Physical Activity and Eating Behaviour Changes in Patients with Obstructive Sleep Apnea Syndrome

HELENA IGELSTRÖM
This thesis aimed at developing and evaluating a tailored behavioural sleep medicine intervention for enhanced physical activity and healthy eating in patients with obstructive sleep apnea syndrome (OSAS) and overweight.

Participants with moderate or severe OSAS (apnea-hypopnea index ≥15) and obesity (Studies I-II) or overweight (Studies III-IV), treated with continuous positive airway pressure (CPAP) (Studies I-II) or admitted to CPAP treatment (Studies III-IV), were recruited from the sleep clinic at Uppsala University Hospital, Sweden. Semi-structured individual interviews were analysed using qualitative content analysis (Study I). Data on moderate-to-vigorous physical activity (MVPA) and sedentary time were collected with three measurement methods and analysed regarding the level of measurement agreement (Study II). Potential disease-related and psychological correlates for the amount of MVPA, daily steps and sedentary time were explored using multiple linear regression (Study III). Physical activity and eating behaviour changes were examined after a six month behaviour change trial (Study IV). A tailored behavioural sleep medicine intervention targeting physical activity and healthy eating in combination with first-time CPAP treatment was compared with CPAP treatment and advice on the association between weight and OSAS.

According to participants’ conceptions, a strong incentive is needed for a change in physical activity and bodily symptoms, external circumstances and thoughts and feelings influence physical activity engagement (Study I). Compared with accelerometry, the participants overestimated the level of MVPA and underestimated sedentary time when using self-reports (Study II). The participants spent 11 hours 45 minutes (71.6% of waking hours) while sedentary. Fear of movement contributed to the variation in steps and sedentary time. Body mass index was positively correlated to MVPA (Study III). The experimental group increased intake of fruit and fish and reduced more weight and waist circumference compared with controls. There were no changes in physical activity (Study IV).

The novel tailored behavioural sleep medicine intervention combined with first-time CPAP facilitated eating behaviour change, with subsequent effects on anthropometrics, but it had no effects on physical activity and sedentary time. Fear of movement may be a salient determinant of sedentary time, which has to be further explored in this population. The results confirm sedentary being a construct necessary to separate from the lower end of a physical activity continuum and highlight the need of developing interventions targeting sedentary behaviours specifically.

**Keywords:** Obstructive sleep apnea, physical activity, eating behaviour, sedentary time, health behaviour change

*Helena Igelström, Uppsala University, Department of Neuroscience, Physiotherapy, Box 593, SE-751 24 Uppsala, Sweden.*

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ISSN 1651-6206
urn:nbn:se:uu:diva-197595 (http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-197595)
To my family

“Change is a process, not an event”
Barbara Johnson
List of papers

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


Reprints of Papers I-III were made with the permission of the publishers.
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## Abbreviations

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<tr>
<td>AHI</td>
<td>Apnea-Hypopnea Index</td>
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<td>BMI</td>
<td>Body Mass Index (kg/m²)</td>
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<td>CPAP</td>
<td>Continuous Positive Airway Pressure</td>
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<td>ESS</td>
<td>Epworth Sleepiness Scale</td>
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<td>ESES</td>
<td>Exercise Self-Efficacy Scale</td>
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<td>IPAQ</td>
<td>International Physical Activity Questionnaire</td>
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<td>LPA</td>
<td>Low-intensity physical activity</td>
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<td>MADRS-S</td>
<td>Montgomery Asberg Depression Rating Scale, self-administered</td>
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<td>MET</td>
<td>Metabolic Equivalent</td>
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<td>MPA</td>
<td>Moderate-intensity physical activity</td>
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<td>MVPA</td>
<td>Moderate-to-vigorous-intensity physical activity</td>
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<td>OSAS</td>
<td>Obstructive Sleep Apnea Syndrome</td>
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<td>RCT</td>
<td>Randomised, controlled trial</td>
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<td>VPA</td>
<td>Vigorous-intensity physical activity</td>
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Introduction

A health behaviour is an overt or covert action undertaken by an individual in order to prevent, manage or relieve symptoms of illness and enhance health (1). Engaging in physical activity and maintaining a healthy diet are examples of common health behaviours, since these behaviours have been concluded to have a major impact on the incidence and progression of several chronic diseases, e.g. heart disease or cancer (2). However, initiating and maintaining a health behavioural change is a challenge. Motivation may be dramatically different depending on which behaviour is in focus and when in life the change is going to occur. Due to the variation in individual prerequisites for behavioural change, a treatment targeting health behavioural change has to be tailored according to unique factors of that individual (3). A behavioural change may therefore require several different strategies, both cognitive and practical, to initiate and maintain a new behaviour.

Behavioural sleep medicine is a growing area in the field of sleep medicine that focuses on the assessment and treatment of sleep disorders by addressing behavioural, psychological and physiological aspects that impede sleep (4). Since research has concluded that physical activity and/or healthy eating have beneficial effects on many sleep disorders, including obstructive sleep apnea, even these behaviours would benefit from being integrated into the field of behavioural sleep medicine.

Obstructive sleep apnea syndrome (OSAS)

Obstructive sleep apnea consists of partial (hypopnea) or total (apnea) occlusion of the air flow during sleep. This reduction in air flow causes desaturation and gradually imposes enormous stress on the body as it attempts to obtain oxygen. Blood pressure and heart rate rise and the autonomic system eventually forces the individual to gasp for air. Sleep apneas enhance the risk of developing hypertension and cardiovascular diseases, such as stroke or heart infarction. In addition, apneas cause fragmented sleep and sleep deprivation and increase daytime sleepiness. This sleepiness impacts not only the individual’s social life but also the risk of traffic accidents (5).

In investigations of potential obstructive sleep apnea, the breathing pattern during sleep is monitored. An apnea is defined as the cessation of air flow in nasal pressure for at least 10 seconds with continuing abdominal and
thoracic movements, while a hypopnea is defined as a ≥ 50% reduction in baseline air flow for at least 10 seconds in combination with an oxygen desaturation of ≥ 3% (6). From the sleep recording, an apnea-hypopnea-index (AHI), i.e. the mean number of apneas and hypopneas per hour of sleep, is derived. The prevalence of daytime symptoms in combination with an AHI of ≥ 5 is considered to represent obstructive sleep apnea syndrome (OSAS).

There is no single explanation for these occlusions in air flow, but, for different reasons, the soft tissue in the pharynx collapses during sleep. Most persons with OSAS have anatomically narrower airways, but the symptoms may not occur until other factors are added. One such contributory factor is weight gain. A weight gain of 10% increases the AHI by 32% (7). It is hypothesised that increased weight augments the load on the pharynx and thereby the occlusion of the airways. In addition, overweight in itself reduces chest wall compliance and increases airway resistance, contributing to a change in respiratory function (8).

Health behavioural change

Several theories and models have been developed to describe human behaviour and behavioural change. Some of the theories deal with the way behaviour is learnt, e.g. respondent learning, operant learning and social cognitive learning.

Respondent learning means learning by associating activities or contextual factors to a stimulus that concurrently elicits an automatic, biological response (9). For example, an individual experiencing intense chest pain during a bout of exercise will most definitely experience an automatic response of fear. This physical activity may eventually be associated with the experienced pain stimuli and the subsequent emotional response. So, the next time the individual encounters that particular physical activity or its contextual factors, he or she will experience fear, even without the presence of chest pain.

According to operant learning principles, behaviour is also driven by its antecedent cues and its consequences (10). Situational factors operate the behaviour and the consequences of the behaviour will have an effect on whether or not the behaviour is repeated each time the particular antecedents are present. Using our former example; the fear arousal may be interpreted as a negative consequence of physical activity and so, whenever the same situational factors (antecedents) are present, the likelihood of the behaviour (i.e. engaging in physical activity) being repeated is diminished. In the long run, this may elicit fear-avoidance behaviour.

Social learning (11) adds to the field the importance of modelling (observational learning) and the impact of internal mental states on behaviour.
Studies of the moderators and mediators for health behaviour change have identified factors of importance for successful behaviour change and self-management in chronic conditions. Theories relating to health psychology stress social, emotional and cognitive determinants of change and it is thus hypothesised interventions will benefit from addressing these factors (12). According to Social Cognitive Theory (SCT) (13), a theory of health psychology derived from social cognitive learning, expectations are crucial components for understanding human behaviour. An individual’s behaviour is determined in particular by the person’s belief about the consequences that impact behaviour, not only the actual positive or negative consequences in themselves. To enhance self-management and behavioural change, beliefs that one’s behaviour will result in a favourable outcome (outcome expectations) and beliefs that one is able to perform specific behaviours leading to this outcome (self-efficacy beliefs) are crucial (14).

