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Physical activity and eating behaviour in sleep disorders

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ACTA
UNIVERSITATIS
UPSALIENSIS
UPPSALA
2016

ISSN 1651-6206
ISBN 978-91-554-9771-2
urn:nbn:se:uu:diva-308395

Dissertation presented at Uppsala University to be publicly examined in Gunnesalen, Psykiatriens hus ingång 10, Uppsala, Friday, 13 January 2017 at 13:00 for the degree of Doctor of Philosophy. The examination will be conducted in Swedish. Faculty examiner: Professor Mai-Lis Hellenius (Institutionen för medicin, Karolinska Institutet, Stockholm, Sverige).

Abstract
Spörndly-Nees, S. 2016. Physical activity and eating behaviour in sleep disorders. *Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine* 1283. 63 pp. Uppsala: Acta Universitatis Upsaliensis. ISBN 978-91-554-9771-2.

Sleep-disordered breathing and insomnia are common sleep disorders and associated with an increased risk of morbidity. The aim of this thesis was to study the contribution of a behavioural sleep medicine perspective on sleep-disordered breathing and insomnia. More specific, factors considered important for changing eating behaviour and the impact of physical activity were studied.

Methods: In study I, semi-structured interviews of participants with obstructive sleep apnoea and obesity (n = 15) were analysed using a qualitative content analysis. A population-based female cohort was followed prospectively over ten years in study II and III using a postal questionnaire on two occasions (n = 4,851 and n = 5062, respectively). In study IV, a series of five experimental single-case studies was conducted testing how an aerobic exercise intervention affected selected typical snores, following an $A_1B_1A_2B_2A_3$ design over nine days and nights (n = 5).

Results: Facilitators and barriers towards eating behaviour change were identified. A low level of self-reported leisure-time physical activity was a risk factor among women for future habitual snoring complaints, independent of weight, weight gain alcohol dependence or smoking. Maintaining higher levels or increasing levels of leisure-time physical activity over the ten-year period partly protected from snoring complaints (study II). Further, a low level of self-reported leisure-time physical activity is a risk factor for future insomnia among women. Maintaining higher levels or increasing levels of leisure-time physical activity over the ten-year period partly protect against self-reported insomnia, independent of psychological distress, age, change in body mass index, smoking, alcohol dependence, snoring status or level of education (study III). Single bouts of aerobic exercise did not produce an acute effect on snoring the following nights in the studied individuals. A pronounced night-to-night variation in snoring was identified (study IV).

Conclusion: Women with sleep disorders would benefit from a behavioural sleep medicine perspective targeting their physical activity in the prevention and management of snoring and insomnia. This is motivated by the protective effects of physical activity confirmed by this thesis.

Knowledge was added about facilitators and barriers for future eating behaviour change interventions.

Keywords: Health behaviour, obesity, sleep-disordered breathing, sleep disorders, public health, diet, physical activity, snoring, insomnia, risk factors, epidemiology

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ISSN 1651-6206
ISBN 978-91-554-9771-2
urn:nbn:se:uu:diva-308395 (http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-308395)

List of Papers

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

I Spörndly-Nees S., Igelström H., Lindberg E., Martin C., Åsenlöf P. Facilitators and barriers for eating behaviour changes in obstructive sleep apnoea and obesity – a qualitative content analysis. *Disability and Rehabilitation.* 2014;36(1):74-81.

II Spörndly-Nees S., Åsenlöf P., Theorell-Haglöw J., Svensson M., Igelström H., Lindberg E.
Leisure-time physical activity predicts complaints of snoring in women: a prospective cohort study over 10 years. *Sleep Medicine.* 2014;15(4):415-421.

III Spörndly-Nees S., Åsenlöf P., Lindberg E. High or increasing levels of physical activity protect women from future insomnia. *Sleep Medicine. Available online 7 June 2016.*

IV Spörndly-Nees, S., Lindberg E., Broman J-E., Arnardottir E.S., Rångtell F., Åsenlöf P. The effects of aerobic exercise and individual variations on snoring over nine nights: five experimental single case studies. *In manuscript.*

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Contents

“Laugh and the world laughs with you, snore and you sleep alone.”

Anthony Burgess

Abbreviations

Apnoea-hypopnoea-index (AHI)
Behavioural sleep medicine (BSM)
Body mass index (BMI)
Cognitive behavioural therapy (CBT)
Confidence interval (CI)
Continuous positive airway pressure (CPAP)
Cut down, Annoyed by criticism, Guilty about drinking, Eye-opener drinks (CAGE)
Dependent variables (DV)
Difficulties initiating sleep (DIS)
Difficulty maintaining sleep (DMS)
Early morning awakening (EMA)
Electroencephalography (EEG)
Fast fourier transformation (FFT)
Health belief model (HBM)
Hospital Anxiety and Depression Scale (HAD)
Independent variable (IV)
Moderate and vigorous physical activity (MVPA)
Obstructive sleep apnoea (OSA)
Odds ratios (OR)
Percentage exceeding the median (PEM)
Sleep-disordered breathing (SDB)
Slow wave sleep (SWS)
Social cognitive theory (SCT)
Standard deviation (SD)
Total sleep time (TST)
Trans-theoretical model (TTM)
Volume of oxygen (VO_2)

Introduction

Sleep is believed to be an important time for restorative processes in the brain[1] and to enhance new learning and memory consolidation.[2] The anabolic role of sleep can be seen in the increased level of growth hormone present during sleep[2] and it is therefore an important part of life. We spend approximately one third of our lives sleeping[3,4] and despite the common belief that we are sleeping less and less from a historic perspective, this does not appear to be the case when studies were reviewed scientifically.[4] Sleep disorders do, however, account for a significant burden on society and the individual regarding physical and mental health and economic consequences.[5]

Sleep-disordered breathing

Sleep-disordered breathing (SDB) is a comprehensive label for sleep disorders ranging from snoring to obstructive sleep apnoea.[6] Snoring is used in epidemiological studies as an indicator of SDB, as snoring has been recognised as a strong predictor of sleep apnoea syndrome.[7] Obstructive sleep apnoea (OSA) and snoring are defined below and SDB will be used in this thesis as a synonym to refer broadly to snoring and OSA.

Obstructive sleep apnoea

OSA is characterised by loud snoring and repeated episodes of obstruction in the upper airway during sleep that cause total stop in the airflow (apnoea) or a decrease in the baseline airflow of $\geq$ 30% accompanied by a decrease in oxygen desaturation of $\geq$ 3% (hypopnoea). A frequency of five episodes per hour of sleep, in which each episode lasts more than ten seconds, is required to fulfil the diagnostic criteria of OSA.[8] The severity of the condition is expressed according to the apnoea-hypopnoea index (AHI) presented as the mean number of apnoeas and hypopnoeas per hour of sleep.[9]

Some mechanisms proposed to explain OSA include loss of activity in the muscles controlling dilatation in the upper airway and a narrow upper airway.[10] Overweight and obesity are associated with OSA[11,12] and occur in about 70% of patients with OSA.[13,14] Obesity is reported as a common cause of narrow upper airways where the superficial fat tissue located in the neck area is thought to compress the pharynx, leading to its night-time collapse.[15,16]

OSA increases the risk of road traffic accidents,[17] impaired quality of life,[18] cardiovascular disease and all-cause mortality.[19-25] OAS is also highly prevalent in people with insomnia.[26,27] Furthermore, patients with OSA contribute to increased socioeconomic costs to society.[28]

Continuous positive airway pressure (CPAP) is the standard treatment and is currently considered the most effective treatment for the disorder.[29,30] Adherence to CPAP is low,[31] which limits its effectiveness.[32] Given the association with overweight and obesity, it may be important to combine CPAP treatment with behavioural interventions targeting eating behaviour and a sedentary lifestyle. Physical activity[33,34] and physical exercise[35,36] are reported to reduce the severity of OSA. Recently, diet restriction in patients with obesity and OSA was found to induce a weight loss of 10.6% and significant reductions in OSA symptoms.[37] A corresponding amount of weight loss is predicted to generate a 26% decrease in the AHI.[38]

Snoring

Snoring may be defined as a sound that is audible to another individual; it occurs due to vibrations of anatomic structures of the pharyngeal airway.[39] Snoring is usually assessed in questionnaires or by means of sleep recordings identifying snoring sounds at a predefined decibel level.[40] There is a lack of consistency in the definition of snoring;[41] however, a recent publication comparing measures of snoring suggests using microphone recordings to measure snoring objectively.[42]

Several studies have reported associations between snoring and morbidity, such as hypertension, stroke, myocardial infarction and type 2 diabetes.[43-51] These associations are at least partly explained by the fact that snoring is the major marker of obstructive sleep apnoea.[7] However, even in the absence of sleep apnoea, snoring is highly associated with excessive daytime sleepiness, subjective work performance problems and traffic accidents.[52-55] The exact mechanisms behind the development of snoring are not fully understood, but established risk factors include age.[56] The male-to-female ratio is estimated to be about 2:1 in the general population.[14,57] In addition, overweight[46,56,58-60] and central obesity, measured as a large neck[56,59,61] or waist circumference,[46,56] are strongly associated with snoring. Weight gain is followed by a higher incidence of snoring,[46,60,62] while the absence of obesity is associated with an increased likelihood of remission from habitual snoring.[62] Cross-sectional studies have revealed an association between snoring and alcohol consumption[56,58] and smoking.[44,56,58]

Weight loss is recommended along with the cessation of smoking and late-night consumption of alcohol.[63] Oral appliances are recommended in individuals with primary snoring (i.e. without OSA)[64] and surgical interventions are often considered as the last choice.[63]

In contrast to the large number of studies on obesity and snoring, there is still a lack of reports on the impact of physical activity on snoring frequency. A protective effect of physical activity on snoring is suggested,[6] however, in Swedish women, an independent relationship is reported between leisure-time physical inactivity and snoring only among women with a BMI of ≥ 30 kg/m2.[56] In a Swedish male cohort, no significant association between physical activity level and snoring was found in a cross-sectional analysis.[60] The cohort was followed for ten years, but unfortunately the questions regarding physical activity were added in the follow-up and thus do not provide information about the influence of physical activity over time. A similar study on a female cohort may add valuable knowledge about the associations between physical activity and snoring over time.

Insomnia

Insomnia is characterised by difficulty initiating sleep (DIS), difficulty maintaining sleep (DMS), or early morning awakening (EMA), in combination with daytime impairment[65] and is often a persistent condition.[66] Previous epidemiological studies have used different definitions, as some report on insomnia symptoms (DIS, DMS and EMA) alone[67,68] and some include daytime impairment in the definition, as recommended by Edinger et al.[65] These diagnostic criteria rely on self-reporting; however, studies have also used more objective measures like polysomnography, actigraphy or sleep diaries to study sleep and associated factors.[69] Depending on the choice of definition, prevalence varies a great deal from about 9% to 33% in the general population.[70] Insomnia is associated with a range of conditions, including hypertension,[71] diabetes,[72] obesity, depression, anxiety, and somatic diseases such as asthma and myocardial infarction.[73] Recently, Sivertsen et al.[74] reported an equally strong bidirectional association between insomnia and depression, implying that depression may be part of developing insomnia.

