-item life satisfaction scale created by Erik Allardt (1973), which has been used in numerous extensive studies (for details, see Section 2.2.2).

The scale comprises three life assessments of happiness, interestingness, and easiness of life, as well as one item on perceived loneliness. Its three life assessments represent the cognitive component of SWB, whereas perceived loneliness (one item) reflects the social aspect of SWB. As SWB is a broader concept than life satisfaction, we used Allardt's scale as an SWB measure. The scale was used as a sum score in Studies I–III, but in Study IV the items were explored as individual observed variables, each representing SWB.

The wording of the items in the life assessments was "*Do you feel that your life at the moment is …*", whereas perceived loneliness was elicited by asking "*Do you feel that at the moment you are …?"* The responses were scored as follows: very interesting/ happy/ easy/ not at all lonely = 1; fairly interesting/ happy/ easy = 2; cannot say = 3; fairly boring/ unhappy/ hard/ lonely = 4; very boring/ unhappy/ hard/ lonely = 5. The sum score range was 4–20, lower values indicating better SWB (Studies I–III).

Based on one standard deviation from the mean, the score (4–20) has been frequently categorized into three groups (4–6; 7–11; 12–20) (Koivumaa-Honkanen et al., 2000). In Study III, we further divided the large intermediate group into two at the mean to create four groups: high SWB (4–6), high intermediate (7–8), low intermediate (9–11), and low SWB (12–20). Thus, both SWB and HB had an equal number of groups to enable comparison of change. *SWB change* was measured by

changes in the four SWB groups during follow-up and was categorized into three groups according to its direction: positive, neutral, and negative change. In Study IV, the four-item score was reversed, and the items were used as individual continuous variables as follows: interestingness of life (1–5), happiness of life (1–5), easiness of life (1–5), and perceived loneliness (1–4).

4.5 Covariates

The baseline HB level was included as a covariate when the effect of baseline SWB on subsequent HB was studied. Similarly, SWB at baseline was included when the effect of baseline HB on subsequent SWB was studied (Studies I–III). In SEM, the baseline levels of both HB and SWB were included in the model.

Sociodemographics and health can substantially affect both HB and SWB, as presented in Sections 2.1.3 and 2.2.3. Age, gender, and education were included as sociodemographic covariates in all Studies I–IV. The original random sampling produced four *age*-groups (ages in 2003): 25–29 years (Group 1), 35–39 years (Group 2), 45–49 years (Group 3), and 55–59 years (group 4). In 1998, the participants reported *gender* (male or female). *Education* was reported in 2003 on seven levels and categorized into four educational groups: 1) no professional education; 2) vocational course/ school/ apprenticeship contract; 3) college; 4) university/ university of applied sciences. *Health status* was measured as the count of self-reported diseases in 2003 from a predefined list of 35 chronic or major conditions and categorized into three groups: 0, 1, ≥ 2 diseases (Studies I–IV). For the complete list of diseases, see the supplementary material of Study I. As *negative life events* can substantially affect changes in both HB and SWB, they were included in Study III. Of the list of 21 life events that may have occurred in 2007–2012 (for details, see supplementary material of Study III), those that the participants reported as burdensome and extremely burdensome were included (Vahtera et al., 2007) and then transformed into a trichotomized covariate: 0, 1, ≥ 2 major negative life events.

4.6 Statistical Methods

We explored the distribution of the baseline characteristics. The association between the sum scores of baseline HB and SWB at follow-up and vice versa was assessed using boxplots, and as the associations appeared linear, we used general linear regression models (Studies I–III). Cronbach's alpha estimates were computed for HBSS and SWB (for details, see original publications I and II). For bidirectional comparison in Studies II and III, linear models for the opposite directions of effect were created separately and then compared. In SEM (Study IV), the cross-sectional, cross-lagged, and longitudinal associations were included in the same model.

4.6.1 Linear Regression Modeling

For the present thesis, the cross-sectional association between HB and SWB were explored using linear regression. The models were adjusted for age, gender, education, and diseases, and the comparable interactions were tested. The interaction with diseases was statistically significant and was included in the final models. These additional analyses used IBM SPSS Statistics 27.

In Study I, the association between $HBSS_{2003}$ and SWB_{2012} was explored using linear regression. First, the models for individual HBs in 2003 predicting SWB_{2012} were adjusted for age, gender, and the comparable interactions. Due to the interest in exploring the combined effect of the four principal HBs and the exponentially growing number of models when covariates were added, we created an HBs sum score, as described in Section 4.3. The linear regression models in which $HBSS_{2003}$ predicted SWB_{2012} were progressively adjusted for age, gender, education, diseases, and SWB_{2003}. The impact of the following interactions was explored but excluded, as none were statistically significant: $HBSS_{2003}$*age, $HBSS_{2003}$*gender, $HBSS_{2003}$*education, and $HBSS_{2003}$*diseases.

Study II explored the opposite direction of the effect. The effect of SWB_{2003} on individual HBs in 2012 was explored and adjusted for age, gender, and comparable interactions. After this, as in Study I, the HBSS was studied instead of individual HBs. The regression models in which SWB_{2003} predicted $HBSS_{2012}$ were adjusted progressively for age, gender, education, diseases, $HBSS_{2003}$, and SWB_{2003}*education, which was the only statistically significant one of the following tested interactions: SWB_{2003}*age, SWB_{2003}*gender, SWB_{2003}*education, and SWB_{2003}*diseases. To explore the bidirectional nature of the relationship between HB and SWB, we compared the estimates of the final models in Studies I and II.

Study III broadened the perspective and included the effect of intraindividual change. The final models of Studies I and II were adjusted for the trichotomized covariates of change for HB and SWB that were created as described in Sections 4.3 and 4.4. The models were additionally adjusted for negative life events, which resulted in the final model of HB predicting SWB. However, non-significant negative life events were excluded from the final model of SWB predicting HB. To study the effect of pure change, HB change was made the predictor and the baseline HB level was excluded. Similarly, SWB change was made the predictor and baseline SWB was excluded when studying the opposite direction of effect. However, the model assessed by the AIC scores did not improve when pure change was studied. Therefore, these were not chosen as final models. In Studies I–III, the data were analyzed using SAS software (version 9.4; SAS Institute Inc. Cary, NC, USA 2016).

4.6.2 Structural Equation Modeling

In SEM (Study IV), HB and SWB were both included as latent variables at baseline and at follow-up. Their cross-sectional, longitudinal, and reciprocal relationships were all included in the structural model, shown in Figure 4. We also included the effect of covariates on all the latent variables.

The latent variables of HB and SWB were formed and tested using confirmatory factor analysis, in which the fit of the models showed an acceptable value on the Tucker-Lewis index (TLI), the comparative fit index (CFI), and the root mean square error of approximation (RMSEA), with the only exception being the TLI value for HB in 2003 (for details, see Study IV). The HB latent variable included individual dichotomized HBs (described in Section 4.3) as categorical observed variables. The path coefficients to physical activity were rather low (0.288–0.362), but physical activity was still included in the factor, as the model fit was good and physical activity is one of the four principal HBs that have been the focus of our studies.

The SWB latent variable included the components of the four-item life satisfaction scale (described in Section 4.4) as continuous observed variables. We tested the suggested modifications in the factor analysis, and including the association between interestingness of life and easiness of life resulted in substantial improvements in the model. Therefore, this modification was also tested at subsequent levels of analysis. The impact of including sleep as an HB in the structural equation model was explored by including dichotomized sleeping hours (7–9 hours vs. < 7 or > 9 hours) as an observed variable associated with HB. However, this caused the model to deteriorate so we excluded it from the analysis.

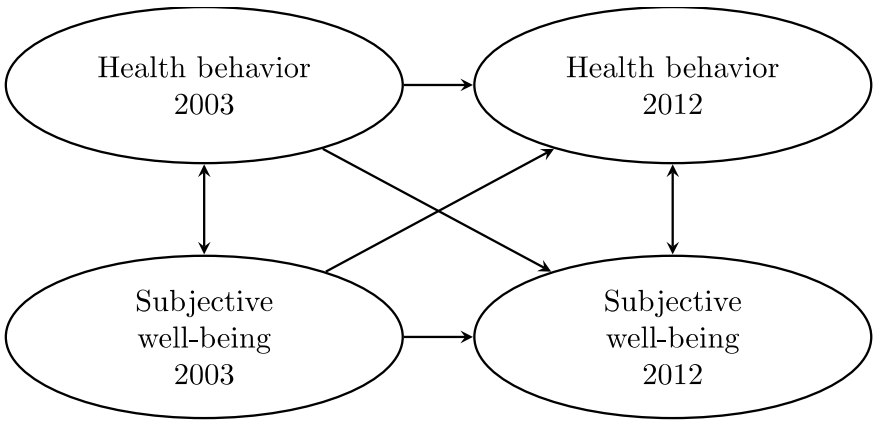

Figure 4. Structural model of Study IV including HB and SWB at both baseline and at follow-up and associations studied. From Study IV.