In addition to behavioural learning and social cognitive aspects of behaviour, the constructs of self-determination and self-regulation have attracted a great deal of attention. Self-determination refers to the fact that a behaviour is changed depending on the type of motivation (or lack of motivation). Deci & Ryan (15) state that a behaviour is performed from either controlled or autonomous motivation. A behaviour performed in order to achieve an external goal or reward requires more control in the individual; in other words, the behaviour is driven by controlled motivation. When a behaviour is performed for its own sake, or to obtain an internal reward such as joy or satisfaction, the motivation has been internalised. The behaviour is therefore performed autonomously (autonomous motivation) (15).

However, high motivation is not sufficient for behavioural change to occur. In a meta-analysis of interventions addressing both intention and behaviour performance (16), a gap has been reported between intention to change behaviour and actually performing the behavioural change. The meta-analysis revealed that a medium-to-large change in intention only leads to a small-to-medium change in behaviour (16). Maintaining a behavioural change thus entails not only motivation or intention but also self-regulatory skills (e.g. goal setting and action planning) and self-efficacy for initiating and maintaining change (17). According to Sniehotta et al. (18), the concept of self-regulation refers to “individuals’ efforts to avoid spontaneous learned, habitual, or innate responses to situational cues and to act in an intentional way” (p.566). According to a review by Williams and French (19), interventions containing behavioural change techniques, such as action planning and time management, produced significant increases in physical activity compared with interventions that did not use these techniques. In a meta-regression on interventions targeting healthy eating and physical activity, it was reported that interventions combining self-monitoring of behaviour with at least one other self-regulating behavioural change technique were significantly more effective than other interventions (20).
In this context, it is worth highlighting the difference between *behaviour change trials* and *health outcome trials*. The former explicitly aim to study the effect of intervention on the behaviour itself (e.g. physical activity), while the latter study the effect of the behavioural change on different health outcomes (21), e.g. OSAS severity. In order to elaborate potent interventions targeting physical activity and healthy eating and study their effect on OSAS, it is essential to study the effects of the included behaviours per se.

**Behavioural sleep medicine**

To date, the most effective treatment for reducing the sleep apneas is continuous positive airway pressure (CPAP) (22). When sleeping, the person wears a mask connected to a machine providing a constant air flow which in turn keeps the airways open and enables sufficient oxygenation. In addition to CPAP, there are alternative treatment modalities, e.g. oral appliances that enlarge the mouth cavity or positional therapy for those that only suffer from apneas in certain positions. In addition to these different treatments, patients are recommended to reduce weight and enhance physical activity. Regardless of the treatment, whether it is initiating CPAP or oral appliances, changing sleeping position, or modifying your activity pattern and eating habits, they all demand a change in the patient’s behaviour. Through the addition of behavioural and psychological ingredients to the interventions, the field of research has expanded the treatments for different sleep disorders, e.g. a higher adherence to CPAP treatment in patients with OSAS (23, 24).

To date, most research on correlates (factors associated with the behaviour) or determinants (factors with a causal relationship) for behavioural change in the OSAS population has focused primarily on adoption of, adherence to and maintenance of CPAP treatment. The field has expanded to comprise not only disease-related determinants, such as the level of disease severity, but also psychological determinants, such as CPAP usage self-efficacy (25), personality characteristics (26) and perceived health risk and outcome expectations of behavioural change (27). A review of intervention trials for improved CPAP adherence has reported that interventions with a cognitive behavioural approach are beneficial (28).

However, even though physical activity and healthy eating have been reported to have beneficial effects on sleep disorders, especially obstructive sleep apnea, these health behaviour changes are not traditionally targeted in behavioural sleep medicine. Most intervention studies targeting weight loss in patients with OSAS have been health outcome trials assessing the effect on OSAS. The studies included intervention strategies of different types, such as group/social support (29-31), motivational interviewing (32), cognitive behavioural therapy (33), identification of personal and environmental influences on eating behaviour and physical activity (30) and self-monitoring.
of behaviour performance (31, 33). However, these health outcome trials did not report the effects on the target behaviours i.e. the eating and physical activity behaviours.

**Physical activity**

Physical activity in itself has many positive physical outcomes, such as enhanced maximum oxygen uptake ($VO_2 \text{ max}$) and muscle strength. Through its positive effects on blood pressure and the stroke volume of the heart, for example, physical activity also reduces the risk of cardiovascular diseases (34). In addition, physical activity increases energy expenditure and appears to redistribute the proportions of fat mass and fat-free mass (35), both of which are valuable in the treatment of overweight.

Recommendations set by American College of Sports Medicine (ACSM), Centres for Disease Control and Prevention (CDC) and the American Heart Association (AHA) in 2007 (36) state that, in order to maintain health and prevent chronic diseases, healthy adults should engage in moderate-intensity physical activity for at least 150 minutes a week, equivalent to 30 minutes five days a week. Moderate intensity can be described as the intensity at which the heart rate is elevated and the exertion is somewhat strenuous, but a conversation can still be conducted. As an alternative to 150 minutes of moderate-intensity physical activity, people can engage in high-intensity activity three times a week with a duration of at least 20 minutes. This approach is appealing, as it leaves it up to the individual to choose an activity with the most suitable intensity, duration and frequency.

In the above-mentioned recommendations and also in a newly published report (37), it is emphasized that the equivalent of 60 minutes five days a week of moderate physical activity (i.e. 300 minutes/week) should accumulate in order to reduce weight. However, in obese individuals with a very low maximum oxygen uptake, a higher relative oxygen cost is demanded causing an increase in perceived exertion (38). Exercise are prone to be experienced as involving more exertion when performed at imposed compared to self-selected intensities (39). Physical activities may therefore be more enjoyable if the type and speed are self-selected and fitted to the individual’s oxygen uptake capacity.

During the last 10-15 years, the relationship between the dose of physical activity and response in terms of the risk of premature death, for example, has been studied intensely. There are indications that the recommended amount of moderate physical activity does not have to be performed all at once but can instead be split into bouts of at least 10 minutes, since this has been proven to be as effective as the former (36). This set-up may indeed make things easier for many people incorporating physical activity into their everyday lives. In addition, a recent cohort study in Taiwan concluded that,
compared with inactive individuals, those who were physically active for a daily average of 15 minutes had a 14% lower risk of all-cause mortality and that every additional 15 minutes beyond the minimum amount of 15 minutes a day further reduced mortality by 4% (40).

Correlates of physical activity
However, to initiate and maintain a change in physical activity, people’s readiness to make this change will truly impact their engagement (41), as will their current motivation and their trust in their own ability (i.e. self-efficacy) to be physically active (42, 43). Individuals perceive different factors as hindering or facilitating physical activity. Lack of motivation, energy or time might be perceived as hindering engagement in physical activity, together with anxiety or depression (44). Persons who are not yet ready to change or who are preparing for a change usually perceive more hindering factors and have lower self-efficacy for physical activity than those already in action (44). Daytime sleepiness (45) and an inclining body mass index (BMI) (46-48) have been reported to be associated with a lower physical activity level and, among people with obesity, fear of injury before and one year after gastric by-pass has been reported to predict physical activity two years after surgery (49). In addition, there are several factors that contribute to the variation in physical activity, but that cannot be affected. Age, ethnic origin and gender, for example, have been reported to correlate with the amount of physical activity (43).

So, when helping clients to take action, the intervention may benefit from targeting the modifiable factors that have been reported to impact behavioural change. In other words, in addition to the duration, frequency and intensity of physical activity, it is necessary to incorporate the individual’s thoughts and feelings towards physical activity and his/her perceived hindering and facilitating factors; the whole physical activity behaviour.

Physical activity in OSAS
Studies report that regular physical activity reduces the severity of OSAS symptoms - even without changes in weight or anthropometric measurements (50-53). The mechanism behind this positive effect remains unclear, however. In addition to the fact that exercise may induce weight loss and therefore reduce obstructive events during sleep (54), there are different hypotheses on the way enhanced physical activity can reduce OSAS symptoms. One explanation is that physical activity has positive effects on the respiratory drive through enhanced chemoreceptor sensitivity (55) and more efficient muscle tone in the upper airway (50, 51). Other explanations relate to metabolic factors, especially inflammatory cytokines (e.g. IL-6, and TNF-α), all of which are potential mechanisms of OSAS because of its systemic
interactions (56, 57). These cytokines are elevated in obesity but also in OSAS, regardless of weight (58). Altered cytokines are thought to cause excessive daytime sleepiness (58) and to cause airway collapse through upper airway inflammation in dilator muscles (56). There are thus hypotheses that exercise may change cytokine quantity and profile (57) and thereby reduce daytime sleepiness (58).