Cognitive behavioural therapy (CBT) is the first-choice treatment, along with other non-pharmacological treatments e.g. sleep restriction, mindfulness stress reduction and exercise. In a recent meta-analysis, CBT was found to be effective in treating chronic insomnia and was superior to hypnotic medication in a 6-month follow-up study.[75] Treatment with CBT, however, must be delivered by specially trained healthcare personnel and is not widely available.[76] Pharmacotherapy may have undesired side effects and should be used with caution as the secondary choice and for shorter periods only.[76]

Higher levels of physical activity have been found to affect sleep quality and insomnia in recent randomised controlled studies on different populations: menopausal women,[77] older adults,[78] inactive adults with insomnia[79-81] and overweight adults with obstructive sleep apnoea,[35] and a dose-response effect of aerobic exercise is reported in postmenopausal women.[82] These studies are all limited to a follow-up period of less than one year. Moreover, cross-sectional findings from epidemiological studies[83,84] as well as a prospective study of elderly people[67,85] and midlife women[86] support the inverse association between physical activity level and insomnia. However, some studies fail to show the positive effect of physical activity on sleep quality.[87,88] In a review of epidemiology in exercise and sleep, Youngstedt and Kline[89] concluded that although a modest, yet consistently established association of exercise with better sleep has been reported across studies, there is a need to assess large, representative samples across all age groups, including prospective assessments of exercise and sleep.

Promotion of health behaviour

The current treatment approaches for both SDB and insomnia are related to adapting new behaviours e.g. sleeping with the CPAP and up or down-regulating behaviours such as physical activity, smoking, alcohol and eating. Therefore, promotion of healthy behaviours may be important to support individuals in adopting a healthier lifestyle.

The processes of health behaviour change have been fundamentally described in several behavioural learning theories and conceptual models.[90] The health belief model (HBM) highlights how an individual reacts to his/her health condition and whether this results in behaviour changes. Accordingly, health behaviour changes depend on how vulnerable you perceive yourself to be and how severe you perceive your health condition to be.[91] The Trans-theoretical model (TTM) describes how motivation and readiness to change develop in stages and how individuals move through stages by using different processes of change. In the early stages, the individual's weighing of pros and cons are important constructs for building motivation and incentives to act.[92] The social cognitive theory (SCT) is a comprehensive theory incorporating classic behavioural learning mechanisms while emphasising role modelling and learning from personnel, as well as social expectancies in a bi-directional process.[93,94] One main construct is self-efficacy, the individual's confidence in dealing with a specific behaviour under certain circumstances. Self-efficacy is widely used to predict the success rate of engaging in health behaviour change.[94,95]

In the effort to change health behaviours, health theories may be a good platform for developing interventions and in order to evaluate the potential effects of an intervention, theory associated behavioural change techniques are suggested as a tool for describing the content of an intervention.[96] As suggested in a recent meta-analysis, there is some support for the increased effectiveness of theoretically derived techniques.[97] It has also been highlighted that interventions may benefit from the systematic tailoring of strategies attempting to initiate and maintain a change to the targeted behaviour on the basis of an individual assessment.[98]

Behavioural sleep medicine

Behavioural sleep medicine (BSM) is a discipline focusing on behaviour aspects as part of the treatment of sleep-related disorders. It has been described as the branch of clinical sleep medicine and health psychology focusing on 1) identification of the psychological (e.g. cognitive and/or behavioural) factors that contribute to the development and/or maintenance of sleep disorders and 2) specialisation in developing and providing empirically validated cognitive, behavioural, and/or other nonpharmacologic interventions for the entire spectrum of sleep disorders.[99]

In SDB, behaviour change support is mainly provided to increase compliance with CPAP treatment and some evidence exists for increased adherence.[100] Interventions aiming to reduce weight have been emphasized as a promising approach in the area of BSM.[99] New information about the influence of weight loss and physical activity has recently emerged. In recent reviews, lifestyle changes aiming at weight loss are suggested as effective treatment for patients with OSA due to a reduction in OSA severity.[101,102] Thus, lifestyle change programmes are suggested as treatment for OSA.[103] Effective weight loss interventions require dietary and physical activity level changes; it is recommended to target these behaviours in combination.[13]

In BSM treatment of insomnia, cognitive-behavioural therapy (CBT) is an established approach.[99] A recent review concludes that CBT is the most effective treatment and exercise, sleep restriction, meditative movement and mindfulness-based stress reduction are highlighted as promising treatment methods.[76] A meta-analysis confirms the positive effects expected from exercise and suggests exercise as an evidence-based intervention for improving objective and perceived measures of sleep.[104]

Eating behaviour

Evidence exists for the effect of calorie restriction and weight loss on sleep-disordered breathing[37,38,62] and changes in eating behaviour to a lower calorie intake may thus be recommended as part of the treatment.[101] Sleep-deprived individuals reportedly increase portion sizes[105] which may suggest that calorie reduction would be harder to accomplish in a population with sleep disorders. It is possible that the need for support in changing eating behaviour is different for individuals with sleep disorders relative to individuals without sleep disorder. In contrast to physical activity[106] and CPAP treatments[107] there is currently a lack of knowledge regarding patients' conceptions of prerequisites and support strategies promoting eating behaviour changes. Such knowledge may be important for the tailoring of future interventions in individuals with sleep disorders.

Physical activity and exercise

Physical activity is associated with insomnia[89] and cross-sectional findings suggest a protective effect of physical activity on snoring.[6]

Physical activity may be defined as bodily movement produced by skeletal muscles that results in energy expenditure.[108] As a subcategory, physical exercise is defined as planned, structured physical activity with an aim to improve or maintain physical fitness.[108]

The public health recommendations for physical activity provided by the British Association of Sports and Exercise Sciences suggest at least 150 minutes of moderate-intensity aerobic activity or at least 75 minutes of vigorous-intensity activity each week, or a combination of moderate to vigorous activity corresponding with this amount. Ten-minute bouts may be added in order to reach the recommended time of activity. The dose of the recommendations is associated with substantial health benefits. Furthermore, it is recommended to perform muscle-strengthening activities involving larger muscle groups two times a week.[109] In recent years, the focus on sedentary behaviour has increased, as prolonged time spent sedentary has been associated with an increased risk of all-cause mortality, cardiovascular disease, cancer and type 2 diabetes.[110]

Physical exercise has acute effects on blood pressure and is recommended for preventing hypertension.[111] Regular aerobic exercise has a positive effect on heart chamber volume and an approximately 20% increase in stroke volume may occur in individuals with poor fitness levels following regular intensive exercise. The maximal oxygen consumption increase and improvements in cardiovascular fitness are associated with a decrease in cardiovascular disease.[112] Moreover, production of hormones such as testosterone, cortisol, growth hormone and insulin[113] witness of acute effects of exercise.

Physical activity can be measured subjectively through self-reporting, for example in questionnaires, which are commonly used in epidemiological studies.[114] Some questionnaires provide a more global picture of the level of physical activity relying on e.g. a five-point scale ranging from inactive to highly active, while others provide more details.[115] The advantage of using questionnaires is simplicity, which allows for large-scale usage. Questionnaires that provide information about time and intensity allow for measures of compliance with physical activity guidelines. The approach relies on memory and individuals' perceptions of their physical activity levels, which reportedly tend to be under or overestimated compared with objective measures.[116-118] More objective methods for assessing physical activity levels are available, including accelerometers, pedometers, heart rate monitors and multiple sensor devices.[115] Accelerometers are gaining popularity and the number of publications using this approach has increased markedly in the last ten years.[119] An accelerometer measures acceleration on one or more planes; the measurement can be calibrated and validated to a known measure e.g. doubly-labelled water.[120] A previous review reported large variation in the ability of accelerometers to predict doubly-labelled water;[120] however a recent study reported accelerometery to be an accurate measure of physical activity as the accelerometers were significantly correlated with oxygen consumption .[121]

Rationale for this thesis

Sleep disorders are a common public health challenge and living with SDB and insomnia is associated with comorbidities. Weight loss in patients with SDB has improved the severity of the condition and eating behaviour changes are taken into consideration along with physical activity in lifestyle interventions aiming at weight loss. There is a lack of knowledge on how to successfully change eating behaviour and on the effect of physical activity on SDB. Some evidence shows that increasing physical activity and exercise are effective interventions for improving sleep quality. Increased knowledge on the impact of physical activity on sleep quality from large population studies would increase evidence in the area.

Aims

The aim of this thesis was to study the contribution of a behavioural sleep medicine perspective on sleep disordered breathing and insomnia. More specific, factors considered important for changing eating behaviour and the impact of physical activity were studied.

Specific aims:

I To identify personal conceptions of prerequisites for eating behaviour change in patients with OSA and obesity.

II To assess the potential impact on incidence and remission of snoring complaints by the level of leisure-time physical activity in women. Furthermore, the aim was to study the role of changes in the level of reported leisure-time physical activity.

III To assess the impact of leisure-time physical activity on insomnia in women. Furthermore, the aim was to study the impact of changes in leisure-time physical activity on insomnia over 10 years.

IV To study the individual, acute effect of physical exercise at moderate and high intensity during the day on snoring during the following night in women with snoring and a low to medium habitual level of physical activity.

Methods

Design

The thesis includes four studies (Study I-IV) based on three study samples. An overview of the study designs, participants, study variables, main approach of analysis along with identification of independent (IV) and dependent variables (DV) are presented in table 1.

Table 1. Design, sample size, main study variables and main method for analysis in the four studies.

	Study I	**Study II-III**	**Study IV**
Design	Inductive qualitative study	Population based cohort study over 10-years	Five single-case experimental studies
Participants	Patients with sleep apnoea and obesity (n=15)	Women ≥ 20 years, randomly selected (n=5193) from a general population	Women ≥ 20 years Habitual snorers from study II and study III
Study variables	Conception of eating behaviour changes	Self-reported physical activity (IV), snoring (DV) and insomnia (DV)	Objectively measured physical aerobic exercise (IV) and snoring (DV)
Analysis	Qualitative content analysis	Multiple logistic regression analysis	Visual inspection

Independent variable (IV). Dependent variable (DV).

Study I was part of a larger qualitative study exploring behaviours related to OSA treatment i.e. experiences of CPAP, physical activity and eating behaviour, respectively. The study had an inductive qualitative design using semi-structured individual interviews to collect data on one occasion for each participant. The study was approved by the Regional Ethics Committee, Uppsala Sweden (EPN D-no. 2008-030).

Study II and III were parts of a large cohort study "Sleep and Health in Women" (SHE), including a population based cohort with two measurements; baseline year 2000 and follow-up year 2010. Written informed consent was obtained from all participants. The study was approved by the Regional Ethics Committee, Uppsala (EPN D-no. 99-486).

In study IV, five experimental single-case studies were conducted following an $A_1B_1A_2B_2A_3$ design.[122,123] This design examines the effect of an intervention by alternating no intervention (phase A) with an intervention (phase B). The intervention is considered effective if the variable of interest improves during the first intervention phase (B_1), reverts towards baseline values in the next A phase (A_2), improves during the second intervention phase (B_2), and once again reverts in the final A phase (A_3).[124] The study was approved by the Regional Ethics Committee (D.no 2014/012).

Participants and procedures

For study I, patients with moderate to severe OSA (AHI ≥ 15), obesity (body mass index, BMI ≥ 30 kg/m²) and sufficient command of the Swedish language were recruited from the sleep laboratory at the Department of Medical Sciences, Respiratory Medicine and Allergology at the University Hospital in Uppsala, Sweden.

Participants were selected purposefully with regard to age, gender, education, marital status, severity and duration of established OSA, level of BMI and self-identified stage of change. This was done to allow variation in experiences from a wide variety of participants. For characteristics of the participants in study I see table 2.

Table 2. Participant in study I. Characteristics presented in mean ±standard deviation (SD) and range or number (%).