After the factor analysis, the structural model displayed in Figure 4 was created. Autocorrelations of the observed variables were included, which accounts for the similarity in the measurement error of a variable at different time points. The gender, age, education, and major disease covariates were included and were allowed to serve as potential predictors of HB and SWB at both times. The results suggested that the following associations were potential modifiers of the model: physical activity with alcohol consumption, dietary habits with smoking, and interestingness of life with easiness of life. These were excluded after testing, as the fit of the model did not substantially improve. The effect of dichotomized sleep was also tested as part of HB in the structural model but was once again excluded due to the deterioration of the fit-related statistics. The modification indices also suggested that sleep could be associated with components of SWB, which indicates that sleep is a more complex HB.

The weighted least squares estimator (WLSMV) was used due to HB being a categorical observed variable. Model fit was evaluated on the basis of the TLI, CFI, and RMSEA values. A good fit using chi-square values can be hard to achieve in large samples (Bentler & Bonett, 1980) so we did not primarily use chi-square values to estimate the model fit, although we did use it to compare the models. The structural equation models were analyzed using Mplus software, version 7.4 (Muthén & Muthén, 2012).

4.6.3 Rescaling Estimates for Bidirectional Comparison

For the present thesis, the rescale estimates were calculated for both the predictors and outcomes on scales ranging from 0 to 10. The rescale estimates were created by multiplying β by the range of the predictor divided by 10, and dividing 10 by the range of the outcome, as shown in Figure 5. When HBSS (range, 0–4) predicted SWB (range 4–20), β was multiplied by 4/10 and 10/16, resulting in a coefficient of 0.25. When SWB predicted HBSS, β was multiplied by the coefficient 4 (16/10 and 10/4).

To explore the rescaled effect of change, the estimate of HBSS change was multiplied by 10/4=0.625 and the effect of SWB change by 10/4=2.5.

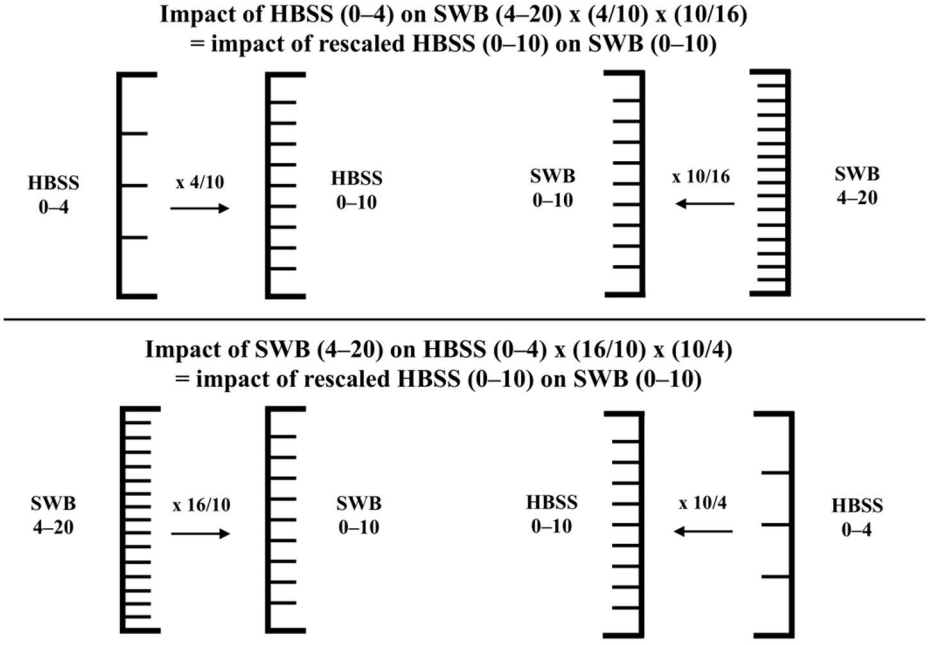

Figure 5. Process for rescaling estimates to scales of health behavior sum score (HBSS) and subjective well-being (SWB) into 0–10 range depicted.

5 Results

5.1 Health Behavior and Subjective Well-being in the Finnish Working-age Population

5.1.1 Baseline Characteristics

The highest percentage of participants (42%) reported three favorable HBs and showed intermediate SWB (57%). The effects of sociodemographic factors and diseases on HB and SWB differed in the models (Table 2). In both the linear and SEM models, belonging to the lowest and highest age groups ($p < .001$), higher education ($p < .001$), and fewer diseases ($p = < .001–.019$) resulted in improved HB and SWB, whereas gender had a significant effect on only HB, women having better HB ($p < .001$). Table 3 and Table 4 present the details of the differences between the covariate groups.

5.1.2 Characteristics of Change

During the nine-year follow-up, both HB (2.87 to 2.99) and SWB (8.53 to 8.37) improved. Positive changes were observed similarly in both HB and SWB, but negative changes were more frequently observed in SWB. Improvements were observed in HBSS in all the covariate groups and in SWB in most covariate groups. Table 5 shows the numerical details of the changes in HB and Table 6 the changes in SWB.

5.1.3 Impact of Baseline Health Behavior and Subjective Well-being

HB predicted its own subsequent level in the linear regression models by a β of 0.48–0.49, indicating that about half of subsequent HB was determined by its baseline level, and in SEM by the strongest path coefficient of 0.896. Baseline SWB predicted subsequent SWB by a β of 0.42–0.44 in the linear models and by a path coefficient of 0.468. in SEM (See also Figure 6).

Table 2. Significance of sociodemographic factors and diseases for HB and SWB in linear modeling and SEM to demonstrate potential differences in effect of covariates on outcomes when SWB predicts HB (upper part) and when HB predicts SWB (lower part).

		AGE	GENDER	EDUCATION	SWB/HB* EDUCATION	DISEASES	HB/SWB* DISEASES
EFFECT ON HB	2003 Linear model*	< .001	< .001	< .001	-	ns	0.019
	2003 SEM	< .001	< .001	< .001	-	< .001	
	2012 Linear model	.038	< .001	ns	.0028	.020	ns
	2012 Linear model and change**	ns	< .001	ns	.0054	.040	
	2012 SEM	ns	ns	ns	-	ns	
EFFECT ON SWB	2003 Linear model*	< .001	ns	.002	ns	< .001	< .001
	2003 SEM	< .001	ns	< .001		< .001	
	2012 Linear model	< .001	ns	.023	ns	< .001	ns
	2012 Linear model and change**	< .001	ns	.038		< .001	
	2012 SEM	< .001	< .001	ns	-	< .001	

For numerical estimates of covariates, see original publications; ns, non-significant

* Cross-sectional model

** Linear models including change were also adjusted for negative life events prior to follow-up

Table 3. Health behavior characteristics of study population by covariate group at baseline to display proportion of beneficial behavior and distribution of health behavior sum score (HBSS). From Study I.

VARIABLE	CATEGORY	SHARE OF STUDY POPULATION % (N)	$HBSS_{2003}$ MEAN (SD)	$HBSS_{2003}$ % (N)					DIET SCORE 60–100 % (N)	NON-SMOKING % (N)	MODERATE ALCOHOL CONSUMP-TION % (N)	PHYSICALLY ACTIVE (MET ≥ 2) % (N)
				0	1	2	3	4				
STUDY POPULATION		100 (10,855)	2.87 (0.90)	0.9 (93)	6.2 (670)	24.5 (2,654)	42.4 (4,602)	26.1 (2,836)	39.1 (4,245)	80.7 (8,759)	94.8 (10,292)	72.2 (7,832)
AGE (2003)	**25–29**	20.6 (2,234)	2.91 (0.84)	0.5 (11)	4.7 (104)	23.1 (517)	46.6 (1,042)	25.1 (560)	34.3 (766)	79.6 (1,778)	96.9 (2,164)	80.4 (1,796)
	35–39	20.7 (2,246)	2.82 (0.89)	0.6 (14)	6.8 (153)	25.5 (572)	43.8 (983)	23.3 (524)	34.6 (777)	78.7 (1,768)	96.2 (2,160)	72.9 (1,637)
	45–49	26.6 (2,885)	2.82 (0.94)	1.3 (36)	7.6 (219)	24.9 (719)	40.5 (1,168)	25.8 (743)	39.7 (1,146)	78.2 (2,257)	92.8 (2,677)	71.2 (2,053)
	55–59	32.2 (3,490)	2.91 (0.91)	0.9 (32)	5.6 (194)	24.2 (846)	40.4 (1,409)	28.9 (1,009)	44.6 (1,556)	84.7 (2,956)	94.3 (3,291)	67.2 (2,346)
GENDER	**MEN**	36.2 (3,925)	2.66 (0.92)	1.5 (58)	8.9 (348)	29.3 (1,150)	42.7 (1,675)	17.7 (694)	27.9 (1,095)	77.7 (3,048)	92.2 (3,620)	68.4 (2,686)
	WOMEN	63.8 (6,930)	2.98 (0.87)	0.5 (35)	4.7 (322)	21.7 (1,504)	42.2 (2,927)	30.9 (2,142)	45.5 (3,150)	82.4 (5,711)	96.3 (6,672)	74.3 (5,146)
EDUCATION (2003)	**NO PRO-FESSIONAL EDUCATION**	12.0 (1,302)	2.67 (0.93)	1.5 (19)	8.9 (116)	30.3 (394)	40.4 (526)	19.0 (247)	31.9 (415)	73.4 (955)	93.6 (1,219)	67.7 (881)
	VOCA-TIONAL SCHOOL	29.0 (3,136)	2.71 (0.92)	1.0 (31)	9.0 (281)	28.0 (876)	42.4 (1,330)	19.7 (618)	33.5 (1,051)	74.9 (2,350)	94.3 (2,956)	68.2 (2,138)
	COLLEGE	39.0 (4,218)	2.91 (0.89)	0.8 (35)	5.2 (219)	23.6 (996)	42.6 (1,798)	27.7 (1,170)	41.2 (1,738)	81.6 (3,443)	95.2 (4,014)	73.3 (3,090)
	UNIVERSITY	19.9 (2,154)	3.13 (0.81)	0.4 (8)	2.4 (51)	17.6 (378)	42.9 (923)	36.9 (794)	47.6 (1,026)	91.6 (1,973)	95.6 (2,059	78.6 (1,694)
DISEASES (2003)	**0**	17.9 (1,931)	2.94 (0.86)	0.5 (10)	4.6 (89)	22.7 (438)	44.4 (857)	27.8 (537)	38.0 (733)	83.6 (1,615)	96.0 (1,853)	76.8 (1,483)
	1	23.3 (2,522)	2.89 (0.88)	0.6 (15)	6.0 (151)	23.6 (596)	43.5 (1,097)	26.3 (663)	37.5 (945)	81.8 (2,064)	95.8 (2,417)	73.6 (1,860)
	2 OR MORE	58.8 (6,355)	2.84 (0.92)	1.1 (68)	6.7 (428)	25.3 (1,607)	41.4 (2,628)	25.6 (1,624)	40.1 (2,545)	79.4 (5,043)	94.1 (5,978)	70.1 (4,456)