In the research field of OSAS, physical activity has mainly been used as a confounder for OSAS (59) or as a predictor of sleepiness (60). There are few studies that report the amount of physical activity in terms of steps, or type, duration, frequency or intensity – each of which is an aspect of interest in interventions aiming to enhance physical activity. Rather, the physical activity is often presented in categories (e.g. low, medium, high) or in hourly arbitrary activity units (61). To date, there are three studies reporting accelerometer-assessed physical activity presented in steps, for example. People with OSAS have been reported to take a daily average of about 7,000 steps (62, 63), which is similar to the number of daily steps reported in a normal weight and overweight (but not obese) US population (47). Diamanti et al., however, reported a substantially lower daily average of about 3,000 steps/day both before and after six months of CPAP treatment (64). In that study, another accelerometer was used, potentially explaining the deviating numbers.

There are only few studies reporting correlates of physical activity in patients with OSAS. Accelerometer-assessed physical activity has been reported to reduce with increasing OSAS severity (measured by AHI) when controlling for age, BMI (63), gender and daytime sleepiness (62). Among people under investigation for potential OSAS, the majority have been described as being in the pre-action stages of exercise and higher self-reported self-efficacy for exercise was associated with higher self-reported physical activity level, regardless of BMI and AHI (65).

There are therefore very few studies describing the amount of physical activity in people with OSAS and, in particular, the issue of correlates of physical activity has to be further explored in this population.

Sedentary time

The term “sedentary time” comprises low levels of energy expenditure and encompasses primarily sitting activities, such as TV viewing or reading (66). The impact of the amount of sedentary time has been studied (e.g. (67, 68) and there are significant associations between the amount of sedentary time, time spent on light-intensity activity, mean activity intensity and waist circumference and metabolic risk factors (68). These findings are independent of the amount of time spent on moderate-to-vigorous-intensity activity (68).
However, being inactive or sedentary should not be seen as the opposite of being physically active. There are instead studies pointing to the fact that inactivity in itself has negative effects and in particular prolonged and uninterrupted sedentary time appears to be important. In another study, Healy and colleagues (69) examined patterns of sedentary time and physical activity, focusing especially on the impact of the duration of the sedentary time. They discovered that people who took more breaks in sedentary time (e.g. standing up or walking around) scored better for metabolic risk variables, particularly adiposity measures (e.g. BMI and waist circumference), triglycerides and 2-h plasma glucose. This finding was independent of the total amount of time spent while sedentary, moderate-to-vigorous-intensity physical activity and also independent of the mean intensity of the breaks (69). One possible mechanism behind these associations could perhaps be found in cellular and molecular physiology. Lipoprotein lipase, LPL, an enzyme essential for the hydrolysis of the triglyceride held in lipoproteins, has been found to be a piece in the puzzle of evolving metabolic diseases such as obesity and type II diabetes. During inactivity, the level of LPL is reduced and the lipoprotein metabolism is thereby constrained, leading to increased triglycerides (70). This new inactivity physiology highlights the importance of minimising prolonged sedentary time and accumulating as many minutes of muscular activity throughout the day as possible. These kind of regular, non-fatiguing muscle contractions contribute to optimal LPL activity and thereby minimise metabolic risk factors. In other words, a sufficient amount of moderate-to-vigorous physical activity is not enough to maintain health, but the amount and duration of sedentary time also has to be addressed.

Depending on definition of sedentary time and measurement methods, the resulting numbers on sedentary time may vary. Using a self-report questionnaire, a median sitting time of five hours a day has been reported in the general Swedish population (71), while accelerometer assessed sedentary time has been reported to a daily average of 7 hours 39 minutes (48). The field of sedentary time is relatively new and there is therefore a need for further exploration of potential correlates and determinants. Depressive symptoms appear to increase sedentary time (72), as do increasing BMI (46, 47) and the amount of TV viewing (73). A low educational level has been reported to influence the amount of TV viewing (i.e. one type of sedentary activity) (74) but in people with high education a higher total sitting time has been reported (71).

Sedentary time in OSAS

Two recent studies have reported the amount of sedentary time in persons with OSAS. Diamanti et al. (64) reported a daily average of about nine hours of time spent lying down, both before and after six months of CPAP treatment. In a study by Verwimp et al. (63), about eight hours were spent lying
down. In both these studies, however, it is unclear whether the time spent lying down was recorded during waking hours or not and it is therefore still uncertain how much time people with OSAS spend while sedentary when they are awake. In addition, among persons with OSAS, there is so far no information on correlates or determinants of sedentary time.

Assessing physical activity and sedentary time

An entity frequently used for grading the intensity of physical activity is metabolic equivalents, METs, derived as multiples of oxygen consumption at rest (1.0 METs). From this, it has been stated that a physical activity of 1.6-2.9 METs is classified as low-intensity (75), 3-6 METs as moderate-intensity and > 6 as high-intensity physical activity (36, 76). When assessing a person’s physical activity or sedentary time, there are different types of measurement to choose from. The most commonly used are self-reports. A well-known drawback with these kinds of self-report is that they are dependent on the reporting person’s memory, sincerity and the type of definition that is used for physical activity (77). Other ways to assess a person’s physical activity level is to use some kind of activity monitor, e.g. pedometers or accelerometers. Self-report measurements of physical activity often generate higher values than those from objective measurements (78). There are different types of accelerometer, most of which register movement (through acceleration round one or two axes), count the number of steps taken, register body position and combine it with the registered skin temperature in order to report the total energy expenditure or time spent at different intensity levels, i.e. MET levels (79). The accelerometer can therefore also measure sedentary time, which is usually defined as the equivalent to energy expenditure while sitting quietly, up to 1.5 METs (75).

In several studies assessing physical activity level in persons with OSAS, different kinds of questionnaire have been used (e.g. (59, 80). There are some published data on physical activity in this group measured with an accelerometer (61-64) and to date, there is still a need to broaden our knowledge of both physical activity behaviour and sedentary time in persons with OSAS. In addition, there are a variety of measurement methods for physical activity and sedentary time and, in order to choose a valid measurement method, it is of interest to study whether the different methods are interchangeable. The level of agreement between some of these measurement methods has been evaluated in different populations (81, 82). However, to our knowledge, no such study has been performed in the population of OSAS.
Eating behaviour

According to Swedish Nutrition Recommendations (83), a healthy diet comprises a regular meal order, i.e. breakfast, lunch, dinner and possibly two to three snacks between meals. A daily intake of at least 500 grams of vegetables and fruit, polyunsaturated fatty acids instead of fatty acids and the intake of dietary fibre such as whole meal bread instead of white bread are also recommended (83). Overweight has a multi-factorial origin, such as genetic factors, disease or medically induced weight gain (84). Sleep deprivation has been reported to reduce energy expenditure (85) and up-regulate thyroid hormones and glucocorticoids (86), which in the long term may contribute to weight gain. However, a disturbed energy balance has the most detrimental impact on weight gain, i.e. an unfavourable or skewed food intake in combination with insufficient physical activity (87). For weight reduction purposes, a daily amount of about 300-1,000 calories, depending on the individual’s BMI, should be deducted from the individual’s expected energy expenditure (84). In other words, in order to ensure healthy eating and weight loss, not only the total energy intake but also the daily meal structure and its macronutrient components should be targeted.

Treatments focusing on a change in food intake vary from altering the individual’s habitual eating patterns, to low or very low calorie diets (i.e. liquid meal replacements), medication and bariatric surgery. Increased physical activity is often included in the treatment, mainly due to its contribution to enhanced energy expenditure. However, not all patients tolerate or are willing to undergo treatment with meal replacements, medication, or surgery and interventions which have an effect on individuals’ habitual eating and physical activity level are therefore needed, especially among people with OSAS. Weight loss interventions based on theories of behavioural learning or behavioural change aim at permanently changing eating behaviour, with weight loss, disease prevention and improved health as the health outcome goals (88).