Participants	**n=15**
Sex	
Male	8 (53%)
Female	7 (47%)
Age in years	
Mean ± SD	56.8 ± 10.2
Range	41-71
BMI*	
Mean ± SD	38.5 ± 5,8
Range	31.7-52.3
Education level	
Compulsory school	4 (27%)
High school	3 (20%)
Collage/University	8 (53%)
Working status	
Working	9 (60%)
Pension	3 (20%)
Of work sick	3 (20%)
Smoking status	
Never smoker	8 (53%)
Stopped smoking	5 (33%)
Smoker	2 (20%)
Duration of established OSA¤ in years	
Mean ± SD	3.2 ± 2,9
Range	0.5-10
Civil status	
Single	6 (40%)
Cohabiting/married	9 (60%)

*The body mass index BMI (BMI in kg/m^2). ¤Obstructive sleep apnoea (OSA)

The interview guide was semi-structured to assure that the objective of the study was covered. Prior to the interview participants were provided with written information by an assistant researcher and gave their written consent to participate in the study.

In study II and III women aged ≥ 20 years were randomly selected from the population registry in the Municipality of Uppsala, Sweden and invited to answer a postal questionnaire in April 2000. The response rate for the baseline questionnaire was 71.6% (n=7,051). A new questionnaire was distributed to all responders available in April 2010 (n=6,455) and was completed by 80.5% (n=5,193) (see overview in figure 1). On both these occasions, the questionnaires were followed by a reminder postcard after one week. Non-responders were sent a new questionnaire after one and two months, respectively.

The questionnaire used to collect data in the SHE study consisted of 109 questions at baseline and 76 questions in the follow-up. Questions included snoring frequency, sleep disturbances, medical disorders and potential risk factors for sleep disorders. All the questions used in the current studies were identical at both baseline and 10-year follow-up, with an exception of education level only included at follow-up (Study III). Baseline characteristics from study II - IV are presented in table 3.

Table 3. Characteristic of participants at baseline in study II and III year 2000 and study IV year 2014. Data are presented in mean (standard deviation) and numbers (proportion).

	Study II **n=4851**	**Study III** **n=5062**	**Study IV** **n=5**
Age	42.3 (14.9)	43 (15.2)	60.4 (1.7)
BMI*	23.9 (4.0)	24 (4.0)	31.5 (5.7)
Neck circumference	33.3 (2.8)	33.4 (2.8)	38.7 (3.0)
Smoking			
Yes	763 (15.8)	798 (15.8)	0 (0)

*The body mass index BMI (BMI in kg/m^2).

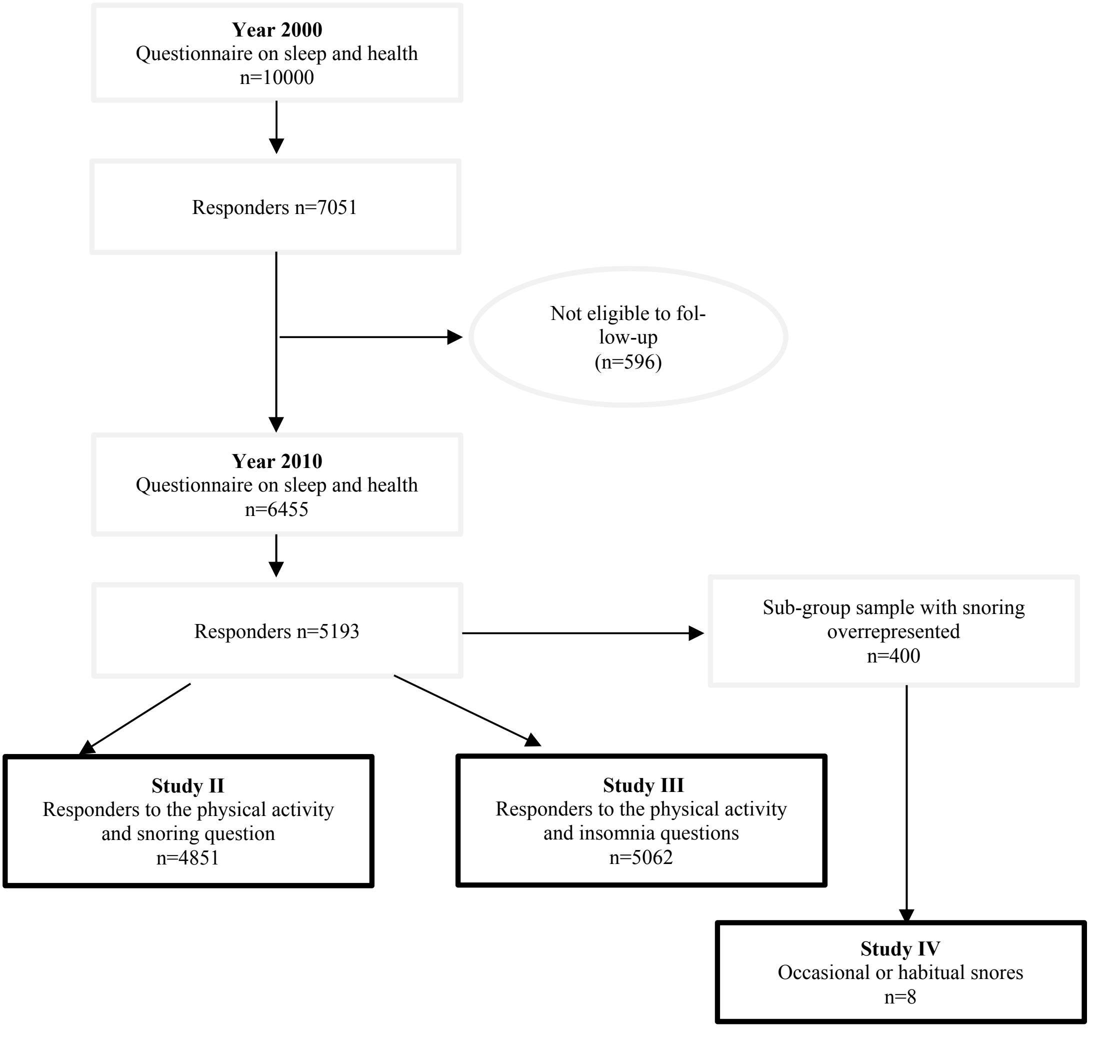

Figure 1. Overview of the inclusion of participants studied in study II-IV. The studies II-IV included in the thesis are highlighted with a black frame.

Participants included in study IV were selected from the SHE study[125] (see figure 1). Women above 30 years of age with a BMI between 20-35 who reported habitual snoring but had no sleep apnoea at a preceding full-night polysomnography (AHI < 15) and reported low to medium physical activity levels were asked to participate. For the purpose of selecting participants reporting habitual snoring and a physical activity on a low to medium level the questions from study II and III were used (se description of assessment in the measure and data collection section). When eight participants had accepted to be part of the study, inclusion was ended. All participants gave their oral and written informed content prior to the study.

Initially the participants were recorded for three nights in the A_1 phase to serve as a baseline. The intervention took place in phase B_1 where the participants performed a single aerobic exercise session followed by one night of sleep registration. In phase A_2 a new baseline was established for two nights followed by a second intervention phase (B_2). The final A_3 phase included measurements for two further nights. In total, the five phases included continuous data collection during 9 days and 9 nights. See figure 2 for a schematic illustration of the study setup.

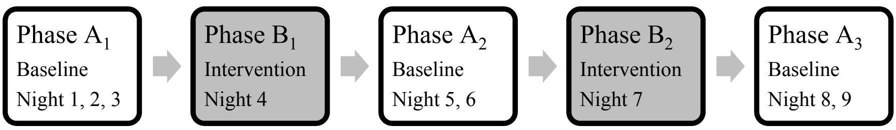

Figure 2. Flow-chart over the study design in study IV

Measures and data collection

Main outcomes

Eating behaviour change

The participant's conception of eating behaviour changes was explored in the semi-structured interviews. The participants were asked open ended questions e.g. "What pros and cons do you see comes out of engaging in sound eating?" and "What could make you change your diet?" Follow-up questions were asked when needed to clarify the answers and get more rich data.

Snoring

Self-report

Snoring was self-reported using a 5-point scale. Participants were asked to score the frequency of their "loud and disturbing snoring". In the statistical evaluation in study II, subjects with scores of 1 (never) and 2 (seldom) were defined as non-snorers, those with a score of 3 (sometimes) as occasional snorers, and those with scores of 4 (often) or 5 (very often) as habitual snorers (study II) [56,60]. In study III participants with scores of 1, 2 and 3 was defined as non-snorers. This question was validated on a random sample of men when compared to snoring measured by a microphone the specificity of the question was high and sensitivity was low.[126]

Objective measure

An objective measure of snoring was applied in study IV, using the microphone in a Nox T3 sleep monitor (Nox Medical, Reykjavik Iceland), a small portable device suitable for home registrations. The microphone on the T3 device has a sampling frequency of 8 kHz. One snore was defined as a sound above 65 dB lasting from 0.3-2.5 seconds and a snore train was defined as minimum 3 consecutive numbers of snore.

Insomnia

To assess insomnia symptoms in study III, participants were asked to state how much difficulty they have 1) "falling asleep in the evening", 2) "waking several times during the night" and 3) "waking too early and having difficulty falling asleep again". A five-point scale was used to score the sleep quality, ranging from score 1 ("none") to 5 ("very severe"). A score of 4 ("severe") or 5 ("very severe") for any of the three items confirmed symptoms of insomnia. To assess daytime sleepiness and fatigue in study III, the participants were asked to state how severe their problems were in terms of daytime sleepiness; for fatigue, they reported how severe their problems were regarding feeling physically tired. Response options ranged from score 1 ("none") to 5 ("very severe") and scores of 4-5 were used to define daytime sleepiness and fatigue respectively.

Insomnia was for the purpose of study III defined as having insomnia symptoms combined with daytime sleepiness or daytime fatigue. The insomnia definition was chosen to mimic common diagnostic criteria according to ICSD-2.[127]

Secondary outcome

Slow wave sleep

Sleep electroencephalography (EEG) was recorded by the Nox T3 device using two channels with electrodes placed at F4-A1, F3-A2 and a ground electrode in the forehead (study IV). The EEG signal was used to differ between sleep and wakefulness. Slow wave sleep (SWS) (sleep stage N3) was defined as frequencies of 0.5-4 Hz and a peak to peak amplitude > 75. Stages N1, N2 and REM sleep was grouped as sleep and not differentiated in this study.

Apnoea hypopnea index

Apnoea was defined as a reduction of flow of ≥ 90 % and hypopnea was defined as a reduction of flow of ≥ 30% of the peak excursions of the pre-event baseline and ≥ 3% oxygen desaturation according to the AASM guidelines.[128]

Protective factors

Physical activity

Self-report

Self-reported leisure-time physical activity (study II-IV). Participants were asked to estimate their level of physical activity during leisure time using a 4-point scale;[129] 1) spending most time watching television, reading and being sedentary for most of their leisure time, 2) some physical activity, like walking and cycling, at least four hours a week, 3) participating regularly in swimming, jogging, tennis and aerobic exercise, for example, for three hours a week, 4) vigorous exercise and competition in swimming, running, football, handball, for example, several times a week. For the statistical evaluation, the level of physical activity was categorised into three groups by pooling of category three and four.

Objective measure

In study IV physical activity was objectively measured using an accelerometer to assess the time in minutes used in moderate and vigorous physical activity intensity (MVPA) using the Freedson cut-off point[130] and the total amount of steps per day. This was assessed using Actigraph GT3x accelerometer (Pensacola, Florida, USA). The Actigraph was worn on the waist throughout the woken hours of the day.