HBSS, Health behavior sum score; SD, Standard deviation

Table 4. Subjective well-being by component and covariate group at baseline. A lower score indicates better subjective well-being. Modified from Study II.

VARIABLE	CATEGORY	SHARE OF STUDY POP-ULATION % (N)	SWB_{2003} SCORE* MEAN (SD)	LOW SWB (SCORE 12–20*) % (N)	INTERMEDIATE (SCORE 7–11*) % (N)	HIGH SWB (SCORE 4–6*) % (N)	INTERESTING-NESS OF LIFE (1–5*) MEAN (SD)	HAPPINESS OF LIFE (1–5*) MEAN (SD)	EASINESS OF LIFE (1–5*) MEAN (SD)	PERCEIVED LONELI-NESS(1–5*)** MEAN (SD)
STUDY POPULATION		100 (10,855)	8.53 (3.20)	18.1 (1,949)	56.8 (6,110)	25.1 (2,696)	2.10 (0.93)	2.03 (0.83)	2.53 (1.02)	1.87 (1.35)
AGE (2003)	**25–29**	21.3 (2529)	8.47 (3.15)	19.0 (427)	51.7 (1,160)	29.3 (656)	2.01 (0.92)	1.93 0.86)	2.57 (1.02)	1.96 (1.38)
	35–39	21.2 (2509)	8.58 (3.28)	18.7 (419)	54.5 (1,223)	26.8 (602)	2.10 (0.94)	2.00 (0.87)	2.61 (1.05)	1.89 (1.36)
	45–49	26.4 (3131)	8.64 (3.31)	18.8 (538)	58.1 (1,663)	23.2 (664)	2.15 (0.96)	2.09 (0.84)	2.56 (1.03)	1.86 (1.36)
	55–59	31.1 (3684)	8.45 (3.06)	16.6 (565)	60.7 (2,064)	22.7 (774)	2.13 (0.89)	2.06 (0.77)	2.43 (0.98)	1.81 (1.32)
GENDER	**MEN**	36.7 (4345)	8.58 (3.18)	17.6 (684)	59.4 (2,302)	23.0 (893)	2.12 (0.92)	2.07 (0.83)	2.53 (1.01)	1.87 (1.35)
	WOMEN	63.3 (7508)	8.51 (3.20)	18.4 (1,265)	55.4 (3,808)	26.9 (1803)	2.10 (0.94)	2.01 (0.83)	2.53 (1.01)	1.88 (1.35)
EDUCATION (2003)	**NO PROFESSI EDUCATION**	12.0 (1298)	8.89 (3.33)	21.5 (277)	58.0 (747)	20.6 (265)	2.28 (0.96)	2.15 (0.88)	2.55 (1.03)	1.90 (1.36)
	VOCATIONAL SCHOOL	29.0 (3126)	8.76 (3.30)	20.1 (620)	58.1 (1,797)	21.8 (675)	2.22 (0.95)	2.09 (0.84)	2.54 (1.01)	1.91 (1.37)
	COLLEGE	39.0 (4204)	8.40 (3.15)	17.1 (712)	56.6 (2,363)	26.4 (1100)	2.06 (0.92)	1.99 (0.81)	2.52 (1.01)	1.83 (1.34)
	UNIVERSITY	20.0 (2163)	8.24 (3.01)	15.4 (333)	54.5 (1,176)	30.0 (648)	1.92 (0.86)	1.95 (0.80)	2.51 (1.02)	1.86 (1.34)
DISEASES (2003)	**0**	18.0 (1935)	7.84 (2.73)	11.8 (228)	56.9 (1,097)	31.2 (602)	1.94 (0.83)	1.86 (0.73)	2.39 (0.95)	1.70 (1.24)
	1	23.4 (2522)	8.12 (2.94)	14.5 (363)	56.0 (1,399)	29.5 (737)	2.00 (0.87)	1.93 (0.77)	2.43 (0.97)	1.76 (1.29)
	2 OR MORE	58.7 (6323)	8.91 (3.37)	21.5 (1,347)	57.1 (3,586)	21.5 (1348)	2.20 (0.97)	2.12 (0.87)	2.62 (1.05)	1.96 (1.40)

SWB, Subjective well-being; SD, Standard deviation

* Lower score indicating better SWB

** Item on perceived loneliness had possible values of 1,3,4, and 5

Table 5. Health behavior sum score at baseline ($HBSS_{2003}$) and at follow-up ($HBSS_{2012}$), and changes in HBSS during follow-up by covariate group. From Study III.

VARIABLE	CATEGORY	SHARE OF STUDY POPULA-TION % (N)	$HBSS_{2003}$ MEAN (SD)	$HBSS_{2012}$ MEAN (SD)	POSITIVE HBSS CHANGE % (N)	NEUTRAL HBSS CHANGE % (N)	NEGATIVE HBSS CHANGE % (N)
STUDY POPULATION		100 (10,855)	2.87 (0.90)	2.99 (0.99)	30.5 (3,100)	48.3 (4,913)	21.2 (2,160)
AGE (2003)	**25–29**	20.6 (2,234)	2.91 (0.84)	3.04 (0.85)	31.9 (674)	46.6 (985)	21.6 (457)
	35–39	20.7 (2,246)	2.82 (0.89)	2.96 (0.91)	31.6 (673)	48.0 (1,024)	20.4 (436)
	45–49	26.6 (2,885)	2.82 (0.94)	2.94 (0.94)	29.9 (804)	48.9 (1,317)	21.2 (572)
	55–59	32.2 (3,490)	2.91 (0.91)	3.01 (0.88)	29.4 (949)	49.1 (1,587)	21.5 (695)
GENDER	**MEN**	36.2 (3,925)	2.66 (0.92)	2.82 (0.92)	32.5 (1,177)	47.1 (1,709)	20.4 (739)
	WOMEN	63.8 (6,930)	2.98 (0.87)	3.09 (0.87)	29.4 (1,923)	48.9 (3,204)	21.7 (1,421)
EDUCATION (2003)	**NO PROFESSIONAL EDUCATION**	12.0 (1,302)	2.67 (0.93)	2.81 (0.92)	31.1 (376)	48.7 (590)	20.2 (245)
	VOCATIONAL SCHOOL	29.0 (3,136)	2.71 (0.92)	2.83 (0.94)	31.5 (922)	47.0 (1,379)	21.5 (631)
	COLLEGE	39.0 (4,218)	2.91 (0.89)	3.03 (0.89)	30.2 (1,195)	48.6 (1,924)	21.3 (844)
	UNIVERSITY	19.9 (2,154)	3.13 (0.81)	3.23 (0.77)	29.2 (591)	49.3 (1,000)	21.5 (436)
DISEASES (2003)	**0**	17.9 (1,931)	2.94 (0.86)	3.06 (0.86)	30.8 (557)	48.0 (869)	21.2 (384)
	1	23.3 (2,522)	2.89 (0.88)	3.04 (0.89)	31.2 (740)	49.2 (1,167)	19.5 (464)
	2 OR MORE	58.8 (6355)	2.84 (0.92)	2.95 (0.91)	30.0 (1,787)	48.0 (2,856)	22.0 (1,306)
SWB_{2003}	**HIGH SWB**	25.04 (2962)	3.03 (0.85)	3.12 (0.84)	29.0 (730)	49.2 (1,238)	21.9 (551)
	HIGH INTERMEDIATE	34.18 (4043)	2.89 (0.88)	3.01 (0.87)	30.4 (1,052)	48.6 (1,684)	21.1 (730)
	LOW INTERMEDIATE	22.61 (2674)	2.85 (0.89)	2.98 (0.88)	31.4 (718)	47.6 (1,086)	21.0 (480)
	LOW SWB	18.18 (2150)	2.63 (0.97)	2.77 (0.98)	31.2 (574)	47.6 (876)	21.2 (391)
NEGATIVE LIFE EVENTS	**0**	39.4 (5135)	2.88 (0.90)	2.98 (0.89)	34.4 (1,286)	51.3 (1,915)	14.3 (533)
	1	25.3 (3299)	2.90 (0.89)	3.02 (0.89)	35.0 (800)	49.6 (1,133)	15.4 (353)
	2 OR MORE	35.4 (4616)	2.83 (0.92)	2.95 (0.93)	34.9 (1,010)	46.3 (1,341)	18.8 (545)

HBSS, Health behavior sum score; SD, Standard deviation; SWB, subjective well-being

Table 6. Subjective well-being at baseline (SWB_{2003}) and follow-up (SWB_{2012}), changes in SWB during follow-up by covariate group. From Study III.