During the past few years, randomised, controlled health outcome trials of weight reduction have been reported to reduce the severity of OSAS (29-31, 33). Even though the studies differed regarding OSAS severity, gender and BMI, they all concluded that weight loss has a positive effect on OSAS. However, these studies all comprised a low or very low calorie diet at varying levels, which are not an alternative for all patients in the clinical population of OSAS. The performed RCTs were designed as health outcome trials and therefore did not analyse the effect on physical activity and/or eating behaviours per se. Most of the interventions were delivered in group format (29-31) and some of them included behavioural change techniques, such as the self-monitoring of behaviour in the study by Johansson et al. (30). However, other techniques and ways of delivering the interventions have to be studied.
Rationale for the thesis

Earlier randomised, controlled health outcome trials have shown that weight loss has a clear effect on OSAS severity (29-31), but there is still a need for behavioural change trials, i.e. studies of how physical activity and eating behaviours are affected by interventions targeting these behaviours. Our research programme has behavioural sleep medicine as its starting point, integrating biomedical, psychological and social aspects in the process of health behavioural change. An underlying assumption is that behavioural change is an individual process comprising various prerequisites for each individual when initiating and maintaining a behavioural change. Physical activity and its correlates have been studied in many groups of patients and sedentary time is on the rise, but, in the OSAS population, the knowledge is still scarce. In order to affect physical activity and eating behaviours in patients with OSAS, the knowledge has to be expanded on individual conceptions on prerequisites for behavioural change, assessments and the impact of individually tailored behavioural sleep medicine treatments.

Aims

The overall aim of the thesis was to develop and evaluate a tailored behavioural sleep medicine intervention for enhanced physical activity and healthy eating in patients with OSAS and overweight.

The specific aims of the studies included in this report were as follows.

Study I
To explore the participants’ conceptions of influences on engagement in physical activity

Study II
To study the level of agreement between three different measurement methods for the daily amount of time spent on moderate-to-vigorous physical activity and time spent while sedentary respectively

Study III
To describe the amount of physical activity and sedentary time in patients with OSAS and overweight and to explore potential disease-related and psychological correlates
Study IV

To evaluate the effects on physical activity and eating behaviour of a tailored behavioural sleep medicine intervention combined with first-time CPAP treatment, compared with first-time CPAP treatment and advice. Further, the aim was to study the effects of the interventions on sedentary time and anthropometric values.
Methods

Design
The thesis comprises four studies based on three samples (Table 1). All the studies have been approved by the Regional Ethical Review Board, Uppsala; Study I: EPN D-nr 2008-030, Study II: EPN D-nr 2008/313 and Study III-IV: EPN D-nr 2009/004. The intervention trial was registered at ClinicalTrial.gov on 12 April 2010 (clinical trial number: NCT01102920).

Participants and procedures
An overview of sample sizes and inclusion criteria is given in Table 1. One exclusion criterion in all the studies was an insufficient knowledge of the Swedish language. In Study II, people with squelae after stroke, known atrial fibrillation, severe heart failure or other symptomatic heart disease were also excluded. In Studies III-IV, persons with a self-reported leisure-time physical activity of ≥ 30 minutes of moderate physical activity, five days a week for ≥ 3 months were excluded, as were persons non-ambulatory and persons with symptomatic heart disease despite medication. For an illustration of participants’ characteristics at inclusion in the studies, see Table 2.

Study I
Between April and October 2008, eligible patients were asked to participate by their physician. A research assistant contacted the patient by phone and, if oral consent was given, he/she was scheduled for an interview. Recruitment and data collection took place concurrently. On the basis of the experience from the interviews and field notes taken during the interviews, the researchers performed a preliminary analysis to see whether new information emerged in each interview (89). Patients were recruited until no more information appeared to emerge. In order to capture a broad spectrum of experiences, the sample was also checked for heterogeneity in terms of age, gender, time with OSAS, as well as self-reported readiness for change in physical activity.
Table 1. Overview of the studies: study designs, sample sizes, data collection, physical activity and sedentary indices and data analyses.

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<th>Study I</th>
<th>Study II</th>
<th>Study III</th>
<th>Study IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design</strong></td>
<td>Qualitative</td>
<td>Cross sectional, descriptive and correlational</td>
<td>Cross sectional, descriptive and correlational</td>
<td>Randomised, controlled behaviour change trial</td>
</tr>
<tr>
<td><strong>Sample size</strong></td>
<td>15</td>
<td>39</td>
<td>73</td>
<td>73</td>
</tr>
<tr>
<td><strong>Inclusion criteria</strong></td>
<td>AHI &gt;15</td>
<td>Obesity</td>
<td>AHI &gt;15 and daytime symptoms</td>
<td>Admitted for first-time CPAP treatment</td>
</tr>
<tr>
<td><strong>Data collection</strong></td>
<td>Semi-structured individual interviews</td>
<td>Accelerometry on daily average of MVPA and sedentary time (5 days)</td>
<td>Accelerometry on daily average of MVPA and sedentary time (4 days)</td>
<td>Accelerometry on daily average of MVPA, steps and sedentary time (4 days)</td>
</tr>
<tr>
<td><strong>PA and sedentary indices</strong></td>
<td>n.a</td>
<td>MVPA ≥ 3 METs in bouts of ≥10-minutes</td>
<td>MVPA ≥ 3 METs</td>
<td>MVPA ≥ 3 METs</td>
</tr>
<tr>
<td><strong>Data analysis</strong></td>
<td>Latent and manifest content analysis</td>
<td>Bland-Altman analysis</td>
<td>Multiple linear regression</td>
<td>Student’s paired t-test</td>
</tr>
</tbody>
</table>

Notes:  
ACSM = American College of Sports and Medicine, AHI = apnea-hypopnea index, CPAP = continuous positive airway pressure, IPAQ = International Physical Activity Questionnaire, LPA = low-intensity physical activity, METs = Metabolic equivalents, MVPA = moderate-to-vigorous-intensity physical activity, PA = Physical activity
Table 2. Participants’ characteristics in the studies. The results are presented as the mean ± standard deviation, median (interquartile range), or in numbers (%).

<table>
<thead>
<tr>
<th>Participants’ characteristics in the studies</th>
<th>Study I</th>
<th>Study II</th>
<th>Studies III-IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>57 ± 10</td>
<td>57 ± 12</td>
<td>55 ± 12</td>
</tr>
<tr>
<td>BMI</td>
<td>38.1 ± 5.7</td>
<td>36.1 ± 4.3</td>
<td>35 ± 5</td>
</tr>
<tr>
<td>Time with OSA, months</td>
<td>24 (48)</td>
<td>18 (18)</td>
<td>2 (5)</td>
</tr>
<tr>
<td>Time with CPAP, months</td>
<td>12 (44)</td>
<td>10 (8)</td>
<td>n.a</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>8 (53.3 %)</td>
<td>32 (82.1 %)</td>
<td>58 (79.5 %)</td>
</tr>
<tr>
<td>Females</td>
<td>7 (46.7 %)</td>
<td>7 (17.9 %)</td>
<td>15 (20.5 %)</td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married/cohabiting</td>
<td>9 (60 %)</td>
<td>28 (71.8 %)</td>
<td>58 (79.5 %)</td>
</tr>
<tr>
<td>Living alone</td>
<td>6 (40 %)</td>
<td>11 (28.2 %)</td>
<td>15 (20.5 %)</td>
</tr>
<tr>
<td>Occupation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working</td>
<td>10* (66.7 %)</td>
<td>25** (64 %)</td>
<td>52 (71.2 %)</td>
</tr>
<tr>
<td>On sick leave or sickness benefit, full time</td>
<td>2 (13.3 %)</td>
<td>1 (2.6 %)</td>
<td>3 (4.1 %)</td>
</tr>
<tr>
<td>Retired</td>
<td>3 (20 %)</td>
<td>12 (30.8 %)</td>
<td>17 (23.3 %)</td>
</tr>
<tr>
<td>Unemployed</td>
<td>0 (0)</td>
<td>1 (2.6 %)</td>
<td>1 (1.4 %)</td>
</tr>
</tbody>
</table>

Note: * whereof 1 was on part-time sickness benefit, ** whereof 3 were on part-time sick leave, n.a = not applicable

Study II
Eligible patients were consecutively recruited between January 2009 and March 2010. They were contacted with a written inquiry about participation, together with an appointment for follow-up sleep registration. Persons interested in taking part were contacted by a physiotherapist (HI) and scheduled for two visits to the hospital. The participants met the physiotherapist individually on two occasions within six to ten days. On the first visit, the participant filled out a written consent, had his/her weight and height measured and answered background questions and the International Physical Activity Questionnaire, IPAQ. The participant was then informed about the accelerometer and the device was applied. He/she was then given information about the logbook and time was allotted for the participant to try it out. During the following week, the participant wore the accelerometer and concurrently made daily notes in his/her logbook regarding physical activities and sitting time. The accelerometer was worn for five to seven consecutive days and nights, including at least one weekend day, with the only exception for activities that could make the accelerometer wet or that could involve the device being hit hard. On the second visit to the hospital (6-10 days later), the participant returned the accelerometer and the logbook and once again filled out an IPAQ.
Studies III-IV

The participants in Studies III-IV originate from a two-armed, randomised, controlled health outcome trial evaluating the effects on OSAS following a behavioural sleep medicine intervention targeting physical activity and eating behaviour changes in conjunction with first-time CPAP treatment. In this RCT, sleep recordings and measurements were performed at baseline (before CPAP treatment), post-treatment (6 months) and follow-up (18 months), plus one additional measurement mid-treatment (3 months). Study IV is a behavioural change trial studying the effects of the intervention on the target behaviours of physical activity and eating and, additionally, sedentary time, weight, BMI and waist circumference, using data from baseline and 6 months.