Confounders

Anthropometric measures

The body mass index (BMI) i.e. body weight in kilograms divided by height in meters squared (kg/m²) was calculated from self-reported data on weight and height (study II and III). In study IV the BMI was calculated from measured weight and height obtained when the participants visited the clinic. For the purpose of study II the participants were categorised into underweight (BMI < 20 kg/m²), normal weight (BMI 20-24.9 kg/m²), overweight (BMI 25-29.9 kg/m²) and obese (BMI ≥ 30 kg/m²). Change in BMI *(delta Δ)* was calculated as BMI 2010 – BMI 2000.

In study II, waist and neck circumference (centimetres) was measured by the participants using a tape measure and instructions provided with the questionnaires. Waist and neck circumference were categorised in accordance to analysis of the baseline data.[56] The waist circumference results were divided into four categories; 1) ≤ 75 cm, 2) 76-81 cm 3) 82-90 cm and 4) ≥ 91 cm. Neck circumference was also categorised into four groups 1) ≤ 31 cm, 2) 32-33 cm, 3) 34-35 cm, 4) ≥ 36 cm.[56] In study IV the measures were obtained when measured when the participants were in the clinic.

Alcohol and smoking

Alcohol dependence (study II and III) was investigated using the CAGE questionnaire which includes four questions targeting; the need to Cut down, being Annoyed by criticism, feeling Guilty about drinking and needing a drink in the morning (Eye-opener).[131] Answering "yes" to at least two of the questions was defined as alcohol dependence.

Participants were classified as smokers, if smoking ≥ 1 cigarette a day, while non-smokers were those who had never smoked or stopped before 2000.

Education

In study III, participants were asked to state the highest achieved education; primary school (5 to 9 years of basic education), secondary school (2 to 4 years of high school education) or university education.

Psychological distress

Anxiety and depression was assessed by the self-reported Hospital Anxiety and Depression Scale (HAD) questionnaire[132] (study II). The questionnaire consists of seven questions related to anxiety and seven to depression. Each item, e.g. "I am nervous or anxious", is rated on a four-point scale ranging from 3 (most often), 2 (often) and 1 (in some cases) to 0 (never). This allows a maximum score of 21 for anxiety and depression respectively. A score above eight is recommended as an indication of a possible pathology[132] and defines the presence of anxiety or depression respectively in this study. For statistical evaluation, anxiety and depression were pooled, creating a combined variable called psychological distress confirming the presence of anxiety, depression or both.

Intervention

The intervention in study IV consisted of aerobic exercise executed on a Tunturi treadmill (model T50, Turku, Finland). After a brief warm-up of 7-10 minutes light walking on the treadmill aerobic exercise was performed at a moderate or a high intensity (60-70% and 70-80 % of heart reserve) with duration of 30 minutes. One participant performed at a moderate intensity level and four participants performed at a high intensity. To determine the participants' maximal heart rate with the purpose to establish the exercise intensity, a direct VO_2 max test was performed on a Sport Art Fitness TR33 treadmill (Tainan, Taiwan), using a Sensor Medics, Vmax 29 (Care Fusion, San Diego, USA) for gas analyses and a Polar s610 pulse measure (Polar Electro KY, Kempele, Finland).

The intensity was regulated by increasing or decreasing walking speed and or level of inclination on the treadmill. Heart rate was measured during the session using a Polar RS400 (Polar Electro KY Kempele Finland) to ensure the right intensity was obtained. The intervention was led and supervised by S.S-N at Uppsala University Hospital.

Data management and analysis

Data analysis

Statistical analysis was performed using Stata 10.0 respective 12 (Stata Corporation, College Station, TX). Data analysis used to evaluate the outcomes in study I-IV are presented in table 4.

Table 4. Data analysis used in studies.

Methods	Study I	Study II	Study III	Study IV
Qualitative content analysis	x			
Median and range				x
Frequencies and percentage	x	x	x	x
Mean and standard deviation	x	x	x	x
Two sample t-test with equal variance		x	x	
Pearson´s chi squared test		x	x	
Mc Nemar test			x	
Logistic regression analysis			x	
Multiple logistic regression analysis		x	x	
Visual analysis of graphical illustration				x
Percentage exceeding the median				x

In study I, the interviews were transcribed verbatim and a qualitative content analysis was conducted following the procedure described by Graneheim and Lundman.[133] The analysis focused mainly on the manifest content and had a low level of interpretation. It was a continuous process and several steps during analysis were repeated and compared with the transcribed text for verification. A more detailed description of the data analysis is provided in the method section in paper I.

The results from the postal questionnaires in study II and III were entered into an Excel file to allow statistical analysis.

To compare risk factors in women with and without snoring and insomnia, respective, analyses of differences were performed. In categorical variables, the chi2 test was used to compare the proportions of the main outcome of the examined risk factor. However, in study III when comparing the prevalence between the baseline and follow-up, the McNemar test was used, as the comparison was made between dependent groups. Continuous variables were compared using the two-sample t-test with equal variances. The results are presented with the mean ± standard deviation (SD). To study the association between risk factors and snoring incidence and remission univariate analysis were conducted on the group not reporting respective reporting snoring at baseline (study II). To study the association between risk factors and incident insomnia, univariate analyses were conducted on the group not reporting insomnia symptoms at baseline (study III).

For simultaneous evaluations of more than two variables, multiple logistic regression analyses were performed and presented as adjusted odds ratios (OR) with 95% confidence intervals (95% CI). In the multiple logistic regression analysis all potential confounding variables described in the previous section were included. In study II the baseline snoring status was adjusted for as the multiple logistic regression analysis was performed on all participants answering to the questions on both snoring and physical activity. In study III the analysis was performed on participants reporting no insomnia at baseline and answering to the question on insomnia and physical activity. The number of participants is reported for each of the analyses. For all statistical tests, $p \leq 0.05$ led to the rejection of the null hypothesis.

In study IV the snore train percentage was automatically calculated as the percent of time in snore trains relative to the total sleep time (TST) in the Noxturnal 4.4.2 software. TST was estimated by the manual assessment of the sleep recording. This automatic scoring was recently found sensitive for manual scoring of snoring.[134] Snore train percentage is reported both as the percent of each period of sleep and visually illustrated as the percentage by the hour.

SWS was scored individually by two examiners. Periods of disagreement between examiners were discussed to reach agreement. The SWS percentage was calculated as the time in slow wave sleep relative to the total sleep time in the Noxturnal 4.42 software. SWS percentage is reported for each period of sleep.

The frequency composition and power spectral density in the EEG signals during sleep is a measure of the quality of the SWS, as opposed to the quantity which is measured by means of sleep scoring. Therefore, to get a qualitative measure of the SWS, delta power (1-4 Hz) was calculated for the SWS occurring during the first 180 minutes from sleep onset. The power spectral density was calculated using a Fast Fourier Transformation (FFT), which is a common method for analysing spectral density of EEG during sleep.[135,136] The FFT was run in the Noxturnal 4.42 software using 1024-sample Hanning windows (sampling frequency 200 Hz) with 50% overlap across each 30-second epoch to calculate the sum power density for the 1-4 Hz frequency band (delta power). Manual artefact rejection was done on the 30-second segments and in case of artefacts, a whole segment was removed. Following artefact rejection, the power density for each 30-second segment was averaged for the first, second and third 60 minutes from sleep onset (covering in total, 180 minutes from sleep onset).

AHI was manually scored using the Noxturnal 4.4.2 software.

To evaluate the physical exercise intervention on the main outcomes, the results of the hour by hour analysis was evaluated by visually inspecting a graphical illustration. The hour by hour analysis include data from the first hour of registration and each hour of registration was included until the last period that included at least 30 minutes of registration. The visual inspection across phases was assisted using two criteria; 1) changes in the median across the phase, 2) percentage of data points exceeding the median (PEM) in the hypothesized direction[137] of the data points presented hour by hour. PEM values of 50 % represent data equally distributed above and below the median. PEM values of < 70, 70-89, ≥90 has previously been used and suggest a questionable effect, moderate effect and large intervention effect, respectively.[138] Further the mean and standard deviation (SD) on the night to night values was presented for each study phase. Finally, to describe the study mean and the variability throughout the nine registrations, mean, SD, minimum and maximum values was calculated for each participant. The mean and SD for the level of MVPA and number of steps of the nine days' study period was presented along with the two days of highest MVPA and number of steps taken.

Ethical considerations

In study I-III the participants were interviewed or filled in a postal questionnaire on sleep and health and would not directly benefit form participation in the studies. In study IV the test of maximum oxygen uptake and the aerobic intervention performed on two occasions were not expected to affect the participant's overall health status. Participation would however allow for increased experience of how to perform aerobic exercise under controlled circumstances. The main benefit for participation in study I-IV was the more overall contributing to the scientific knowledge in the area of eating behaviour, physical activity and sleep disorders.

Results

Eating behaviour change

According to the participants, a wide variety of cognitive, affective, bio-physiological and contextual aspects influence eating behaviour change. These are presented in categories representing 9 barriers and 8 facilitators, with one or more sub-categories to clarify the content.

For more detailed descriptions and quotations representing each of the categories, see the result section in paper I.

Table 5. Barriers and facilitators to eating behaviour change in patients with obstructive sleep apnoea (OSA) and obesity.

	Category	Sub-category
Barriers	Desire and reward	Needing to satisfy the desire for food
		Compensating the desire for tobacco
	Cravings and emotional control	Eating a tool to control feelings
		Mental state leads to ignorance towards eating behaviour
	Low self-confidence	Not feeling able to cope with the problem
	Insufficient support	Nagging back-fired
		Personal chemistry
		Wanting support
	Taxing behaviours	Regularity
		Demanding and time-consuming
	Cost	Too expensive
	Lack of knowledge about healthy eating strategies	Poor knowledge
	Perceived helplessness	Not feeling able to affect one's own situation
	Low susceptibility	Perceived low susceptibility
Facilitators	Positive expectations	Results and expectations are motivating
	Fear of negative consequences	Expecting consequences
	Experience of success	Good self-confidence
		Results visible on the scale
	Support and follow-up	Support from peers or professionals
		Group support
		Follow-up as support
		Family support
		Individual support
	Accessibility	Time
		Readily accessible healthy food
	Applied skills for healthy eating	Knowledge about healthy food
		Strategy for changing routines and avoiding risky situations
		Need for energy input/output calculations
		Strategy
		Insight and knowledge
	Personal involvement	Wanting to be in control
	Challenged self-image	Not recognising oneself

Impact of physical activity and exercise on snoring

The prevalence of habitual snoring complaints increased during the study period from 7.6% (n=370) at baseline to 9.2% (n=448) at the ten-year follow-up ($p<0.0001$) (study II). The ten-year incidence of habitual snoring complaints was 3.3% (n=121) and a remission in snoring complaints was reported in 20.3% (n=75) of the women.

In this study, increases or decreases in level of self-reported physical activity were associated with decreases or increases in snoring complaint prevalence. At follow-up, the highest prevalence of 20.4% was found in the group who reported a low level of physical activity at both baseline and follow-up and the lowest prevalence of 4.8% was found in those reporting a high level of physical activity on both occasions (figure 3).