VARIABLE	CATEGORY	SHARE OF STUDY POPULATION % (N)	SWB_{2003} SCORE* MEAN (SD)	SWB_{2012} SCORE* MEAN (SD)	POSITIVE SWB CHANGE % (N)	NEUTRAL SWB CHANGE % (N)	NEGATIVE SWB CHANGE % (N)
STUDY POPULATION		100 (10,855)	8.53 (3.20)	8.37 (3.18)	30.2 (3,546)	44.0 (5,172)	25.8 (3,034)
AGE (2003)	**25–29**	20.6 (2,234)	8.47 (3.15)	8.43 (3.15)	31.6 (773)	37.6 (918)	30.8 (752)
	35–39	20.7 (2,246)	8.58 (3.28)	8.67 (3.38)	27.9 (675)	43.1 (1,045)	29.0 (703)
	45–49	26.6 (2,885)	8.64 (3.31)	8.57 (3.31)	28.5 (896)	45.6 (1,435)	25.9 (815)
	55–59	32.2 (3,490)	8.45 (3.06)	7.96 (2.90)	32.1 (1,202)	47.4 (1,774)	20.4 (764)
GENDER	**MEN**	36.2 (3,925)	8.58 (3.18)	8.36 (3.16)	31.2 (1,357)	44.3 (1,926)	24.5 (1,067)
	WOMEN	63.8 (6,930)	8.51 (3.20)	8.38 (3.20)	29.6 (2,189)	43.9 (3,246)	26.6 (1,967)
EDUCATION (2003)	**NO PROFESSIONAL EDUCATION**	12.0 (1,302)	8.89 (3.33)	8.58 (3.26)	29.5 (417)	46.3 (654)	24.2 (342)
	VOCATIONAL SCHOOL	29.0 (3,136)	8.76 (3.30)	8.54 (3.27)	30.2 (1,013)	45.3 (1,521)	24.5 (821)
	COLLEGE	39.0 (4,218)	8.40 (3.15)	8.24 (3.07)	29.9 (1,362)	43.1 (1,964)	27.1 (1,236)
	UNIVERSITY	19.9 (2,154)	8.24 (3.01)	8.08 (3.01)	31.0 (737)	42.6 (1,012)	26.3 (625)
DISEASES (2003)	**0**	17.9 (1,931)	7.84 (2.73)	7.91 (2.85)	27.4 (579)	45.2 (957)	27.4 (581)
	1	23.3 (2,522)	8.12 (2.94)	7.98 (2.89)	30.6 (834)	42.5 (1,160)	26.9 (733)
	2 OR MORE	58.8 (6,355)	8.91 (3.37)	8.60 (3.31)	30.6 (2,115)	44.3 (3,035)	24.9 (1,705)
$HBSS_{2003}$	**0 OR 1**	7.0 (763)	9.90 (3.87)	9.53 (3.73)	30.4 (227)	43.7 (326)	25.9 (193)
	2	24.5 (2,654)	9.02 (3.37)	8.78 (3.35)	30.9 (810)	43.8 (1,148)	25.4 (665)
	3	42.4 (4,602)	8.38 (3.06)	8.22 (3.07)	29.8 (1,355)	44.4 (2,021)	25.8 (1,174)
	4	26.1 (2,836)	8.03 (2.91)	7.85 (2.77)	30.6 (856)	42.7 (1,195)	26.8 (749)
NEGATIVE LIFE EVENTS	**0**	39.4 (5,135)	8.16 (2.99)	7.68 (2.67)	31.6 (1,470)	46.8 (2,174)	21.6 (1,004)
	1	25.3 (3,299)	8.40 (3.05)	8.15 (3.01)	30.7 (930)	44.8 (1,356)	24.5 (742)
	2 OR MORE	35.4 (4,616)	9.07 (3.45)	9.29 (3.58)	28.1 (1,146)	40.3 (1,642)	31.6 (1,288)

HBSS, health behavior sum score; SD, Standard deviation; SWB, subjective well-being
* Lower values indicate better subjective well-being

5.2 Bidirectional Relationship Between Health Behavior and Subjective Well-being

5.2.1 Cross-sectional Correlation

A cross-sectional association between HB and SWB was observed in the linear models ($p < .001$). In the cross-sectional linear models, the covariates seemed to have a slightly stronger effect on SWB, as the change in the estimate for $HBSS_{2003}$ was greater when adjusted for covariates than the change in the estimate for SWB_{2003} when adjusted for covariates. Table 7 and Table 8 illustrates this.

In SEM, when longitudinal associations were simultaneously included, the cross-sectional associations between HB and SWB were also significant at both baseline ($\beta = 0.302$, $p < .001$) and follow-up ($\beta = 0.159$, $p < .001$), when adjusted for baseline age, gender, education, and diseases. In contrast to the linear models, the covariates had stronger overall path coefficients, i.e., a stronger effect towards HB_{2003} than towards SWB_{2003}, which was also supported by higher R-values, indicating that the covariates accounted for 18% of the variation in HB_{2003} ($R = .183$) and for 3% ($R = .032$) in SWB_{2003}. These details are shown in Figure 6 and Study IV.

5.2.2 Linear Regression Modeling

In the linear models that were adjusted for all covariates and included both SWB_{2003} and HB_{2003}, HB_{2003} predicted SWB_{2012} (Table 7, rescaled $\beta = –0.06$) with overlapping 95% confidence intervals in comparison to SWB_{2003} predicting HB_{2012} (Table 8, rescaled $\beta = –0.076$). Table 2 presents information on the significance of the covariates. For numerical estimates, see Studies I and II.

Table 7. Estimates (95% confidence intervals) for linear models of Studies I–III in which HB predicted SWB in a nine-year follow-up.

MODEL	COVARIATES	$HBSS_{2003}$	RESCALED EFFECT OF $HBSS_{2003}$	SWB_{2003}	AIC
CROSS-SECTIONAL $HBSS_{2003}$–SWB_{2003}	NO COVARIATES	–0.56 (–0.63, –0.49)	–0.14 (–0.16, –0.12)	Outcome	55,490
	COVARIATES*	–0.63 (–0.72, –0.55)	–0.16 (–0.18, –0.14)	Outcome	54,860
LONGITUDINAL $HBSS_{2003}$–SWB_{2012}	NO COVARIATES	–0.51 (–0.58, –0.45)	–0.13 (–0.14, –0.11)	-	55,160
	COVARIATES**	–0.47 (–0.54, 0.41)	–0.12 (–0.14, –0.10)	-	54,490
	COVARIATES** +SWB_{2003}	–0.24 (–0.30, –0.18)	–0.060 (–0.076, –0.045)	0.44 (0.42, 0.46)	51,830
	CHANGE***	–0.35 (–0.42, –0.28)	–0.088 (–0.11, –0.070)	0.42 (0.40, 0.43)	48,330

For all estimates, p < .001; HBSS, health behavior sum score; SWB, subjective well-being
* Covariates included: baseline age, gender, education, diseases, and $HBSS_{2003}$*diseases.
** Covariates included: baseline age, gender, education, and diseases.
*** Change in HBSS and negative life events prior to follow-up were additional covariates to those in the model above.

Table 8. Estimates (95% confidence intervals) for linear models of Studies I–III in which SWB predicted HB in a nine-year follow-up.

MODEL	MODEL	SWB_{2003}	RESCALED EFFECT OF SWB_{2003}	$HBSS_{2003}$	AIC
CROSS-SECTIONAL SWB_{2003}–$HBSS_{2003}$	NO COVARIATES	–0.044 (–0.050, –0.039)	–0.18 (–0.20, –0.16)	Outcome	28,100
	COVARIATES*	–0.044 (–0.050, –0.038)	–0.18 (–0.20, –0.15)	Outcome	27,250
LONGITUDINAL SWB_{2003}–$HBSS_{2012}$	NO COVARIATES	–0.038 (–0.044, –0.033)	–0.15 (–0.17, –0.13)	-	28,010
	COVARIATES**	–0.040 (–0.050, –0.031)	–0.16 (–0.20, –0.12)	-	27,330
	COVARIATES** +HB_{2003}	–0.019 (–0.028, –0.011)	–0.076 (–0.11, –0.043)	0.49 (0.47, 0.50)	23,110
	CHANGE***	–0.025 (–0.034, –0.017)	–0.10 (–0.14, –0.67)	0.48 (0.46, 0.50)	22,980

For all estimates, p < .001; HBSS, health behavior sum score; SWB, subjective well-being
* Covariates included: age, gender, education, diseases, and SWB_{2003}*diseases.
** Covariates included: age, gender, education, diseases, and SWB_{2003}*education.
*** Change in SWB was an additional covariate to those in the model above.