Between March 2010 and March 2012, eligible patients matching the criteria were asked by their physician or by mail about participation. All the patients had met a clinician experienced in sleep medicine who had evaluated their overnight sleep recording in conjunction with their symptom profile. Patients interested in taking part were contacted by phone by a physiotherapist (HI) and, if oral consent was given, they were contacted by a research nurse to schedule baseline measurements. On the first visit, the participant filled out a written consent, had his/her waist circumference, weight and height measured and answered background questions. The participant then filled out questionnaires on daytime sleepiness, exercise self-efficacy, fear of movement and depressive symptoms as well as questionnaires on food frequency and eating style. The participant was then informed about the accelerometer and the device was applied. The accelerometer and logbook were used according to the same instructions as in Study II (see above) and were returned on the second visit to the hospital (about 10 days later). This assessment procedure was repeated six months after baseline and the research nurse was blinded to the participants’ study conditions on both occasions.

After the baseline assessment, each participant was randomly allocated to one of the two study conditions by a senior researcher not involved in the assessment procedures. The randomisation procedure was made in blocks of 10 using a random integer generator (www.random.org).

Assuming a medium-size relationship ($f^2 = 0.15$) between the correlates and moderate-to-vigorous physical activity (MVPA), steps and sedentary time, it was estimated that 91 participants would be an adequate sample size for multiple regression calculations of five independent variables (90) in Study III. For Study IV, 132 participants were calculated to be a sufficient sample size to detect a difference between groups of a daily average of 15 minutes of a MVPA. Fourteen participants would be sufficient to detect a difference of three points between groups regarding the total score for food intake frequency of vegetables, fruit, fish/shellfish and sweets. These power calculations were valid when $\alpha$ was set at 0.05 and $\beta$ at 0.20.
Setting
Participants in all the studies were recruited from the sleep clinic in Uppsala University Hospital in Uppsala, Sweden.

Interventions in Study IV

CPAP regimen and advice (control group)
The CPAP regimen included a diagnosis by a physician (consultant in lung medicine), who was familiar with the results of the initial whole-night sleep recording. All the patients were informed about the association between overweight and sleep apnea and about the aim of the CPAP treatment. They were all recommended to lose weight, but no behavioural goal setting, action plans, or functional behavioural analyses were provided. The patient then met a CPAP nurse and was taught how to use the CPAP device. The correct CPAP pressure was titrated by an auto-CPAP during a period of 5-14 nights at home. On a follow-up visit to the CPAP nurse, the patient received his/her own CPAP device. In clinical practice, the patients are then followed up with a whole-night sleep recording at home (with CPAP) after 12 months, followed by contact with either the physician or the nurse.

CPAP regimen and a tailored behavioural sleep medicine programme (experimental group)
The above mentioned CPAP regimen was provided. In addition, a behavioural sleep medicine intervention based on health psychology theories, e.g. Social Cognitive Theory (13), and the constructs of self-determination (15) and self-regulation (18) was applied. Tailored behavioural modification strategies to enhance physical activity and implement sound eating habits were applied in a stepwise manner. Eight to ten therapist-guided individual sessions were scheduled for the first six months, gradually reduced in frequency. Following the evaluation at six months, another four booster sessions took place during a period of nine months. However, the patients themselves managed the principal part of the treatment through homework assignments. The behavioural change activities were tailored to match identified preferences, goals and behavioural analyses (3), including OSAS-specific medical factors and individual risk perceptions, health beliefs, expectations and incentives for health behaviour change. Additional behavioural problem identification took place at regular intervals, goals were continuously stepped up and action planning was aimed at successively increasing self-management by the patient.
Description of the behavioural sleep medicine treatment components
The behavioural intervention comprised seven components, to be employed by each participant and in both physical activity behaviour and eating behaviour. Michie and colleagues have formulated a taxonomy for behavioural change techniques that are regarded as the “active ingredients” of interventions targeting behavioural change (91) and this taxonomy has been used as inspiration for the description below.

1. Preparation for action and motivational analysis
A dialogue was initiated with the patient about motivation to and self-efficacy for change in physical activity and eating habits. By asking open-ended questions and listening attentively, the therapists strove to evoke and strengthen the individual’s motivation to change and encourage the patient to explore his or her own perceptions and thoughts regarding the pending behavioural changes. An interview was conducted on current and past physical activity, current and past experiences of dieting and critical situations relating to food and eating. Information was provided about recommendations for physical activity according to ACSM (36) and for weight-reduction purposes (37). Additional information was given regarding the benefits of reduced sedentary time, e.g. by reducing prolonged sitting (68) and enhancing the amount of non-exercise thermogenesis (NEAT) (92). Information was also provided on the components and positive effects of sound eating habits, e.g. regular food intake, increasing the amount of vegetables and replacing saturated fatty acids with polyunsaturated fatty acids. An individual nutrition suggestion for a reduced calorie intake was calculated by deducting about 500 kcal/day from the estimated energy expenditure (84, 93). Patients were prompted to set an outcome goal, i.e. to specify what they wanted to result from enhanced physical activity and a healthy diet.

2. Goal setting (behaviour)
After a thorough examination of the individual’s prioritised physical activities and eating behaviours (including scoring self-efficacy for those activities), one specific activity was identified for each health behaviour and a S-M-A-R-T (Specific, Measurable, Achievable, Relevant and Time-limited) (94) goal was set for the week to come.

3. Action planning
The participants were asked to transform their intentions into an action plan for the physical activity and eating behaviour change in terms of when, where and how to act (95) for the next week. At every session, this procedure was repeated.
4. Self-monitoring
The participants were encouraged to self-monitor their physical activity behaviour and eating behaviour, in a diary, for example. The self-monitoring process is a self-regulatory strategy enhancing the individual’s awareness of the behavioural change in relation to his or her goals (96).

5. Review of behavioural goals, action plans and functional behavioural analysis
At each meeting, the behavioural goals and action plans of the patient were reviewed and feedback was given on performance, based on the patient’s verbal recall and the self-monitoring data. Functional behavioural analyses took place at each session and were performed in order to identify functional relationships between antecedents, behaviour and consequences in each individual. These analyses assisted in the identification of barriers and facilitators for behavioural change and cues for problem-solving (97). The result of the analysis was discussed with the patient and integrated into the action plan for the next week.

6. Barrier identification/problem-solving
At every session, the participants and therapists discussed perceived barriers (anticipated risk situations) that could constrain their planned actions for behavioural performance (95).

7. Maintenance and relapse prevention/coping planning
The patient was informed that relapses are common in the process of behavioural change (98). After about four months of treatment (approximately session 8), discussions on strategies for maintenance and relapse prevention were introduced. The discussion was completed with a written document on 1) personal reasons for continuing the initiated behavioural changes, 2) the individual’s new eating behaviours worth maintaining, 3) the individual’s new physical activity behaviours worth maintaining and 4) potential risk situations that could hamper their action plans.

Treatment fidelity
The dietician and the physiotherapist (HI) delivering the behavioural sleep medicine intervention in Study IV had completed formal university courses in behavioural medicine. To prepare for the study, the therapists worked with patients under the guided supervision of a senior researcher (P. Åsenløf) with long experience of behavioural medicine interventions. During the course of the study, the senior researcher held regular coaching sessions with the two therapists to guide them and to check for treatment fidelity. In order to guard against contamination between study conditions, the undersigned
researcher visited the CPAP reception repeatedly in order to inform the personnel about the importance of staying with the protocol, i.e. provision of information on the relationship between OSAS and weight but omitting advice on motivational and self-regulatory strategies.