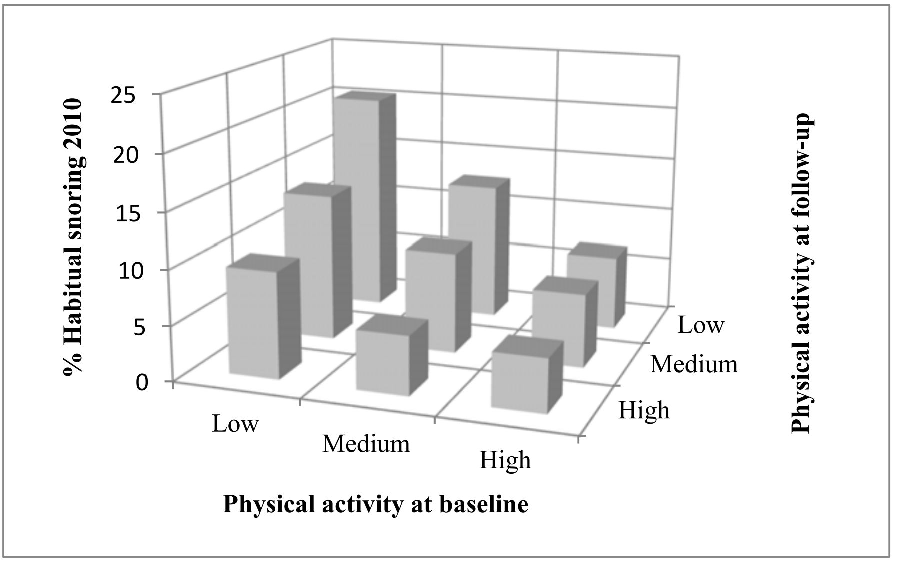

Figure 3. Prevalence of habitual snoring complaints (%) in relation to reported physical activity level (low, medium, high) at baseline in 2000 and in the follow-up year, 2010. Each bar represents the prevalence of snoring complaints for a specific physical activity profile at baseline and follow-up (n=4,934).

A low level of physical activity was an independent risk factor for snoring ten years later. Medium or high levels of physical activity at baseline were independent protective factors for reporting snoring at follow-up. Reporting a high physical activity level at baseline increased the chance of reporting no snoring complaints at the ten-year follow-up. An increase in the anthropometric measures was associated with an increased risk of being a habitual snorer. Smoking significantly reduced the chance of becoming a non-snorer, while there was no association between alcohol dependence and snoring status at follow-up (see table 6).

Table 6. Risk factors at baseline for incidence and remission of snoring during the 10-year period.

(n=4,657)	Habitual snoring 2010	Non-snoring 2010
Age in 2000		
20-29 years	1	1
30-39 years	1.6 (1.0-2.3)	0.6 (0.5-0.7)
40-49 years	2.1 (1.5-3.1)	0.4 (0.3-0.5)
50-59 years	1.3 (0.9-1.9)	0.5 (0.4-0.6)
60-69 years	0.6 (0.4-1.1)	0.8 (0.6-1.1)
> 70 years	0.7 (0.4-1.5)	1.1 (0.7-1.7)
BMI in 2000		
<20	0.6 (0.3-1.1)	1.7 (1.3-2.2)
20-24.9	1	1
25-29.9	1.3 (1.0-1.6)	0.7 (0.6-0.9)
>30	1.5 (1.1-2.2)	0.6 (0.4-0.8)
ΔBMI*	1.2 (1.1-1.2)	0.9 (0.87-0.92)
Waist circumference in 2000 in cm		
≤ 75	1	1
76-81	1.4 (0.98-2.2)	0.7 (0.5-0.8)
82-90	1.7 (1.2-2.5)	0.5 (0.4-0.7)
≥ 91	2.6 (1.8-3.8)	0.4 (0.3-0.5)
ΔWaist circumference‡	1.05 (1.04-1.07)	0.97 (0.96-0.98)
Neck circumference in 2000 in cm		
≤ 31	1	1
32-33	1.2 (0.8-1.8)	0.8 (0.6-0.9)
34-35	1.3 (0.9-2.0)	0.5 (0.4-0.6)
≥ 36	2.1 (1.4-3.1)	0.5 (0.4-0.6)
ΔNeck circumference‡	1.1 (1.1-1.2)	0.9 (0.86-0.92)
Snoring in 2000		
Never	1	1
Occasional	6.1 (4.6-8.0)	0.2 (0.1-0.2)
Habitual	24.4 (17.8-33.4)	0.1 (0.05-0.09)
Smoking habits in 2000		
Non-smoker	1	1
Smoker	1.2 (0.9-1.6)	0.7 (0.6-0.9)
Alcohol dependence in 2000		
No	1	1
Yes	1(0.6-1.6)	1 (0.7-1.3)
Physical activity level in 2000		
Low	1	1
Medium	0.7 (0.5-0.9)	1.1 (0.9-1.4)
High	0.5 (0.4-0.8)	1.3 (1.0-1.7)

The data are presented as adjusted odds ratios with 95% confidence intervals after adjusting for all the variables in the table. Waist and neck circumference are entered in the model separately to avoid multi-collinearity.
*OR calculated for an increase of 1 kg/m2. ‡ OR calculated for an increase of 1 cm.

Women who increased their physical activity during the follow-up period no longer ran an increased risk of snoring. On the contrary, an increased chance of remission from snoring was evident in those with a high level of physical activity, but only if they remained at a high level. The OR of each physical activity profile is presented in table 7.

Table 7. Odds ratios for habitual snoring complaints and no snoring complaints in 2010 for different self-reported physical activity profiles.

Physical activity level in 2000/2010	Habitual snoring 2010	No snoring 2010
Low/low	1	1
Low/medium	0.8 (0.5-1.2)	1.4 (1.0-2.1)
Low/high	0.4 (0.1-1.2)	1.5 (0.8-3.1)
Medium/low	0.6 (0.4-1.0)	0.6 (0.4-1.0)
Medium/medium	0.6 (0.4-0.8)	1.3 (1.0-1.8)
Medium/high	0.4 (0.2-0.7)	1.6 (1.1-2.3)
High/low	0.3 (0.1-1.3)	1.4 (0.6-3.3)
High/medium	0.5 (0.3-0.8)	1.3 (0.9-1.9)
High/high	0.4 (0.2-0.7)	2.1 (1.4-3.1)

The data are presented as adjusted odds ratio (95% confidence interval) after adjusting for all the variables in table 6.

Acute effects of exercise on snoring

In study IV, the pattern seen in the snore train percentage throughout the baseline and intervention phases in the five studied individuals does not support an isolated acute effect of aerobic exercise training on the following night. The findings suggest an individual difference in the response of aerobic exercise on snoring. Some individuals appear not to respond to the intervention while others might respond with an immediate or delayed response, as exemplified in figures 5 and 6.

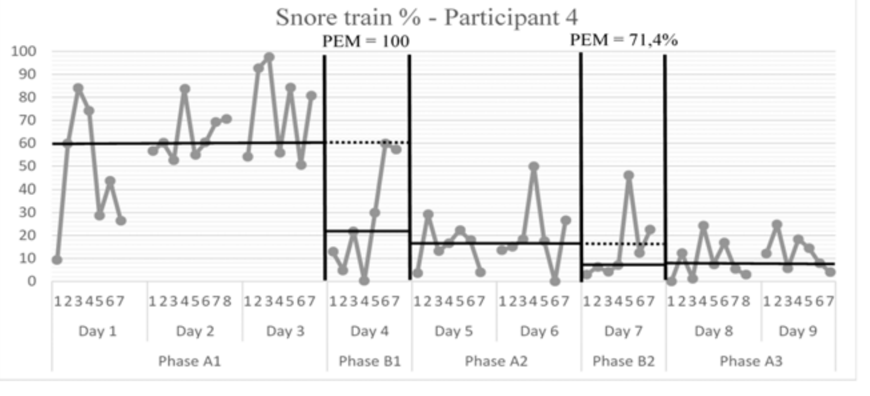

Figure 5. Example of graph showing an immediate change in median snore train percentage. Graph showing the median snore train percentage level for each of the five phases. In the intervention phases (phases B1 and B2), the percentage of data points exceeding the median (PEM) of the preceding A phase is reported. The median value of the previous A phase is represented by the punctured line.

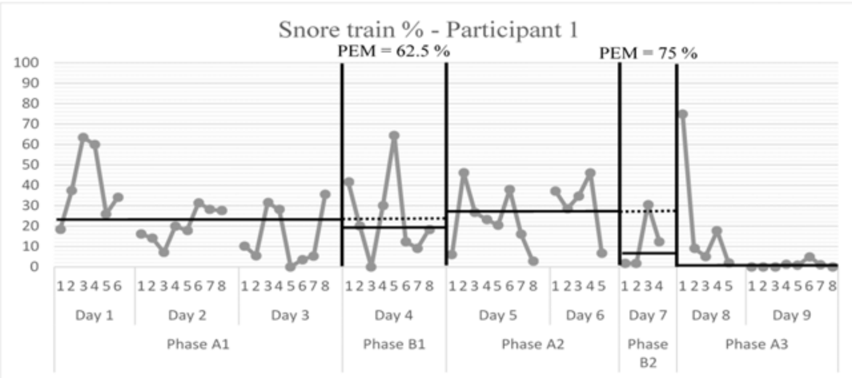

Figure 6. Example of graph showing delayed change in median snore train percentage. Graph showing the median snore train percentage level for each of the five phases. In the intervention phases (phases B1 and B2), the percentage of data points exceeding the median (PEM) of the preceding A phase is reported. The median value of the previous A phase is represented by the punctured line.

Impact of physical activity and exercise on insomnia

Over the study period the prevalence of self-reported insomnia was stable and at the ten-year follow-up 15% (n=759) of the women reported insomnia. The ten-year incidence rate among the 4,308 women without insomnia complaints at baseline was 10% (n=429) and remission was reported in 56.2% (n=424) of the 754 women who reported insomnia at baseline.

There was an association between the changes in physical activity level and the prevalence of insomnia. The highest prevalence was found in the group of women with a low reported physical activity level at both baseline and follow-up. The lowest insomnia prevalence was present in the women reporting a high level of physical activity on both occasions (figure 6).

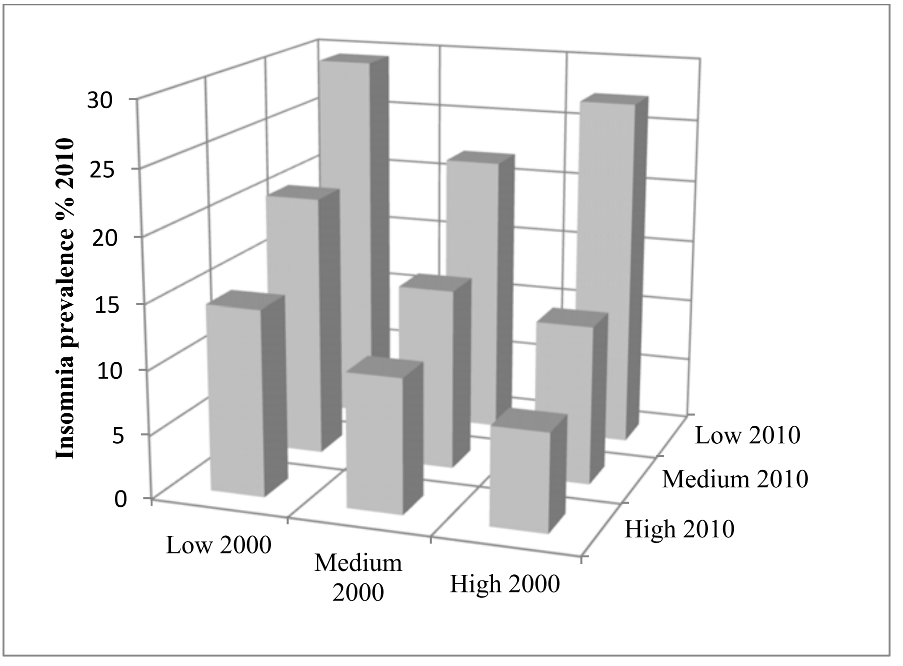

Figure 6. Prevalence of reported insomnia (%) year 2010 in relation to reported physical activity level (low, medium, high) at baseline, in 2000 and at follow-up in 2010. Each bar represents the prevalence of insomnia for a specific physical activity profile at baseline and follow-up (n=5,062)

Increasing or maintaining a higher self-reported level of physical activity during the study period proved to be protective in terms of reporting insomnia at follow-up. The protective effect remained after adjusting for age, BMI, snoring, smoking, alcohol dependence, education and psychological distress (Table 3, model B). There was no significant association between a reduced level of physical activity and the OR of reporting insomnia at follow-up. The women who reported psychological distress at any time ran higher odds of developing insomnia, with the highest OR for the group reporting psychological distress on both occasions. Moreover, lower age and smoking were independent risk factors for incident insomnia, while BMI, snoring, alcohol dependence and education level did not significantly influence the OR after adjusting for confounders. When examining the extent to which the effect of physical activity level on insomnia was mediated by psychological distress in the multiple logistic regression model (model B), the OR did not differ largely from model A (table 8).