5.2.3 Structural Equation Modeling

In the structural equation model (Figure 6) HB_{2003} predicted SWB_{2012} by a path coefficient of 0.156 ($p < .001$), whereas SWB_{2003} did not significantly predict HB_{2012}. The structural equation model may account for 79% of the level of HB_{2012} ($R = .791$) and 25% of the level of SWB_{2012} ($R = .249$).

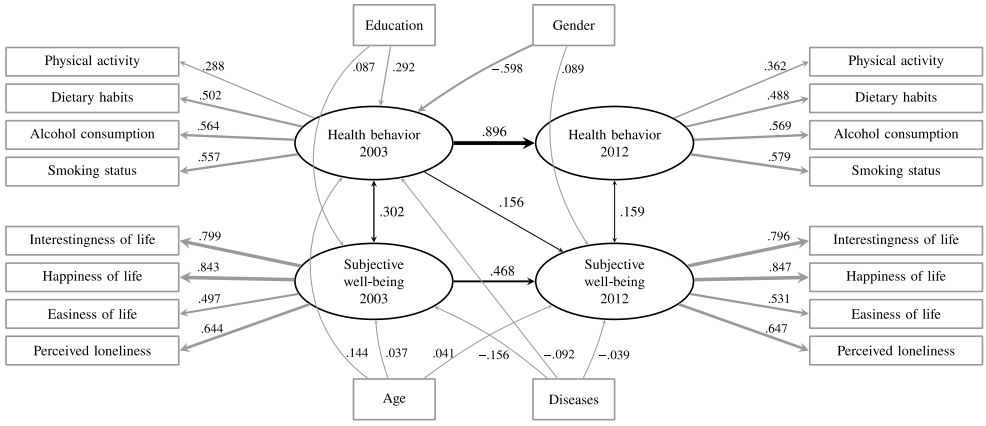

Figure 6. Structural equation model in Study IV displaying standardized path coefficients for associations between latent variables of health behavior and subjective well-being in 2003 and in 2012, adjusted for all covariates. From Study IV.

5.3 Effect of Changes in Health Behavior and Subjective Well-being

The model in which HB_{2003} predicted SWB_{2012} improved when adjusted for HBSS change during follow-up (AIC 51,825–48,332, 6.7% change) and the estimate for $HBSS_{2003}$ increased by 46%. Table 7 shows this in more detail. The model in which SWB_{2003} predicted HB_{2012} also improved slightly when adjusted for SWB change (AIC 23,110–22,980, 0.56% change) and the effect of SWB_{2003} increased by 31%. This is illustrated in Table 8.

In all the models, the effect of change was statistically significant ($p < .001$) and the 95% confidence intervals for the magnitudes of the rescaled estimates overlapped. Table 9 shows this in more detail. For non-rescaled results, see Study III.

In the models that included change, negative life events had a statistically significant effect on the level of SWB_{2012}, but not on the level of HB_{2012}.

Table 9. Rescaled estimates (95% confidence intervals) of the effect of a change in HBSS on SWB_{2012} and a change in SWB on HB_{2012} during follow-up (2003–2012) (Study III). A decrease in SWB score indicates better SWB. All values are rescaled to an outcome scale ranging from 0 to 10, i.e., the estimate value indicates the increase or decrease in the outcome scale ranging from 0 to 10 when the specific change occurs.

	HBSS CHANGE	SWB CHANGE
POSITIVE CHANGE	–0.19 (–0.27, –0.11)	0.18 (0.086, 0.27)
NEGATIVE CHANGE	0.23 (0.14, 0.32)	–0.18 (–0.27, –0.084)

For all estimates, $p < .001$; Positive change, participant has moved from either a lower HBSS (first column) or SWB (second column) group to a higher group of comparable variables during follow-up; Negative change, participant has moved from either a higher HBSS (first column) or SWB group (second column) to a lower group of comparable variables during follow-up.

5.4 Effect of Individual Health Behaviors and Components of Subjective Well-being

Exploring the relationship between individual HB and SWB revealed that non-smoking was a more reliable predictor of good subsequent SWB (AIC = 55,660) than being physically active (AIC = 60,380), having better dietary habits than the median (AIC = 60,600), or moderate alcohol consumption (AIC = 60,540). Good SWB, on the other hand, appeared to be a more reliable predictor of subsequent moderate alcohol consumption (AIC =3,342) and non-smoking (AIC = 4,253) than being physically active (AIC =10,971) and eating a healthy diet (AIC =12,552). For details see original publications I and II.

In SEM, alcohol consumption ($\beta = 0.56–0.57$) and smoking status ($\beta = 0.56–0.58$) had the strongest effect, i.e., path coefficient, on the latent variable of HB. The effect of dietary habits was slightly lower (0.50–0.49), whereas the effect of physical activity was clearly lower (0.29–0.36), as shown in Figure 6. For the SWB latent variable, the effect, i.e., path coefficient, of the observed variables progressively decreased as follows: happiness of life (0.84–0.85), interestingness of life (0.80), perceived loneliness (0.64–0.65), and easiness of life (0.50–0.53).

6 Discussion

The goal of the present thesis was to gain a broader understanding of the bidirectional relationship between HB and SWB. In our data on over 10,000 working-age Finns, good HB and its favorable changes positively and consistently predicted subsequent SWB in a nine-year follow-up. The results concerning the opposite direction, i.e., SWB predicting HB, are somewhat mixed. Nevertheless, positive change in SWB resulted in positive change in HB. Our studies are the first to explore the bidirectional relationship between multiple HBs and SWB in a longitudinal setting.

6.1 Perspectives of the Bidirectional Relationship

It has been suggested that the relationship between HB and SWB is bidirectional (Diener, Oishi, et al., 2018; Kushlev et al., 2019), but longitudinal studies have primarily been unidirectional and explored only one HB. Like our study, the bidirectional studies on single HBs and a measure of SWB have reported that HB is a stronger predictor of SWB than vice versa. Alcohol consumption was a stronger predictor of life satisfaction than vice versa in a 15-year follow-up that calculated odds-ratios and compared the statistical significance of various follow-up times (Koivumaa-Honkanen et al., 2012). Analyzed by SEM, smoking status showed more than twice a stronger path coefficient, i.e. stronger effect on subsequent SWB than vice versa among older adults (mean age = 64) in a four-year follow-up (Lappan et al., 2018). In a two-year follow-up, fruit and vegetable consumption predicted better life satisfaction in fixed-effect regression models, but not vice versa (Mujcic & Oswald, 2016). Therefore, our results, in combination with these previous bidirectional results, strongly suggest that HB is a stronger predictor of SWB than vice versa in a bidirectional longitudinal follow-up.

Even though the results regarding whether SWB predicts HB were somewhat mixed, our studies suggest possible pathway. SWB predicting subsequent HB was statistically significant in our linear models and in two previous studies (Koivumaa-Honkanen et al., 2012; Lappan et al., 2018), but this pathway was insignificant in SEM and one other previous study (Mujcic & Oswald, 2016). The latter might be because the other baseline HBs were adjusted for when predicting fruit and vegetable consumption because HBs tend to cluster (Geller et al., 2017). In SEM, SWB did not

directly predict HB, but a statistically significant pathway from SWB to HB went from baseline SWB to follow-up SWB, which in turn was associated with follow-up HB. Thus, SWB might have affected concurrent HB, which then accounted for the longitudinal prediction in the linear models. Figure 7 presents a graphical illustration of this result.

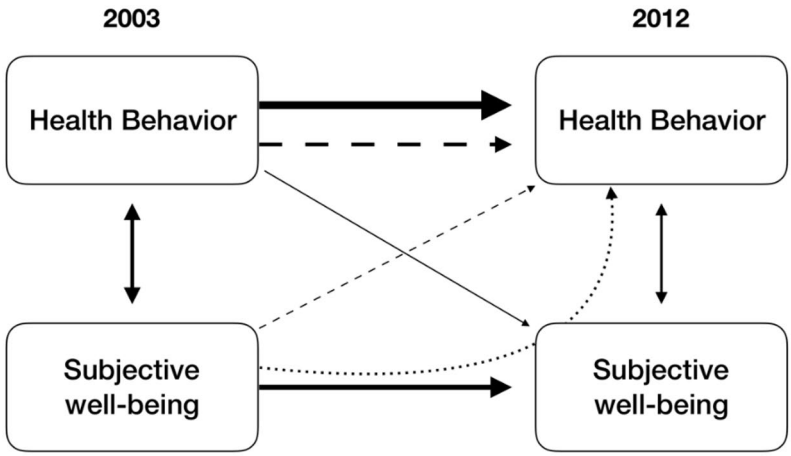

Figure 7. Proposed pathway of SWB_{2003} predicting HB_{2012} (dotted line) that was significant in linear models (broken lines representing associations in linear models) but insignificant in SEM (solid lines representing significant associations in SEM). The thickness of the lines roughly represents the magnitude of the effect.