The median number of sessions for all the participants in the experimental group was 9 (min 1, max 11). All the participants received the first component, *Preparation for action and motivational analysis*. Five patients declined participation in the intervention; three of them withdrew within the first 3 sessions and thus did not complete the components of *Self-monitoring* or *Goal setting (behaviour)*. The other two patients declined participation after 3 months but before the completion of *Maintenance and relapse prevention/coping planning*. Thirteen participants (36.1%) completed all seven components including *Maintenance and relapse prevention/coping planning* and 33 patients (91.7%) completed the first 6 components.

**Measures**

**Semi-structured interview (Study I)**

In *Study I*, data were collected through semi-structured individual interviews. A specific interview guide was created covering three content areas based on three health behaviour theories: 1) health perceptions and susceptibility derived from the Health Belief Model (99), 2) outcome expectations from the Social Cognitive Theory (13) and 3) facilitating and hindering factors for physical activity derived from the Transtheoretical Model of Stages of Change, TTM (98). Follow-up questions were used to further explore individual answers.

The interview guide was tested by the interviewer (P. Åsenlöf) and a research assistant with the first eligible participant. That informant perceived the questions as understandable and the interviewer found that this participant’s responses captured the research question and no further modifications were therefore made. Each interview took place at the Department of Neuroscience, Uppsala University. The interviews were audio-recorded and ranged in length from 25 to 60 minutes. Prior to the interview, the informants filled out a questionnaire on their demographics and current readiness to engage in physical activity (according to TTM).

**Accelerometry on physical activity and sedentary time (Studies II-IV)**

A Sensewear Pro 3 Armband (Body Media, Pittsburgh, PA), was used, in combination with the proprietary Sensewear Professional 6.1 software. The software adds up information from heat sensors, information on galvanic reaction and movement and acceleration round two axes. After combining the input data with the subject’s height, weight, gender and age, the software reports the data in terms of steps taken and time spent at different intensity
levels. The applications for the software were set at different MET intervals in order to classify sedentary and physical activity (see Table 1).

The armband has fairly good validity as it estimates energy expenditure within 16% of the values derived by indirect calorimetry (100) and the intra-class correlation (ICC) has been reported to be 0.80 against doubly labelled water (101). The device tends to underestimate energy expenditure during higher intensity activities, such as tennis, road running and track running (100, 101), but has been shown to overestimate energy expenditure in obese adults during cycle ergometry, stair climbing and treadmill walking (102). A test-retest of the ability of the device to estimate energy expenditure during two separate and structured 13-hour observations produced an ICC of $r = 0.97$ (103).

**Self-reports of time spent on physical activity and sedentary**

In *Study II* the *International Physical Activity Questionnaire, short version, (IPAQ)*, was used. The IPAQ is a seven-day recall regarding time spent sitting and the number of days and time spent on activities at different intensity levels (104). The respondent is asked to enter the daily average time spent sitting and the number of days and daily average time spent on “walking activities”, “somewhat hard activities” and “hard activities” respectively. Only activities of $\geq 10$ minutes are to be included (104). The IPAQ is reliable in test-retest regarding both physical activity ($r = 0.66-0.88$) and sitting time ($r = 0.71-0.95$) (104). The test as a whole has overall acceptable criterion-related validity ($r = 0.16-0.35$) against an accelerometer in a general Swedish population (82).

**Logbooks** were used in *Studies II-IV*. The logbook was produced for this project in which participants logged their daily time spent sitting and their physical activities, including type, time and duration of the physical activities in which they participated. They also rated their perceived exertion (according to Borg’s RPE 6-20 (105)) for every activity. Only activities of $\geq 10$ minutes were to be included. In *Study II* the logbook was used as a separate data collection method for physical activity and sedentary time. In *Studies III-IV*, the logbook was thus far only used to double-check whether the participant had engaged in any physical activities that involved removal of the accelerometer and were thus not captured by the device.

**Eating behaviour (Study IV)**

**Food frequency**

The Swedish National Board of Health and Welfare (NBHW) has formulated national guidelines for disease prevention (2). Questionnaires on lifestyle factors in order to facilitate the screening of individuals at risk of disease due to unhealthy choices in eating habits, physical activity, tobacco use and/or alcohol consumption are included as appendices. The questionnaire
ing habits used in this study is the preliminary version from 2010. The individual is asked to reflect on his/her eating habits in a normal week and mark one alternative for each of the four following questions:

1. How often do you eat vegetables and/or root crops (fresh, frozen or prepared)?

2. How often do you eat fruit and/or berries (fresh, frozen or prepared)?

3. How often do you eat fish or shellfish as your main course?

4. How often do you eat buns/cakes with coffee, chocolate/candy, chips or soda/cordial?

Every item included four categorical alternative answers which were scored from 0 (= once a week [item 1-2], a couple of times a month or more seldom [item 3]) to 3 (= twice a day or more often [items 1-2], three times a week [item 3]) but with a reverse score on item 4 ranging from 0 (= every day) to 3 (= a couple times a month or more seldom). A total score ranging from 0 to 12 points was calculated. A value of less than four points indicates unhealthy eating, while individuals scoring 9-12 points mainly stick to the Swedish Nutrition Recommendations (2).

Eating style
The Dutch Eating Behavior Questionnaire, DEBQ (106), is a self-administered questionnaire capturing how external and emotional factors impact on eating, and whether or not the individual restricts his or her eating. The scale comprises three subscales reflecting Restrained eating (items 1-10), Emotional eating (items 11-22, and 33) and External eating (items 23-32), with five alternative answers, each ranging from 1 (= never) to 5 (= very often). An average for each subscale on the DEBQ is calculated and a total score is derived by adding these three averages and dividing by the numbers of scales. On the subscales for Restrained eating and External eating, the minimum value is 1 and the maximum 5, while the values on the subscale for Emotional eating range from 1.3 to 6.5. The total score on the DEBQ ranges from 1.1 to 5.5.

Disease-related measures
Daytime sleepiness was measured with the Swedish version of the Epworth Sleepiness Scale, ESS (107), which was used in Study III. The individual scores relate to the risk of dozing off in eight different situations and the scoring was made on eight four-point scales with anchors 0 (= would never doze) and 3 (= high chance of dozing). The total sum score ranges from 0 to 24 points and scores above 10 indicate excessive daytime sleepiness (108).
Body Mass Index (BMI) was derived from weight (in kilos) divided by squared height (in metres) and rounded off to the nearest 0.1 kg/m². A BMI of 18.5-24.9 kg/m² is defined as normal, while < 18.5 is considered underweight, ≥ 25 overweight and > 30 as obesity (87).

Waist circumference (Study IV) was assessed with a tape measure midway between the lower rib margin and the iliac crest, with the patient standing in underwear. The figures were rounded off to nearest 0.5 cm.

Psychological measurements (Study III)

Self-efficacy for exercise was measured with the Exercise Self-Efficacy Scale, ESES (109). The individual scores are for confidence in engaging in physical activity in 18 specific and potentially hindering situations (110) and the scale was modified by Everett et al. (111) regarding response format. The scoring system included 18 numerical rating scales with anchors 0 (= not confident at all) and 10 (= highly confident) and the total score ranged from 0 to 180 points.

Fear of movement was assessed using selected parts of the Swedish version of the Tampa Scale of Kinesiophobia (112), originally developed to capture patients’ perceptions regarding fear of movement and (re)injury when in pain. A sub-set of the original 17 questions was chosen to reflect somatic domains, i.e. items not primarily focusing on fear of pain, yet capturing a potential fear of movement and included:

1. I’m afraid that I might injury myself if I exercise
2. My body is telling me I have something dangerously wrong
3. Pain always means I have injured my body
4. I am afraid that I might injure myself accidentally
5. It’s really not safe for a person with a condition like mine to be physically active
6. I can’t do all the things normal people do because it’s too easy for me to get injured
7. No one should have to exercise when he/she is in pain

Scoring took place on four-point Likert scales (1 = I do not agree at all, 4 = I totally agree), and the total score ranged from 7 to 28 points.

Mood and depressive symptoms were evaluated with the Montgomery Asberg Depression Rating Scale, MADRS-S (113). In this self-administered
questionnaire, the individual reflects on the questions for the previous three days. The MADRS-S consists of nine items reflecting common symptoms of depression ranging from 0 (= no symptoms) to 6 (= severe symptoms). The total score ranged from 0 to 54 points. A score of 0-6 indicates no depression, 7-19 mild depression, 20-34 moderate depression and > 34 severe depression (114).

Demographic and medical data (Studies I-IV)
The participants filled in questionnaires on civil state, education, occupation, diseases, medication and time with OSAS. For Studies I-II, the time on CPAP treatment was also requested.