Table 8. The crude and adjusted impact of risk factors for incident insomnia during the 10-year study period.

	Unadjusted	Model A	Model B
	Insomnia OR (95% CI) n=3,841	**Insomnia** Adj. OR (95% CI) n=3,574	**Insomnia** Adj. OR (95% CI) n=3,509
Physical activity change 2000/2010			
Low/low	1	1	1
Low/medium	0.57 (0.35-0.93)	0,49 (0.28-0.83)	0.53 (0.3-0.94)
Low/high	0.19 (0.04-0.8)	0.16 (0.04-0.71)	0.17 (0.03-0.81)
Medium/low	0.77 (0.48-1.25)	0.77 (0.46-1.28)	0.83 (0.48-1.42)
Medium/medium	0.42 (.029-0.61)	0.44 (0.29-0.66)	0.53 (0.35-0.83)
Medium/high	0.3 (0.18-0.49)	0.28 (0.16-0.48)	0.36 (0.21-0.64)
High/low	1.09 (0.44-2.7)	0.85 (0.32-2.29)	1.18 (0.42-3.3)
High/medium	0.34 (0.21-0.57)	0.3 (0.18-0.51)	0.37 (0.21-0.66)
High/high	0.23 (0.13-0.39)	0.21 (0.12-0.37)	0.3 (0.16-0.54)
Age in 2000[1]	0.99 (0.98-0.99)	0.98 (0.97-0.98)	0.98 (0.96-0.99)
BMI in 2000[2]	1.02 (0.99-1.04)	1.01 (0.98-1.04)	1.008 (0.99-1.04)
Habitual snoring in 2000			
Yes	1.4 (0.97-2.03)	1.42 (0.96-2.12)	1.13 (0.73-1.74)
Smoking in 2000			
Yes	1.98 (1.54-2.54)	1.61 (1.22-2.12)	1.75 (1.31-2.33)
Alcohol dependence in 2000			
Yes	1.74 (1.19-2.56)	1.44 (0.96-2.13)	1.3 (0.85-1.99)
Education in 2010			
Primary	1	1	1
Secondary	1.65 (1.18-2.3)	1.28 (0.86-1.89)	1.24 (0.81-1.88)
University	1.09 (0.81-1.48)	0.97 (0.66-1.41)	0.93 (0.6-1.04)
Psychological distress 2000/2010			
No/no	1	-	1
Yes/no	1.85 (1.19-2.87)	-	1.79 (1.13-2.86)
No/yes	5.94 (4.43-7.96)	-	5.42 (3.96-7.41)
Yes/yes	7.08 (4.89-10.25)	-	7.01 (4.68-10.49)

Model A: adjusting for change in physical activity, age, BMI, snoring, smoking, alcohol dependence and education level. Model B: adjusting for change in physical activity, age, BMI, snoring, smoking, alcohol dependence, education level and psychological distress for the reported variables (adjustment A and B). The data are presented as the odds ratios with 95% confidence intervals.

[1] OR calculated for an increase of one year. [2] OR calculated for an increase of 1 kg/m2.

Variation in sleep measures

This series of experimental single-subject studies identified a pronounced variation in snore train, SWS percentage and delta power, whereas the AHI showed relatively low variation (table 9).

Table 9. Snore train percentage, slow wave sleep (SWS) percentage, delta power and apnoea-hypopnoea index (AHI) over nine nights presented as mean (SD), minimum and maximum values.

	Snore train % of sleep time	**SWS % of sleep time**	**Delta power (uV)**	**AHI**
Participant 1				
Mean (SD)	20.3 (11.5)	40.2 (7.5)	331.0 (104.1)	9.7 (1.9)
Min – max	1 - 40	22.5 - 48.6	163.0 – 623.5	6.6 - 12.5
Participant 2				
Mean (SD)	37.6 (8.5)	23.3 (7)	214.5 (65.5)	7.6 (1.2)
Min – max	26.3 - 51.7	13.4 – 31.4	119.3 – 357.4	5.9 – 9.3
Participant 3			132.0 (32.7)	
Mean (SD)	22.9 (8.2)	22.9 (5.2)	77.1 - 193.1	3 (1.6)
Min – max	6.4 – 32.7	14 – 28.8		0.8 – 6.1
Participant 4			285.4 (75.2)	
Mean (SD)	32.1 (23.8)	32.7 (7.8)	158.4 - 481.4	19.2 (7.2)
Min – max	9.4 – 73.3	14.6 – 41.3		9.7 – 28.5
Participant 5				
Mean (SD)	10.5 (10.2)	25.9 (2.5)	114.5 (16.9)	4 (1.5)
Min – max	0.6 – 28.6	20 – 28.6	78.8 – 135.6	1.4 - 6

Discussion

This thesis contributes novel and confirmatory knowledge about the meaning and influence of health behaviours, i.e. eating and physical activity on SDB and insomnia. The main findings of the thesis are summarised in the text below.

In study I, several aspects were similar to the findings in other populations; however, two aspects had not been previously identified: low perceived susceptibility regarding detrimental consequences was a barrier, and sudden or significant weight gain challenged participants' self-images and seemed to act as a facilitator for eating behaviour change.

In the SHE study (study II and III) on a female cohort followed prospectively over 10 years, physical activity behaviour appears to have potentially important implications for the management of snoring and insomnia. In study II, a low level of self-reported leisure-time physical activity was a risk factor for habitual snoring complaints at follow-up, independent of weight, weight gain, alcohol dependence and smoking. Participants who increased their physical activity during the follow-up period no longer ran an increased risk. On the contrary, an increased chance of remission from snoring complaints was evident among those with a high reported level of physical activity, but only if they remained at a high level. In study IV, concerning the acute effect of aerobic exercise on snoring, no isolated acute effect from aerobic exercise training on the following night was found. However, two of the studied subjects had an immediate or delayed response (study IV). In addition, a pronounced variation in the snore train percentage was found in the studied individuals.

Furthermore, the results of study III showed that women who maintained higher levels or increased their level of leisure-time physical activity over the ten-year period were partly protected from self-reported insomnia, independent of psychological distress, age, change in BMI, smoking, alcohol dependence, snoring status and level of education.

Eating behaviour change

Changes in eating behaviour to reduce calorie intake have been suggested as part of the treatment approach for SDB.[101] The importance of eating behaviour changes may be apparent in light of the clear effect of weight loss on

OSA.[37,38,62] This seems to be an area of SBM that would benefit from more focus on the scientific evaluation of the initiation and maintenance of changing eating behaviour. The perceived conceptions of important aspects for eating behaviour change in patients with OSA and obesity were studied in order to develop an intervention aimed at eating behaviour change.

The results from this thesis add aspects to those identified in previous studies. Low perceived susceptibility regarding the detrimental consequences of and diseases secondary to severe OSA combined with obesity have a negative influence on readiness for behaviour change, according to participants. This was interpreted as a barrier, which is also theoretically supported in the HBM describing an association between low susceptibility and the reason for not engaging in healthy behaviours.[91] Therefore, a hypothesis is that low susceptibility causes some individuals to disregard the known risks of OSA and obesity and thus opt not to initiate eating behaviour change. However, perceived fear of negative consequences on health was regarded as a facilitator for change, a finding supported in a study of behaviour change in low-income mothers with overweight or obesity.[139] These results suggest that perceived susceptibility to a health threat is important to the willingness to change eating behaviour.

Sudden or significant weight gain presented a challenge to the self-images of some participants. They did not identify as obese. For these participants, the shock of a weight increase may trigger to eating behaviour change. The TTM suggests that dramatic relief in early stages of changes is important.[92] In the studied participants with OSA and obesity, dramatic relief may occur when they realise the risks associated with OSA. Sudden weight gain may also change their level of susceptibility to OSA and serve to trigger change.

More identified factors share similarities with findings from previous studies of other populations. We reported cost, support, and desire and reward as barriers to weight loss. In addition, support from others was highlighted as an important facilitating aspect for weight loss in this study. These aspects were previously reported in a study on women participating in a weight-loss intervention.[140]

Overall, insights into potentially important factors for successful eating behaviour change are important for developing future interventions. A recent review examined mediators used in intervention studies and their importance for dietary changes. While self-efficacy for overcoming barriers and self-regulation skills were found to be promising mediators of dietary intake in the short term (< 12 month), no mediators were identified for a long-term perspective. The mediators are suggested to be an important part of future behaviour change programmes focusing on healthy eating.[141] Interestingly, these mediators correspond with the findings about facilitators in this thesis: specific skills for healthy eating and the experience of success.

The results of study I have been used to guide eating behaviour changes in an intervention targeting both eating behaviour and physical activity on OSA.

The results were incorporated into the behavioural medicine treatment delivered by a dietician. Eating habits were evaluated and the participants in the intervention group reported more healthy eating behaviour compared with the control.[142]

Patients' views of barriers and facilitators for eating behaviour change should be taken into account when promoting weight loss as a strategy for improving SDB. Future studies of mediators for successful eating behaviour change in patients with OSA will reveal whether these factors will be important.

The impact of physical activity and exercise on snoring

Snoring is associated with a number of health consequences, including daytime sleepiness, cardiovascular diseases and mortality[52,53,143] and a cross-sectional study suggests a protective effect from physical activity on snoring frequency.[6] This highlights the importance of identifying modifiable behaviours for developing a strategy to reduce future snoring and its consequences.

The findings from study II confirm that snoring is a prevalent disorder. The prevalence of habitual snoring complaints was 9.2% (n=448) at the ten-year follow-up, which was higher compared to the baseline findings, although in line with previous findings.[43,58] Snoring is not a constant condition: the ten-year incidence of habitual snoring complaints was 3.3% (n=121) and remission in snoring complaints was reported by 20.3% (n=75). Incidence and remission are somewhat lower than those reported previously by a general population[62] of men and women aged 61-63 who were monitored for ten years,[144] and by a general male population.[60] The higher incidence previously reported could potentially be due to the mixed populations studied and the increased risk among men compared with women. The higher remission rate of 50% reported by Juuti et al.[144] may be due to the higher age of the group studied; similar numbers in a previous report from the group aged over 65 supports this explanation.[62] Study II supports the association between age and snoring, as seen by the lower OR for snoring remission seen in the age groups between 20-59.