The magnitude of the effect should also be considered, and not only its statistical significance (Panagiotakos, 2008). At first sight, the effect of HB on subsequent SWB might appear modest, but the path coefficient of HB predicting SWB was about a third of the path coefficient of SWB predicting subsequent SWB, an association that has been described as fairly stable if circumstances remain unchanged (Diener, Lucas, et al., 2018). However, the SEM model can account for only 29% of the subsequent SWB level, indicating that SWB is mostly determined by factors outside our model. Furthermore, the linear model estimates show a similar magnitude to that of the effect of fruit and vegetable consumption on life satisfaction in a previous study (Mujcic & Oswald, 2016), in which the maximum effect on life satisfaction was estimated to be comparable to moving from unemployment to employment on a population level. Furthermore, the small to moderate effects of SWB on work-related outcomes have been explained by the complexity of their relationship, which involves multiple moderators and mediators (Tenney et al., 2016). This presumably also applies to the relationship between SWB and other outcomes. Therefore, the effect of HB on SWB and vice versa being observable in a nine-year follow-up in the lives of 10,000 individuals makes the result robust and even a modest effect can

indicate an existing trend as the effect studied can be attenuated by the vast number of various affecting factors.

Our results reveal more about the time perspective and strength of the effects than the potential pathways. Previous studies have suggested that HB affects SWB through both slowly evolving better health (Portugal et al., 2013) and biochemical and psychological mechanisms on a day-to-day basis (Maher et al., 2015; Mujcic & Oswald, 2016; Ocean et al., 2019; Portugal et al., 2013; Sin et al., 2015). Our results suggest that HB has long-term effects on SWB, but they do not exclude the possibility of day-to-day effects. When SWB predicts HB, self-efficacy and health-information processing are suggested potential mediators (Sin et al., 2015), and are also emphasized in the *Social Cognitive theory* (Bandura, 1977)*, The Health Belief Model* (M. H. Becker, 1974), and the *Theory of Reasoned Action* (Ajzen, 1991, 2011). Our results also suggest that better health literacy could lead to SWB having greater effects on HB. Multimorbidity appears to have a moderating effect on cross-sectional associations, as the number of diseases resulted in a smaller effect on HB among individuals with better SWB than among those with worse SWB. In the opposite direction, better HB potentially buffered the effect of diseases on SWB. Therefore, our results both strengthen the previous views of pathways and raise new questions that warrant further research.

As we combined multiple HBs in our studies, we obtained new knowledge on their differences in respect to SWB. Of the four major HBs studied, non-smoking showed the lowest AIC in predicting subsequent SWB, whereas low SWB more consistently predicted alcohol consumption and smoking. In addition, smoking status and alcohol consumption showed the strongest effect on the latent variable of HB in SEM. Therefore, unhealthy addiction-based behaviors, non-smoking and alcohol consumption appear to be more important in the relationship between HB and SWB than dietary habits and physical activity.

Exploring change (Study III) broadens the perspective from interindividual differences to intraindividual changes. We adjusted the model exploring the effect of baseline HB on follow-up SWB for change in HB during follow-up, which appeared to be a statistically significant covariate. This was also true in the opposite direction, when a change in SWB during follow-up predicted HB at follow-up. However, firm conclusions regarding the magnitude of the effect of changes during follow-up were not possible because we only explored the direction of change. The results of the analysis of changes in the models also further support our main conclusion that HB is a stronger predictor of SWB than vice versa. Measured in percentages, a greater change in the effect of baseline HB and model fit was observed when we adjusted for HB change than when we adjusted for SWB change in the opposite directions.

Previous studies have shown that both HB and SWB are fairly stable characteristics (Burgard et al., 2020; Diener, Oishi, et al., 2018; Lappan et al., 2018), and in

our studies also, the baseline level of HB and SWB had a substantial impact on their subsequent level. Using our measures, HB appeared more stable than SWB, which might, however, have been caused by HB being a cruder measure than SWB. In addition, the covariates appeared to have a stable effect on HB, as the association was only significant at baseline but not at follow-up in SEM.

Exploring HB and SWB by covariate groups showed similarities with previous research in terms of favorable characteristics of HB and SWB clustering among individuals with a high education (Cowell, 2006; Yakovlev & Leguizamon, 2012), men showing worse HB than women (Conner, 2015; Waldron, 1976) and SWB showing a U-shaped curve by age in the descriptive means (Dolan et al., 2008; Graham & Ruiz Pozuelo, 2017; Maher et al., 2015). On the other hand, previous findings have suggested that men have slightly higher life satisfaction than women (Batz-Barbarich & Tay, 2018), which was not observed in our studies, perhaps due to the high gender equality in Finland. In our studies, the middle-aged appeared to have less favorable HB, whereas previous research has shown that HB improves with increasing age (Berrigan et al., 2003; Conner et al., 2015; Ocean et al., 2019).

6.2 Integration of Concepts

The results of our studies support also a less dualistic view of health and SWB as well as that of HB and intentional actions to improve SWB. Health and SWB represent personal characteristics or outcomes that cannot be directly voluntarily chosen. Instead, they can be affected by personal actions such as HB and *contentment behavior,* i.e., intentional actions aiming to improve SWB (Buettner et al., 2020) (Figure 8). Further, HB and contentment behavior overlap, as many HBs can improve SWB (outlined by Buettner et al., 2020).

Health has been traditionally defined as *"a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"* (WHO, 1946). Later, the definition was refined to "*the ability to adapt and self-manage in the face of social, physical and emotional challenges"* (Huber et al., 2011). Here, SWB, as well as physical and mental health, could be perceived as important resources that enable adapting and self-managing. Furthermore, SWB measures have repeatedly been associated with mental health measures (Koivumaa-Honkanen et al., 2004). If the goal of health care and political strategies is to promote health in the sense of the new definition, i.e., the ability to adapt and self-manage, health and SWB could both serve the same purpose, and both deserve attention in society and in health care strategies (Figure 9).

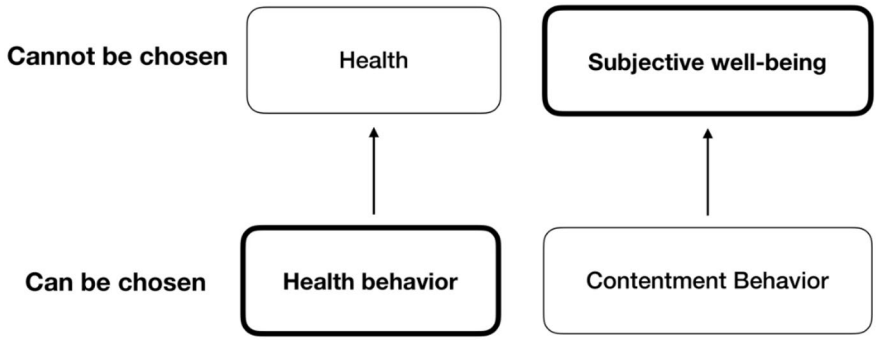

Figure 8. Simplified conceptualization of the difference between HB and SWB. Health and SWB represent qualities that cannot be directly chosen but can be affected by HB and contentment behavior, which can be voluntarily altered.

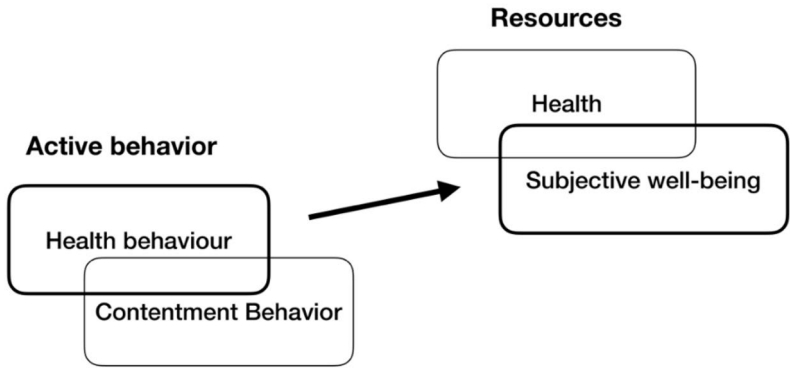

Figure 9. Conceptual suggestion of how the variables overlap. Health behavior and contentment behavior share common actions and represent active behaviors that support resources for everyday life, including health and subjective well-being, which overlap especially when health is perceived as the ability to adapt and self-manage.

6.3 Methodological Evaluation

6.3.1 Study Population and Generalizability

In this large population-based random samples, results were obtained using a consistent survey procedure. The non-response and attrition in this study resulted in slight underrepresentation of men, and younger and lower educated participants in the study population, which is typical of postal health surveys (Korkeila et al., 2001). As the study population originated from surveys at Time 2 and Time 3, it shows similarities to that of Time 1 respondents in sociodemographic characteristics, except for the over-representation of the oldest group (for details, see Study I). At

Time 1, a slightly higher seven-year mortality among non-respondents and slight underrepresentation of illness prevalence were observed in comparison to the general population (Suominen et al., 2012), but this may potentially be explained by differences in definitions (Korkeila et al., 2001). Furthermore, non-response and attrition primarily affect prevalence measures and generalizability, and do not affect the analysis of protective factors and their effects to the same extent (Suominen et al., 2012). As all the covariate groups and HB domains were represented and could be compared, the results can be generalized to the Finnish working-age population. However, some caution is advised in terms of underrepresented men, younger participants, and individuals with lower education. The Finnish social security system is strong. Finns usually rank highly in happiness globally when life evaluation (Helliwell et al., 2021) and societal indicators are measured (OECD, 2020). Therefore, the results are most generalizable to the working-age population in Western societies, in which basic social and health coverage is a certainty. However, this effect might also exist in other cultures and other age groups.