Data management

Interview data (Study I)
The interviews were audio recorded and transcribed verbatim.

Management of accelerometer data (Studies II-IV)
For data to be considered valid, they had to contain at least five (Study II) or four days (Studies III-IV), preferably including one weekend day, with at least 10 hours of wear time and ≥ 90% of waking hours.

In Study II, we managed the data from the accelerometer in a way that would enable comparison with the two self-reports. Since the proprietary software could not be set to identify bouts with a specific duration, a visual analysis was made of the time axis in order to identify bouts of MVPA of ≥ 10 minutes. All MVPA for a total of at least 10 minutes within a 15-minute period was defined as a bout of MVPA. If the activity was interrupted by low-intensity activity for ≥ 2 minutes or by any sedentary time, however, that activity was not included as a bout. From these bouts, the group’s daily average minutes of MVPA was calculated.

The participants wore the accelerometer for both day and night and the proprietary software has a feature which classifies sleep through the diminished input from the different sensors. However, when looking at the collected data, all the time during the night that the software had not considered as sleep had been classified as sedentary time. So, in order to delimit sedentary time to only time awake, in Study II, an average of 7.5 h of sleep was subtracted from the identified total of sedentary time. In Studies III-IV, however, every individual’s time axes were visually analysed and all sleep regarded as night-time sleep was removed. In addition to the description of the number of minutes spent at different intensities, in Study IV, the proportion of time spent at different intensities in relation to total time awake was analysed and described in per cent.
In Study II, three participants had invalid data from the accelerometer and these persons were thus excluded from the analysis of agreement. In three cases, there were invalid data from the logbooks relating to the time spent sitting. When exploring the level of agreement, only those cases with complete data for both measurements in each calculation were included.

In Studies III-IV, the files on accelerometer data for five participants were inaccurately downloaded, resulting in no data. Five participants had valid accelerometer data but for less than four days. In the end, sixty-three participants had valid data from wearing the accelerometer for four days. For one participant, the missing accelerometer data for time off during water calisthenics were substituted with minutes at MET level, according to the Compendium of Physical Activities (115). The imputation technique of last observation carried forward was applied in cases without valid accelerometer data at the six-month follow-up (control group: n=8, experiment group: n=5).

Management of self-reports on physical activity and sedentary time (Study II)

International Physical Activity Questionnaire, IPAQ

The IPAQ recommendations on data cleaning and processing (116) were followed. In order to enable comparisons with other measurements in the study, MET minutes (time (minutes) x days x MET value) were not calculated. Instead, the three activity domains were combined and each individual’s daily average minutes of MVPA were calculated according to the following equation:

$$\text{Daily average of MVPA} = \frac{\text{Walking (time (minutes) x days)} + \text{Moderate (time (minutes) x days)} + \text{Vigorous (time (minutes) x days)}}{7 \text{ days}}$$

Figure 1. Calculation from IPAQ data of an individual’s daily average minutes of MVPA

Since it is not possible to distinguish certain days in the IPAQ, the data on MVPA and sitting were calculated for seven days (as intended) and thereafter a daily average was derived, followed by a total and daily average for five days. All the comparisons were based on the IPAQ from the second visit to the hospital. A t-test was made between the two performed IPAQs in order to identify potential differences. In two cases, data on MVPA were missing and these cases were therefore not included in the agreement analysis.
**Study-specific logbooks**

From the self-reported type of activity, its duration and accompanying exertion, each physical activity was classified into MET levels corresponding to the Compendium of Physical Activities (115). In ambiguous cases, the self-reported exertion for each activity concluded the classification of intensity level. Data used from the logbooks were only those days corresponding to the days of valid data from accelerometry. In three cases, there were invalid data from the logbooks regarding the time spent sitting.

**Management of data on eating habits (Study IV)**

Since there are no recommendations relating to how to impute missing values on the questionnaire from NBHW, a missing value at the assessment at six months was substituted according to last observation carried forward (control group: n=4, experimental group: n=1). Missing values on one of the subscales of the DEBQ (at baseline n=4, at 6 months n=3) were substituted with the median value of the subscale for that individual.

**Management of anthropometric data (Study IV)**

The imputation technique of last observation carried forward was applied in cases with missing anthropometric data at the 6-month follow-up (control group: n=3, experimental group: n=2).

**Descriptive statistics**

Descriptive statistics were used for demographic data in all studies. Categorical variables were presented as numbers and proportions (%). Continuous variables were presented as mean and standard deviation (SD). Ordinal data were presented as median and interquartile range (IQR) or minimum and maximum values, together with continuous data not normally distributed. In Study IV, descriptive statistics for clinically relevant changes in MVPA, steps, weight change and change in waist circumference were presented in numbers and/or per cent.

**Data analysis**

**Content analysis (Study I)**

The working process followed the guidelines for content analysis according to Graneheim and Lundman (117). The text was analysed in several steps, starting with dividing the text into content areas. In the present study, the content areas covered the three issues in the research questions: Health perceptions and susceptibility, Expectations of engaging in physical activity and Facilitators and barriers for physical activity. The analysis then continued with identifying meaning units that were condensed and labelled with a
code. All the codes in all the interviews were then abstracted into manifest categories and latent themes. The main author (HI) was responsible for the analysis, but detailed discussions took place on a regular basis with two or three other researchers (PÅ, CM, ME) regarding labelling and decisions made in the analytical process (researcher triangulation). In the end, eight categories that answered the research question emerged. As a last step in the process, two themes were created, which infer comprehensive names for the latent or implicit meaning of all conforming categories, sub-categories and codes (117).

**Agreement between methods (Study II)**
To analyse the agreement between methods, the Bland and Altman analysis and additional graphical plot were used (118, 119). The level of agreement was estimated between two measurements at a time which required four different calculations. Only those cases with complete data for both measurements in each calculation were included, resulting in 34 cases in the analysis between the accelerometer and the IPAQ and 36 and 33 cases in the analysis between the accelerometer and the logbook relating to MVPA and sedentary time respectively. For detailed information for the procedure on Bland and Altman analysis, see Paper II.

For the methods to be regarded as interchangeable in this study, they were expected not to differ by more than 15 minutes in terms of MVPA and 60 minutes in terms of sedentary time. These a priori hypotheses were based on two research findings. Regarding MVPA, it seems important to detect a clinical change of 15 minutes (40) while, when it comes to sedentary time, every one-hour increase in TV viewing, for example, is linked to an increase in the prevalence of metabolic syndrome (67).

**Multiple linear regression (Study III)**
Pearson’s bivariate correlation test was used to assess associations between each of the independent variables (daytime sleepiness, BMI, exercise self-efficacy, fear of movement, and depressive symptoms) and the three outcome variables (daily average time spent in MVPA, daily average number of steps and daily average time spent sedentary). To assess the impact of the independent variables on MVPA, steps and sedentary time, a multiple linear regression analysis was performed using the forced entry method. In addition, a backward selection method examined the stability of the findings across the methods.

In the regression analysis, the participants with standardised residuals over three standard deviations from the mean were excluded; one person was excluded from the MVPA and the steps models, while another was excluded from the model for sedentary time: this resulted in n=62 for each regression model. To check for multicollinearity, the variance-inflation factor (VIF) was calculated. The VIF for the three regression analyses was acceptable
(range 1.00-1.21), suggesting there was no multicollinearity. Missing data were assumed to be missing at random and a missing value on an item on the ESS (n=2) or the ESES (n=6) was substituted with the median value of the scale for that individual.

**Within- and between-groups analyses (Study IV)**

The intention-to-treat principle (ITT) was applied in all the analyses, regardless of completion of actual treatment and adherence to assessment protocol. Student’s paired t-tests were used to assess differences within groups regarding the changes from baseline to six months in outcomes for all continuous variables. Since the data on MVPA were not normally distributed, even after logarithmic transformation, Wilcoxon’s signed-rank tests were used to analyse within-group changes. Given ordinal data, the same statistical method was used when analysing the difference within groups regarding eating style (DEBQ).

Student’s independent t-tests were used to assess differences between groups regarding changes from baseline to six months in outcomes for the continuous variables, whereas Mann-Whitney U tests were used to analyse differences between groups regarding MVPA. Given ordinal data, Mann-Whitney U tests were used when analysing the difference between groups regarding the DEBQ. Fisher’s exact test was used to assess the difference in food intake frequency between groups at baseline and at six months respectively. Cohen’s effect size ($d$) (120) was calculated for the variables that were normally distributed. Missing data were assumed to be missing at random.