To the best of our knowledge, this study is the first to report low self-reported physical activity as an independent risk factor for complaints of snoring over time. The OR of future snoring complaints decreased with increased reported physical activity. The findings support the suggested protective effect from previous cross-sectional studies[6,56] and demonstrate a dose response relationship between self-reported physical activity at baseline and snoring complaints at follow-up. This was confirmed in a complementary analysis of the changes in reported physical activity over the 10-year study period. Interestingly, the OR for habitual snoring complaints at follow-up decreased among participants who increased their physical activity level. Similarly, OR of remission at follow-up increased when higher physical activity levels were obtained.

The results confirmed that increased anthropometric measures are associated with an increased risk of snoring[60] and not being obese or overweight increases the chances of remission from snoring.[62] The prospective design of this study allows for analysis of changes over time and adjusting for weight gain in the statistical analysis. The adjusted results of the effect of physical activity on snoring show that the effects were not achieved due to weight changes. Instead, the results presented are independent of the adjusted variables: weight and weight gain, alcohol dependence and smoking. Given the dose response relationship and the design of this study allowing for analysis of changes over time, we suggest that self-reported physical activity is part of a causal relationship with the development of snoring.

In accordance with the findings from study II, physical activity is a significantly interesting behaviour for managing snoring problems. However, study II did not provide any data that informed guidelines about the type, duration and intensity best suitable for managing snoring. Also, no information was gained regarding when the effects may have occurred during the ten-year follow-up.

Acute impact of exercise on snoring

To understand the mechanisms underlying the causal relationship between self-reported physical activity and snoring suggested in study II, information is needed about the acute effect of exercise on snoring.

The hypothesis of study IV was that acute exercise decreases the occurrence of snoring the following night. However, the pattern seen in the snore train percentage was not as hypothesized in the studied cases and therefore, this study does not support an isolated acute effect of aerobic exercise training the following night. No previous study has reported on the acute effect of exercise on snoring. Taking the dose-response relationship found in study II into account, the lack of evidence for the night-to-night effect may be due to the relatively short duration of the intervention. Also, it is possible that in order to influence the occurrence of snoring, exercise should be continuously repeated in order to improve training and increase aerobic capacity. Studies of a three-month period of exercises specific to the oropharyngeal muscles have reported a positive effect on snoring.[145-147] The findings from study IV suggest an individual difference in the response of aerobic exercise on snoring. Some individuals appear not to respond to the intervention while others might have an immediate or delayed response. Study IV did not show a consistent effect on snoring from one single bout of moderate or high-intensity aerobic exercise, but some individuals displayed changes in snoring. This may indicate that the potential effects of exercise increase when repeated, lasting longer than one night, which is why there is no reverse after the intervention night.

It must be taken into consideration that the assessments of snoring differ between studies II and IV, which are self-reported and objective, respectively. Self-reports reflect the subjective impression over a longer period and the objective measures evaluate a single night of snoring.[148] This may be adequate, as the two studies differ regarding the timespan of interest. A previous study examined the difference of objectively and self-reported measures of a uvulopalatopharyngoplasty treatment for snoring. No effect from the surgery was found when measured objectively, but when asked, both patients and bed-partners reported that the treatment was effective.[149] This implies a mismatch between objectively and self-reported measures of snoring; the patients in that study perceived an effect that was not captured in the objective measure. A significant amount of knowledge about the health risks associated with snoring are based on studies using questionnaires for assessment and it is possible that replicating findings using objective measures will prove to be difficult. The extent to which the differences from using objective or self-reported outcomes influence the result of this and future studies is unknown, but it complicates direct comparisons between studies.

The impact of physical activity and exercise on insomnia

People with insomnia experience nocturnal symptoms as well as daytime impairment and the condition is associated with increased morbidity such as hypertension,[71] diabetes,[72] obesity, asthma, myocardial infarction, depression and anxiety.[73] A relatively large number of studies including reviews[89,104] report an association between exercise and better sleep, but prospective cohort studies are needed to help establish the association.

Insomnia is characterised by a relatively high incidence and remission, which makes it interesting to study factors that may influence the variation of insomnia over time. The prevalence of insomnia was 15% in the studied population-based cohort of women (n=5,193), similar to the previous findings from a Norwegian population.[150] A somewhat lower prevalence of 10% was reported in a one-year follow-up study of a Swedish population possibly including both men and women,[151] explaining at least some of the difference in prevalence. The ten-year incidence was 10% (n=429) which differed markedly from the one-year incidence of 3% previously reported on a Swedish population.[151] Apart from gender, this difference might be due to different periods of calculating the incidence. In study III, remission from insomnia was present in 56.2% (n=424) of those who reported insomnia at baseline. Despite different periods of follow-up, the results are similar to the findings from the previous study of a Swedish population followed for one year[151] and a study examining the persistence of insomnia over three years in 388 individuals who reported insomnia at baseline.[66]

In study III a low level of leisure-time physical activity was a risk factor for future insomnia in the population-based cohort of women followed over ten years. Women maintaining higher levels or who increased their levels of leisure-time physical activity over the ten-year period were partly protected from self-reported insomnia, independent of psychological distress, age, change in BMI, smoking, alcohol dependence, snoring status and level of education. These findings from the population-based cohort are supported in previous epidemiological studies on two elderly populations.[67,85] Previous studies have experimentally examined the effect of physical activity on sleep quality by exposing study participants to moderate aerobic exercise. The studies differ in size and period, but consistently support the effect of exercise on increased sleep quality.[35,77,78,152-154] A recent large randomised controlled trial (n=437) examined the effect of moderate-intensity aerobic exercise using three different durations. The authors report a dose-response effect of the increased duration of the intervention on sleep quality.[82] The study population comprised post-menopausal women with overweight or obesity and a high prevalence of sleep disturbance, allowing for larger improvements than expected from a general population. However, the results of study III, which was on a general population of women, support the results of the previous study.

Physical activity level is associated with anxiety and depression[74,155] and there is a bi-directional association between insomnia and anxiety and depression.[74] To obtain information on the extent to which the reported association between physical activity and insomnia was influenced by anxiety and depression, the multivariable analysis was performed both with and without psychological distress. Improvements in psychological distress appear to account for only a small part of the positive effect of physical activity on insomnia. This is seen by the small changes in the OR of reporting insomnia at follow-up when including psychological distress. Anxiety and depression are confirmed as risk factors for insomnia and reports of psychological distress on both occasions or at follow-up comprised the most important risk factor for insomnia. The result also points to a history of psychological distress leading to an increased risk of future insomnia.

A recent meta-analysis of the effect of acute and regular exercise on sleep reports moderate effects from regular exercise on overall sleep quality. Additionally, acute exercise was found to be effective for sleep quality, but resulted in smaller effects. The authors conclude that the acute effect combined with the increasing effects of regular exercise should provide and facilitate motivation for continuing to engage in physical activity on a higher level.[104]

Variability in sleep measures

In the series of experimental single-subject studies, data were collected continuously over nine consecutive sleep registrations. To the best of our knowledge, this is the first study to report the results from nine sleep registrations, an approach that was used to allow for the study of an exercise intervention in individual cases. Furthermore, this innovative approach allows for the examination of variation in the measured variables. Pronounced night-to-night variation in snore train percentage was seen throughout study IV. Previously, only one study had reported on the night-to-night variation of snoring over four nights.[40] Of the overall variance in snoring, 33% was due to intra-subject variance, supporting our finding of significant night-to-night variation.

According to the present findings, some individuals vary from relatively low values of snoring to high levels on different days, e.g. the same woman may have a snore train percentage of 9.4% or 73.3%. The apnoea-hypopnoea index showed less variation. The relatively low variability in AHI in this study might be due to the selection criteria, as only women with no or mild sleep apnoea were included. Large variation in the measure is a potential problem from both a clinical and scientific point of view. In order to detect and verify changes from interventions in a clinical or scientific setting, the effect must be larger than the expected natural variation. This means that differences beyond the range of individual variation in a measure should be present in order to document changes beyond those that may be accounted for by individual variation. In the individual with the lowest variation, the range of measured snoring over the nine nights was 25.4 and in the individual with the highest variation, the range was 63.9.

Methodological considerations

There are some methodological considerations that are important to discuss when considering the conclusions of this thesis. It is essential to consider the validity of the findings regarding both internal and external validity and the credibility, transferability, dependability and confirmability of the qualitative research.[133,156]

Credibility, corresponding to the internal validity of the findings, was sought by using a semi-structured interview approach in order to ensure the coverage of the behaviours in focus for the study. The semi-structured interview guide could increase the risk of too much guidance over participants' answers for maintaining the inductive approach of the study.[157] The interview guide was tested prior to the start of study I and found to be comprehensive and relevant by both respondents and researchers. The analysis was made transparent by giving examples in the form of quotations to document the different categories and sub-categories. To seek confirmability, the analysis process was discussed among the authors. Transferability corresponding to external validity was pursued in the purposeful selection and description of the participants. This was done to ensure variation in the selected variables of the participants' backgrounds, to allow for different views and obtain data-rich information. To enhance dependability, the interviews were conducted by the last author following the same semi-structured manual to ensure a uniform approach towards the participants.

In the SHE study, 80.5% of participants responded to the follow-up questionnaire. Non-responders were older, somewhat more overweight and less physically active at baseline. Insomnia was more present in the non-responders, but the groups did not differ in snoring prevalence. There is a risk of bias due to the differences between the responders and non-responders, which may affect the results e.g. concerning prevalence.

The self-reported nature of the data is a limitation in studies II and III, which may be a threat to the validity of the findings. The questions included to evaluate change over time were all identical at baseline and follow-up.

The question on leisure-time physical activity was created by the Swedish National Institute of Public Health.[158] It is limited to four response options, giving a somewhat rough indication of the perceived level of physical activity. As such, this study does not provide information on the type, intensity and duration of physical activity. In self-reported physical activity, there is a risk of over or underestimating the actual level of activity.[116-118] The questions used here have been used in previous cohort studies and although the validity of assessing physical activity levels via questionnaire remains a problem,[114] responses to these questions have been correlated with mortality.[129,159]

Assessing snoring and comparing the results between studies is complicated by the lack of an accepted "gold standard".[41] When validated in a random sample of Swedish men, the question used in this study had high specificity compared with snoring measured by a microphone during one night, while sensitivity was low and validity did not differ by age group.[160] As women who live alone might not be aware of their snoring, the analyses were repeated with the inclusion of only those who reported sleeping alone (study II). No significant differences were seen in the results.

Depending on self-reports to examine the presence of insomnia may contribute to the risk of recall bias. The definition of insomnia does rely entirely on self-report[65] and it may therefore be the best way to measure insomnia.

The major strengths of the study include the large size of a population-based cohort prospectively studied over ten years. This allows for analysis of changes in predictors and outcomes of interest, allowing for inference of causality.[161] Due to the high response rate and large sample from the general population in studies II and III, the results may be generalised to adult populations of women. However, the threat to generalisability due to the differences between responders and non-responders must be considered.

Experimental single-case design

The design of study IV allowed for studying the hypothesised intervention effects in each individual case. Each participant acted as their own control and close monitoring of the variables of interest provided detailed information throughout the study. Given the high degree of control, the design makes it possible to draw causal inferences in the individual case.[123] This approach provides information on the effect of an intervention along with the individual patterns in the variable of interest. As such, it may be a way to test the feasibility of aerobic exercise ahead of a large-scale intervention study.[122] This approach was chosen to test the hypothesis and to learn how variables varied over time before setting up a randomised controlled trail. It also made it possible to test procedures and measurement techniques.