6.3.2 Evaluation of Measures

The present study was observational and based on self-reports. Observational studies enable the exploration of phenomena in natural settings and can answer the question "*Does* a phenomenon occur?" as opposed to studies with experimental settings that answer the question "*Can* a phenomenon occur?" and provide stronger arguments for cause and effect (Diener et al., 2017). Further, according to Diener, longitudinal studies can determine sequences of events in the natural world, explore the role of covariates as possible mediators and moderators, cover even decades, and assess questions that could be difficult to answer through experiments alone. Self-reporting also enables the effective surveying of a large population. SWB is arguably best measured by self-reporting, as it reflects subjective evaluations and experiences (Diener, Oishi, et al., 2018).

The four major HBs accountable for chronic diseases (OECD, 2019; WHO, 2020) were dichotomized and combined into a sum score of beneficial HBs, in accordance with previous studies (McAloney et al., 2013). Also in line with previous studies, we focused on the four major HBs, excluding many other HBs relevant to health such as sleep (Ding et al., 2014). However, we did briefly explore the impact of sleep in the factor analysis in Study IV, and the results supported its exclusion from the analysis. The dichotomization of HB results in a crude scale and many changes and small differences between individuals in real life remain unrecorded. Therefore, the results primarily describe the characteristics and trends in a population.

The four-item life satisfaction scale has shown both cross-sectional and longitudinal associations with various health outcomes and longevity (Koivumaa-Honkanen et al., 2000, 2004; Lukkala et al., 2016; Rauma et al., 2014). Here it was explored in respect to HB. The scale captures both the positive and negative dimensions of SWB, unlike the most currently used mental health measures. In Study I, the scale was used in line with previous studies as a measure of life satisfaction. As it includes three life assessments (cognitive component) and perceived loneliness (affective component) it was subsequently used as an indicator of SWB (Diener, Oishi, et al., 2018). In the factor analysis (Study IV) the measure showed a good fit, and the value of Cronbach's alpha (Studies I, II and IV) was acceptable, indicating that the scale was a consistent measure.

Self-reporting, like any measurement, is subject to a certain degree of measurement error. Self-reports can be affected by differing interpretations of questions on SWB (Diener, Lucas, et al., 2018) or underreporting undesirable behaviors in HB studies (Wasserman & Hilliard, 2018): Both can cause slight systematic errors. Differing interpretations of questions could result in some systematic bias, but in a panel setting, at least part of the effect should be controlled for. Worse SWB might also be underreported, which may have a greater effect on the results due to the more delicate SWB scale compared to underreporting of unfavorable HBs, if the systematic error for HB occurs in only the lowest values and not across the dichotomization cut-off values. SWB is a subjective evaluation of one's life with no objective true value, whereas HBs could also be measured objectively. Therefore, self-reporting of HB is subject to more measurement errors. As HBs were reported on delicate scales and then dichotomized, the risk of misclassification is smaller than if they had initially been reported on dichotomized scales. However dichotomization increases variance and random error (Cohen, 1983). In the HBSS, the four dichotomized HBs were further combined, and their individual measurement errors add up. Therefore, HB has a higher measurement error than SWB, which can reduce the magnitude of the estimate by dilution bias when HB predicts SWB compared to vice versa (Hutcheon et al., 2010). When SWB predicts HB, the larger measurement error in HB could lead to a lower observed significance level and broader confidence intervals, which we also observed in our rescaled results (Table 7 and Table 8). These effects could have been of concern in the bidirectional comparison. However, as the confidence intervals greatly overlapped, and no indications of differences in the magnitudes of the estimates was observed, it is unlikely that dilution bias affected the estimates to an extent that would change this. Increasing the sample size does not reduce the effect of measurement error for HB when HB_{2003} predicts SWB_{2012} but it can improve the statistical power in respect to measurement error in HB when SWB_{2003} predicts HB_{2012}.

A limited number of sociodemographic covariates that might affect both HB and SWB in a top-down manner were included: age, gender, and education, which can partially also reflect socioeconomic status. The self-reported diseases were of varying severity, but as a covariate, the disease count appeared statistically significant in all the studied models. A recent review (Lee et al., 2021) found self-reported diseases, as a measure of multimorbidity, to be associated with various health outcomes. Many other top-down effects such as genetics, personality, and childhood environment are controlled for by the panel-setting. Major negative life events emerged as an important covariate when HB change predicted SWB.

Good scientific practice was followed in accordance with the Declaration of Helsinki. The HeSSup study began in 1998 and was approved by the concurrent joint Ethical Committee of the University of Turku and the Turku University Central Hospital. The studies of the present thesis were in line with the HeSSup studies and received approval from the HeSSup committee. The participants gave their signed consent for a panel-setting follow-up. Neither the personal integrity nor privacy of the participants were violated. The responses were pseudonymized before data processing.

6.3.3 Statistical Considerations

Life is a complex interplay of personality, social relationships, circumstances, and event. Quantitative study of HB and SWB, requires radical simplification. Multiple steps, from self-reports through analysis to interpretation, can affect the results. Complex HB and SWB networks, with multiple factors involved in various directions can also attenuate the observed effects (Tenney et al., 2016). Therefore, even modest results are relevant. On the other hand, not including certain confounders in the models could affect both the predictor and the outcome, causing bias in the observed results. Observational studies cannot rule out the existence of such confounders (Diener et al., 2017), but a panel-setting can control for some of them. The use of a large dataset can also reduce response variability due to inaccuracies in interpreting the items. In addition, in this study, the study power was high, which reduced the risk of type II error and enabled the exploration of interactions. Education showed a statistically significant interaction in the longitudinal models when SWB predicted HB and diseases in the cross-sectional models in both directions, which indicates that these interactions were stronger than the other interactions tested, but does not exclude the possibility that the other interactions were also meaningful.

Two related but different methods, i.e., general linear regression and SEM, were used to explore the relationship between the sum scores of HB and SWB. Combining these two methods created a deeper perspective of the studied relationships than either of the methods would have created alone. The results might have benefitted from

more detailed scales and variables such as disease severity to provide more specific effects. Linear regression modeling (Studies I–III) is a straightforward method that gives easily interpretable results. It is suitable for studying linear longitudinal relationships, but enables only one outcome. Therefore, bidirectionality cannot be analyzed in the same model. SEM included both baseline and follow-up HB and SWB, resulting in cross-sectional, cross-lagged, and longitudinal associations in the same model. In addition, the effect of the covariates at all the time points could be observed simultaneously, standardized path coefficients for all the aforementioned associations were obtained for direct comparison, and a more detailed analysis of the individual components of HB and SWB was possible. Overall, SEM provided a more delicate perspective of the bidirectional relationship than linear models, but required more collaboration between professionals, and interpreting the results was more complicated.

The rescaling of the estimates might cause concerns about the reliability of the bidirectional comparison, as information changes when scales are altered. However, when comparing magnitudes of opposite directions, this should not be an issue. Furthermore, comparing skewed scales—in which extreme values in one direction are rare—might also lead to unbalanced comparisons. Both HB and SWB had a lower representation of the lower values. This might potentially reduce the magnitude of the estimates as a smaller range of responses is well represented. One possible way to deal with the issue of skewness could be to use the data on individuals with values within one or two standard deviations of the mean. However, even this somewhat crude rescaling enabled us to compare the opposite directions and yielded important perspectives.

6.4 Implication for Policy and Practice

The results, together with those of previous research, strongly suggests that HB is a greater predictor of SWB than vice versa. However, concurrent SWB might also support better HB. In Western countries, despite the knowledge that HB should be of a good level and information being easily available, unhealthy behavior persists on both the population and individual level. Our results can provide new perspectives of HB change through a theoretical framework and on five practical levels: *on the individual level, in clinical medicine, in interventions, in health care planning*, and *on the policy level.*

The use of theoretical background for HB interventions has been encouraged (Janevic & Conell, 2018). As individuals value SWB highly, HB theories could provide a framework for how SWB could serve as a motivator and as support for HB changes (López Ulloa et al., 2013).

The Theory of Planned Behavior (Ajzen, 1991, 2011) describes the motives for HB change that derive from the perception of the likelihood and desirability of an outcome as well as from the impact and evaluation of the expectations of significant others (Janevic & Conell, 2018). SWB is a desirable outcome for most people (López Ulloa et al., 2013). The results suggest that SWB being improved by HB increases the likelihood of an HB change if the results are communicated effectively.

The Health Belief model (M. H. Becker, 1974) outlines personal motivation for HB change that arises from two beliefs: personal desire to avoid illness and the perception that intentional actions can reduce the risk of illness (Janevic & Conell, 2018). The same principles might be applicable to positive outcomes such as SWB. If an individual has the desire to improve SWB and believes that HB change will lead to enhanced SWB, the person is likely to perform such actions.