The low number of participants does not allow for generalisation of the result to the target population. On the contrary, internal validity is prioritised[124] and possible to achieve via continuous measurement of the dependent variable over pre-determined phases.[124] With this method, the stability of the baseline data is important to assure that potential changes occur as an effect of the intervention and not due to the individual's normal variation or to a trend in the measured variables.[123,124] The large variation in the measured snoring is a threat to the validity of the present study; it makes assessment more challenging and should be kept in mind when considering the results. As a complement to the visual analysis, changes to the level in median and PEM were used to detect potential differences between study phases despite large variability.

The intensity used in the intervention was calculated from the measured maximal heart rate to ensure the specific aerobic intensity. During the intervention, intensity was controlled with a pulse measure. A continuous objective measure of physical activity was performed using an ActiGraph to allow for control of the independent variable when not in intervention. The ActiGraph measure of physical activity has been found to be a positive correlated with of compared to oxygen consumption.[121] However, the intensity measured during the intervention was not always captured by the ActiGraph. This uncertainty is a threat to internal validity and therefore, the total number of steps during the day was used as a complement to assess the level of physical activity during the study period.

While the automatized assessment of snoring is accurate compared to manual scoring[42] and scoring of AHI was carried out manually according to AASM guidelines,[128] there is no consensus for how to measure SWS using only two frontally placed electrodes. The validity of the SWS scoring was sought by comparing the individual scoring from two examiners. In the event of a disagreement, scoring was discussed to reach an agreement.

Conclusions

Women with sleep disorders would benefit from inclusion in a behavioural sleep medicine perspective targeting physical activity in the prevention and management of snoring and insomnia. This is motivated by the protective effects of physical activity confirmed by this thesis.

More specifically, a low level of self-reported leisure-time physical activity is a risk factor for future habitual snoring complaints, independent of weight, weight gain, alcohol dependence and smoking in women. Maintaining higher and increased physical activity levels partly protects from future snoring. Furthermore, a low level of self-reported leisure-time physical activity is a risk factor for future insomnia in women. Maintaining higher or increasing levels of leisure-time physical activity over the ten-year period partly protected from self-reported insomnia, independent of psychological distress, age, change in BMI, smoking, alcohol dependence, snoring status and level of education.

Contrary to the long-term effects of physical activity on snoring, this thesis did not confirm an acute effect from exercise on snoring. Single bouts of aerobic exercise did not lead to an acute effect on snoring during the following nights in the studied individuals. However, a pronounced night-to-night variation in snoring was identified, which should be accounted for when planning the duration of the assessment of snoring in clinical work and future research.

Essential barriers and facilitators for eating behaviour change according to individuals with obesity and OSA were identified. To the best of our knowledge, perceived low susceptibility and a challenged self-image have not previously been documented in scientific qualitative studies as a barrier and facilitator in individuals with obesity. Hence, these findings add to the knowledge about targets for future eating behaviour change interventions.

Implications for clinical practice

In clinical practice, strategies based on a BSM perspective have great potential when patients seek help for snoring and insomnia. Knowledge about scientifically documented facilitators and barriers may facilitate behaviour analysis and individual support for eating behaviour change.

Physical activity should be recommended to women who snore or suffer from insomnia. The dose response effect of physical activity on snoring and insomnia suggests an increased effect from higher intensity and/or duration.

Due to the large night-to-night variation of snoring in some individuals, sleep registrations aiming at assessing snoring should be performed on several consecutive nights. The subjective perception of snoring should be included in the overall assessment to ensure correspondence with the patient's experience.

Implications for future research

As the results of this thesis suggest that physical activity is causally associated with both snoring and insomnia, future research should focus on understanding the mechanisms behind these associations.

In this thesis, no acute effect was found of aerobic exercise on snoring. Therefore, an intervention study should examine the effects of exercise on participants with snoring. To allow for analysis of the impact of exercise on snoring over time, measures should be conducted at baseline, one week, 12 weeks and at six-month follow-up. Including measures suggested to be mechanisms behind the effect of physical activity on snoring would increase knowledge about these associations.

To make this part of a more integrated BSM approach for managing snoring and insomnia, studies should examine strategies for promoting interventions aiming at initiation and maintenance of healthy eating behaviour and physical activity in these patients. The results of this thesis have guided patients with OSA and overweight or obesity to healthier eating in a recent study.[142] Along with a selection of well-defined behavioural change strategies, these facilitators and barriers should be included in the intervention. The use of well-defined strategies would allow for evaluation and replication of the effective elements of treatment to achieve healthy eating and increased physical activity.

Finally, public health recommendations including a BSM approach on how to manage snoring and insomnia would be of great importance.

Svensk sammanfattning

Sömnrelaterade andningsbesvär och sömnsvårigheter är vanliga problem, som ökar risken för sjukdom. Det övergripande syfte med denna avhandling var att undersöka hur ett beteendemedicinskt perspektiv kan bidra till behandlingen av sömnrelaterade andningsbesvär och sömnsvårigheter. Faktorer som kan vara viktiga för ändrade matvanor samt effekterna av fysisk aktivitet undersöktes.

Metoder: Semistrukturerade intervjuer av deltagare med obstruktiv sömnapné och fetma (n=15) analyserades med en kvalitativ innehållsanalys i studie I. En kvinnlig kohort svarade vid två tillfällen, med tio års intervall, på en enkät och svaren från deltagarna analyserades i studie II och studie III (n=4851 respektive n=5062). I studie IV genomfördes en serie av experimentella fallstudier på typiska vanemässig snarkare (n=5). Effekten av aerob träning på snarkningsmönstret efterföljande natt studerades. Studien pågick över nio dagar och nätter.

Resultat: Underlättande faktorer och hinder för att ändra matvanor identifierades (studie I). Hos kvinnor var en låg nivå av fysisk aktivitet på fritiden en riskfaktor för att utveckla snarkning i framtiden, oberoende av vikt, viktökning, alkoholberoende och rökning. Höga nivåer eller ökad nivå av fysisk aktivitet under tioårsperioden hade en skyddande effekt på snarkning (studie II). Vidare är låg självrapporterad fysisk aktivitet på fritiden en riskfaktor för sömnsvårigheter i framtiden. Höga nivåer eller ökad nivå av fysisk aktivitet på fritiden hade en skyddande effekt på sömnsvårigheter oberoende av psykisk ohälsa, ålder, viktförändringar, rökning, alkoholberoende, snarkning och utbildningsnivå (studie III). Ett enskilt aerobt träningspass gav ingen effekt på snarkning den efterföljande natten hos de studerade individerna. Emellertid, identifierades en uttalad variation i snarkningen mellan nätterna (studie IV).

Slutsats: Kvinnor med sömnrelaterad andningsbesvär och sömnsvårigheter skulle gynnas av ett beteendemedicinskt behandlingsperspektiv med inriktning på fysisk aktivitet i sjukdomsprevention och behandling av snarkning och sömnsvårigheter. Detta motiveras av de skyddande effekterna av fysisk aktivitet, som bekräftats i denna avhandling. Kunskapen ökades om underlättande och hindrande faktorer som kan testas i framtida interventioner för att ändra matvanor.

Acknowledgement

Stort tack till alla som har deltagit och varit involverade i att insamla data till studierna. Tack till er som har varit en del av min forskarutbildning och till er som har varit stöd i allt som inte har med jobbet att göra. Ni har alla bidragit till att de senaste sex årens jobb med avhandlingen har varit en stor upplevelse.

Framför allt tack till:

Pernilla Åsenlöf, för det sätt du har handlett mig genom hela forskarutbildningen. Låtit mig jobba på i dataanalys och manusskrivande för att själv få utveckla arbetet med stöd och råd allteftersom. Tack för att du gav mig möjligheten att få doktorera, det har verkligen varit kul.

Eva Lindberg för dina raka svar i handledning kring dataanalys och i själva skrivandet av manus. Inte minst har jag uppskattat att få dina idéer till hur man kan gå tillväga nerskrivna, med förklarande ritningar på papper. Dessa har fungerat utmärkt som stöd och påminnelse om hur vi resonerade vid just det tillfället.
Mimmie Willebrand för att du som handledare i början av min forskarutbildning, ställde upp till diskussioner omkring upplägget av avhandlingen.

Institutionen för Neurovetenskap, Fysioterapi, Uppsala Universitet under ledningen av biträdande prefekt, Cathrin Martin för att ha get mig möjligheten till att genomförare doktorandstudierna. Tack även till alla kollegor på fysioterapeut programmet för intresse i projektet. Tack för hjälp och engagemang i undervisningen på programmet, det är ett engagemang som smittar och gör det roligt att gå till jobbet.

Tack till personalen på enheten för lung– allergi och sömnforskning för ett mycket trevligt mottagande när jag har varit i de krokarna. Gun-Marie Bodman-Lund för hjälp till resebokning och positivt engagemang. Gunilla Hägg och Katarina Göthberg för all hjälp med att rekrytera deltagare i studie IV.

Karin Ersson för hjälp med och diskussioner omkring tolkning av sömnregistreringarna.

Jan-Erik Broman för att du delar med dig av din kunskap om sömn och dit engagemang i studie IV, som har smittat av sig och gjort att det var kul att sitta med tolkningen av EEG-kurvorna.

Tack Helena Igelström, Cathrin Martin, Malin Svensson, Jenny Theorell-Haglöw, Frida Rångtell, Jan-Erik Broman, Erna Sif Arnardottir för ett riktigt bra samarbete som medförfattare.

Stort tack alla doktorander vid institutionen för Neurovetenskap, Fysioterapi; Hanna Ljungvall, Hedvig Zetterberg, Christina Emilsson, Susanna Tuvemo Johansson, Ann Essner, Regina Bendrik, Ylva Åkerblom och tidigare doktorandkollegor Carina Hagman, Åsa Revenäs, Henrik Johansson, Mickael Andersson, Birgit Vahlberg, Sara Holm, Helena Igelström, Charlotte Urell och Annika Bring, för en unik miljö till att få vända tanker och funderingar i samt massa bra diskussioner.

Eva och Rolf för att ni alltid ställer upp när vi behöver hjälp, det är otrolig värdefullt.

Til min familie i Danmark. Tak for at i har støttet mig i at flytte til Uppsala, selvom det betyder at vi ikke ses så ofte.
Min Mor, Bente, fordi du alltid har sagt at jeg kunne hvis jeg ville, selv som barn, hvor motivationen ikke var så stor.
Min Far, Ole, for at du har lærte mig en masse om træning og din måde at se positivt på tingene og få det bedste ud af det hele, selv når det ser sort ud.
Min bror, Jakob, for at du altid er der, når der er behov for at snakke om alt fra stort til småt.

Min fru och käreste – stor tack för all hjälp, du har fått jobba på hemma. Nu är det klart och min tur att få vara hemma och se till du får tid att skriva klart din avhandling. Ellinor, du är den bästa som finns.

Min fantastisk fina Sander, Mira och Viggo. Det är så kul att komma hem och bli mött av er alla tre och få tänka på annat än jobbet. Ni är det viktigaste och finaste som finns.

Denna avhandling har delfinansierats med stöd från:

ALF medel, Vårdforskningsmedel Uppsala Universitet, Hjärtlungfonden, Bror Hjerpstedts stiftelse, Uppsala läns förening mot hjärt- och lungsjukdomar, Svensk Förening för Sömnmedicin och Sömnforskning

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Acta Universitatis Upsaliensis

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