In the *Transtheoretical Model* (Prochaska & Velicer, 1997), the results could be relevant at different stages of HB change. The results could motivate individuals to move from not considering a change in Stage 1, to considering HB change in Stage 2, and proceed to planning an action in Stage 3. The focus could be broadened to SWB during preparation in Stage 3 as a support strategy for HB change by, for example, addressing issues that reduce SWB and helping adopt habits that improve SWB. These actions would support HB changes in Stage 4, when an individual takes action and in Stage 5 when the new behavior is maintained. Previous research has shown that HB could affect SWB on a day-to-day basis in Stages 4–5, but the longitudinal effect observed in our studies of a maintained HB on SWB would finally emerge in Stage 6.

These results could also be combined with the *Relapse Prevention Model* (Janevic & Conell, 2018) as a support strategy for moments when the risk of relapse is high. Considering what factors affect and support SWB at such times could serve as a supporting force against relapse.

It has been argued that *Ecological Models* of HB are a contemporary framework for integrating HB theories and models. They emphasize that HB has multiple levels of influence and highlight the interaction between the environment and the individual (Glanz et al., 2015). These perspectives would be relevant if the results of the present thesis were applied to a specific HB change.

For an *individual,* the characteristics of a good life usually include happiness, health, and longevity (Diener & Chan, 2011). As outlined above, actions leading to such outcomes are both interesting and relevant for most. Therefore, if the potential of HB to improve SWB and the potential of SWB to support HB change were effectively communicated they could lead to HB changes.

In *clinical medicine* and practical health promotion, the beneficial effects of HB changes on SWB could serve as an additional motivator and support for an HB change. The opportunities that can arise from improved SWB are most probably a

more appealing motivator than the risk reduction of possible future health problems, even at a stage when an HB change does not feel urgent but would be beneficial. *Interventions* aiming to improve HB could also consider the theoretical perspectives outlined above and support HB changes (Peterson et al., 2012) by including strategies for improving SWB (Buettner, 2017; Diener et al., 2017; Lyubomirsky & Layous, 2013).

The naturalistic view of disease that *health care* traditionally follows (Marcum, 2008) is challenged by the overlap in the concepts of health and SWB, and of HB and contentment behavior (in Section 6.2). The naturalistic view perceives diseases as biomechanical phenomena and excludes perspectives such as SWB. In contrast, the normativistic view takes into account personal experiences and expectations and perceives health as a continuum rather than a definite state (Marcum, 2008)—here perspectives of SWB would be relevant. Adopting perspectives from the normativistic view would be better in line with the new definition of health that emphasizes individuals' ability to adapt and self-manage (Huber et al., 2011). This could also help address the quality-of-care crisis, in which patients frequently feel neglected (Marcum, 2008). Therefore, health care could benefit from considering aspects of SWB and quality of life.

For *political decision making,* the results from our large, population-based sample outline the potential of HB and its changes to improve citizens' SWB. Ensuring citizen's SWB is a central goal for societies (Ngamaba et al., 2017). Furthermore, as SWB appears to have many beneficial effects, placing long-term well-being at the heart of policies has been argued as urgent for promoting flourishing in society (De Neve et al., 2013). Experts have agreed more on societal actions to improve SWB than on individual strategies (Buettner et al., 2020), indicating the potential of political decision making to improve citizens' SWB, and subsequently also productivity (Diener, 2013). Such societal actions include promoting voluntary work, reducing loneliness, and conducting SWB research (Buettner et al., 2020). It has also been claimed that societies would benefit from adopting national SWB measures to reflect the quality of life of their citizens and help decision makers evaluate policies beyond economic measures (Diener & Tov, 2012). According to our results, SWB can also support HB changes, which in the long term, as a result of subsequently improved health, could potentially contribute to reducing health care costs. Therefore, our results, as well as those of previous research, emphasize the importance of considering both HB and SWB in political decision making.

Our results also provide some insights into societal groups and inequality. The descriptive means show trends in which individuals with low education and more diseases tend to also have worse HB and SWB than better educated and healthier groups. According to our results, the highly educated are also privileged because the effect of SWB on HB is stronger than among individuals with lower education.

Health literacy might mediate this effect, i.e., when knowledge of HB is at a good level, improved SWB has a greater effect on HB than when knowledge of HB is lacking. However, we observed no difference between educational groups or disease groups in terms of how HB predicts SWB. This suggests that all individuals' SWB benefits from HB equally. In contrast to SWB, HB polarization appears to occur when age increases, which underlines the importance of health promotion in counteracting the increasing inequality in HB and in supporting SWB among the aging population.

The corona pandemic has underlined the importance of HB, as chronic diseases and obesity have made people more vulnerable to the COVID-19 virus (de Siqueira et al., 2020). The burden of chronic disease is no longer solely a personal or economic challenge; it now also affects citizens' safety and access to care in pandemic situations. Therefore, targeting and preventing chronic diseases through HB should not only be the responsibility of health care professionals; it should be considered at the policy level, and even a citizen's duty.

6.5 Prospects for Future Study

The present thesis provides a general idea of the bidirectional relationship between HB and SWB, in which HB seems to be a stronger predictor than vice versa, but this relationship should be studied in more detail and elaborated. A wider range of HBs could be tested, such as sleep, sedentary behavior, screen time, stress management, meditation, and mental and social activities: This is needed to broaden the perspective of policies and recommendations (Armstrong, 2009). The perspectives of inequality in the relationship between HB and SWB could also be expanded by analyzing the effect of various covariates, such as the quality of social networks, employment, income, or positive life events. The various aspects of SWB could also be explored, including positive and negative affect, stress, gratitude, optimism, and sense of coherence. More detailed scales of HB, HB changes, and diseases could increase the information obtained in the analysis. The rescaling of estimates could have been performed more delicately and warrants further research. Following the reflections in Section 6.2 on the overlap of HB and contentment behavior, both aspects could be included in SEM as observed variables towards the same latent variable associated with a later outcome.

The insights could be deepened by varying the research settings. Experimental studies could provide further insights into the causality for SWB improving HB (Diener et al., 2017). Interventions could also provide insights of personal characteristics in order to identify those who would benefit most if SWB was targeted by interventions aiming to improve HB. For example, it has been suggested that exercise interventions for the aging population could incorporate SWB monitoring and

support and be targeted at subgroups with less beneficial life situations and health statuses (Vilpunaho et al., 2021). The results of the present and similar studies have mainly been obtained in Western countries, but studies could be extended to various countries (Diener et al., 2017) to determine how the concepts of both HB and SWB and their relationship vary across cultures.

Advances in technology could provide new possibilities for assessing HB and SWB (Diener, Oishi, et al., 2018; Kagawa Singer et al., 2016). Accelerometers measuring physical activity or photographs evaluating food consumption could provide objective HB measures. Expansions of SWB research on, for example, internet searches, social media analysis, cortisol levels, or neuroimaging could also provide new ways to evaluate SWB (Diener, Oishi, et al., 2018).

The bidirectional nature of the relationship between HB and SWB was explored by various statistical methods, which could serve as an example for other research questions. A bidirectional perspective could be used more often, for example, when exploring the relationship between SWB and health (Diener et al., 2017). Instead of trying to control or eliminate the effect of reverse causation, both directions of effect could be analyzed simultaneously. The effect of moderation and confounding could also be studied by analyzing the effect of the various factors related to HB and SWB displayed in Figures 1 and 2. The present thesis suggests that applying different statistical methods can deepen research findings from the same dataset, which could also be tested more rigorously.

7 Conclusions

The aim of the present thesis was to explore new perspectives of HB changes. Studying the bidirectional relationship between HB and SWB provided positive and motivating results concerning the benefits of HB changes, which can be used in practical health promotion, policymaking, and health care planning, and may also be of interest to the general public.

The main conclusions of the thesis were the following:

1. Good HB and positive HB changes more strongly predicted better SWB than vice versa in a follow-up of almost a decade. The more beneficial HBs are, the greater the impact on SWB. Similarly, unhealthy behavior and its negative changes predict worse SWB. This result remained unchanged in linear regression and SEM.
2. SWB predicts HB but this seems to affect concurrent HB more, which is probably mediated by individual qualities such as self-efficacy. This knowledge could be used as a supportive strategy in interventions targeting HB, and in practical health promotion when HB changes are challenging.
3. In addition to improving health, HB enhances SWB. HBs can be seen as contentment behaviors, i.e., actions that increase happiness and SWB. This perspective can be a useful motivator in health promotion, which could be communicated to the general public.
4. Using two different statistical methods in quantitative health studies can offer deeper insights into a phenomenon.

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"'We have such a long way to go', sighed the boy.
'Yes, but look how far we've come', said the horse."

The Boy, the Mole, the Fox and the Horse, Charlie Mackesy

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"'What do you think success is?' asked the boy.
'To love', said the Mole."

The Boy, the Mole, the Fox and the Horse, Charlie Mackesy

Vancouver, January 7, 2022

Säde Stenlund

Säde Stenlund

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Health, happiness, and longevity are typically listed as the most important characteristics of a good life. However, the burden of chronic diseases, foremost caused by unhealthy behavior, continues to increase. This thesis explores the bidirectional relationship between health behavior and subjective well-being to find new and positive perspectives on health behavior change. Good health behavior appears to be a stronger predictor of subjective well-being than vice versa, according to a longitudinal follow-up study with 10,000 working-age Finns. However, subjective well-being can also support concurrent health behavior. The results can serve as a motivator towards better health behavior, outline possibilities for health care to support health behavior change, and broaden the view of societal benefits of good health behavior.

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