All statistical analyses in Studies II-IV were performed with SPSS 19.0 (Inc., Chicago, Illinois, USA) and the statistical significance level was set at 0.05 (two-tailed) for all analyses.
Results

Physical activity and sedentary time

**OSAS and obesity - on CPAP treatment (Study II)**
For the whole group, the daily average minutes spent on MVPA from the accelerometer (from bouts of $\geq 10$ min), IPAQ and logbooks was 37 minutes (SD 44), 84 minutes (SD 80) and 69 minutes (SD 69) respectively. The average time spent while sedentary, according to the accelerometer, IPAQ and logbooks, was 9 hours 55 minutes (SD 3:10), 7:51 (SD 2:59) and 8:24 (SD 3:00) respectively.

**OSAS and overweight - prior to initiation of CPAP treatment (Study III)**
At baseline, the participants took a daily average of 7,734 steps (SD 3,528, min-max 1,333-20,216) and spent 3h 13 min (SD 1:05) or 19.8% (SD 7.1) on low-intensity physical activities. They spent a daily median of 70 minutes (IQR 61) or 7.3% (IQR 6) of waking time on moderate-to-vigorous physical activity. The average time spent while sedentary according to the accelerometer was 11h 45min (SD 2:08) or 71.6% (SD 10.4) of waking time.

Influences on initiation of and engagement in physical activity

In the interviews with persons with CPAP-treated OSAS and obesity, two themes evolved reflecting influences on engagement in physical activity: 1) *Incentives strong enough* and 2) *Facilitators for success and challenges to overcome*. For an overview, see Table 3.

**Theme 1: Incentives strong enough**
Having a strong incentive to engage in physical activity was crucial for informants. This was expressed by statements revealing personal reasons for, and positive expectations of, engaging in physical activity. It was also articulated by statements relating to the absence of reasons and desire for some sort of incentive. The statements regarding outcomes from physical activity varied from a wide range of positive outcomes to a few side-effects. For some informants, there was ambivalence between positive and negative outcomes of physical activity.
<table>
<thead>
<tr>
<th>Consequences of OSA and obesity</th>
<th>Facilitators for success and challenges to overcome</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incentives strong enough</strong></td>
<td><strong>Facilitators for success and challenges to overcome</strong></td>
</tr>
<tr>
<td>CATEGORIES</td>
<td>SUB-CATEGORIES</td>
</tr>
<tr>
<td>Future risks for medical diseases</td>
<td>- Future risks - There are risks but I rarely think about them - There are risks but I do not care</td>
</tr>
<tr>
<td>Lack of knowledge about risks</td>
<td>- Lack of knowledge about the risks</td>
</tr>
<tr>
<td>Limitations in everyday life</td>
<td>- Pain - It is hard to move around - Tiredness - Low self-esteem - Hard time concentrating - It is hard to find clothes</td>
</tr>
<tr>
<td><strong>Reasons to devote oneself to physical activity</strong></td>
<td><strong>Thoughts and feelings</strong></td>
</tr>
<tr>
<td>Desire for a change</td>
<td>- I want to lose weight - I want to be more active and supple - I am fed up with being in this situation</td>
</tr>
<tr>
<td>Lack of personal incentive</td>
<td>- Only a threat would get me started - I need inspiration and motivation</td>
</tr>
<tr>
<td>Health care advice</td>
<td>- I am just awaiting my physician’s approval - I got advice not to exercise - I got advice/orders to exercise</td>
</tr>
<tr>
<td>An established habit</td>
<td>- Physical activity is a habit</td>
</tr>
<tr>
<td><strong>Positive outcomes</strong></td>
<td><strong>External circumstances</strong></td>
</tr>
<tr>
<td>Physical and medical benefits</td>
<td>- To become more supple - To reduce pain - Enhanced blood circulation - Enhanced capacity - To reduce weight - Reduced risks of medical diseases</td>
</tr>
<tr>
<td>Enriched personal well-being</td>
<td>- Positive feelings from physical activity - Enhanced mental health - Generally to feel good</td>
</tr>
<tr>
<td>Fulfilled self image</td>
<td>- I wish to get a routine for physical activity - I wish to become more social</td>
</tr>
<tr>
<td>Socializing</td>
<td>- Physical activity is a way to meet people</td>
</tr>
<tr>
<td>Better sleep</td>
<td>- Better sleep</td>
</tr>
<tr>
<td><strong>Side effects</strong></td>
<td><strong>Disease and physical symptoms</strong></td>
</tr>
<tr>
<td>Bodily sensations</td>
<td>- Physical activity hurts - Exertion - Sensations from the heart creates fear of moving</td>
</tr>
<tr>
<td>Lack of time</td>
<td>- Physical activity takes time</td>
</tr>
<tr>
<td>Knowledge about benefits but lack of personal experience</td>
<td>- It would not make a difference</td>
</tr>
<tr>
<td>Ambivalence</td>
<td>- Common sense in conflict with one’s feelings - Logically yes, but emotionally no</td>
</tr>
</tbody>
</table>

Table 3. Results from Study I classified in themes, categories, sub-categories and codes.
Theme 2: Facilitators for success and challenges to overcome

When the informants were asked to say what might influence their engagement in physical activity, a wide range of aspects emerged from the data. The category *Thoughts and feelings* comprised thoughts, feelings and cognitions (i.e. perceptions and expectations) about physical activity that might influence engagement in physical activity. This was articulated as whether or not you feel confident about performing physical activity, whether or not you prioritise physical activity and make time for it, having too many excuses to get going and how earlier positive or negative experiences of physical activity influence you. Dosage and goal setting were mentioned as a way of making the activity achievable and some informants mentioned the importance of a welcoming, tolerant atmosphere of feeling accepted and fitting in (e.g. at a health centre).

The category of *External Circumstances* included expressions relating to the impact of support from friends (both appropriate and mismatched support) and from work or health care (from individual coaching and contracts to group activities and equipment). In addition, environmental conditions, such as time of day, place, weather, cost and equipment, were important, and lapses from daily routine, such as having guests, were likely to hamper the engagement in physical activity.

In the third category, *Disease and Physical Symptoms*, pain was one of the issues. It appeared to hinder some individuals, while others stated that it did not hinder them, but they chose different types of physical activity depending on the prevalence of pain or not. Another aspect of this category was exhaustion. This was perceived as a hindering factor and was described as walking up a gradient or that the heart was pounding hard. Some informants suffered from psychological distress and perceived this as a substantial barrier to being physically active.

Agreement between methods assessing physical activity and sedentary time

The agreement between the accelerometer, IPAQ and the study-specific logbook was limited. Using either method a mean difference of 47 minutes between the accelerometer and IPAQ and 32 minutes between the accelerometer and logbook could be expected. The higher the amount of MVPA, the larger the differences between methods. The dispersion for the differences was wide, which is an indication of lower agreement.

Even regarding sedentary time, the agreement was limited. The compared methods had a mean difference of 114 minutes (accelerometer-IPAQ) and 86 minutes (accelerometer-logbook) respectively. There were no statistically significant differences between the accelerometer and logbook, even though the lower confidence interval only just passed $y=0$ (-1). The dispersion was
wide in both calculations, but no trend was seen regarding the level of agreement and the magnitude of the test values.

**Correlates on physical activity and sedentary time**

Daytime sleepiness, BMI, exercise self-efficacy, fear of movement and depressive symptoms explained 22.9% of the variance in sedentary time, but they did not explain variance in MVPA or steps. In backward selection analyses, BMI contributed 9% to the explanatory degree of MVPA. Fear of movement explained 6.3% of the variance in steps and 14.3% of the variance in sedentary time.

**Changes in physical activity and eating behaviours**

**Physical activity**

Already at baseline, the majority of participants in both the experimental group (57.6%) and the control group (63.3%) surpassed the recommendations for physical activity for weight loss, i.e. 60 minutes/day of MVPA. At six months, 72.7% in the experimental group were physically active at that level, while, in the control group, the equivalent number was 56.7%. However, there were neither any statistical differences over time regarding the median time spent on MVPA nor any between-group differences regarding change scores. There were no differences over time in time spent at low physical activity (LPA) either within or between groups, see Table 4.

Of the patients in the experimental group, 39.4% (n=13) increased their daily number of steps by at least 2,000 steps/day and the whole group significantly increased their daily average number of steps over time by 1,192 steps (t(32)= 2.100, p=0.044). In the control group, 26.7% (n=8) made an average increase of 2,000 steps/day, but no significant increase was seen in that group. There were no statistically significant differences between groups regarding the change in the number of steps.

**Eating behaviour**

At six months, the participants in the experimental group had a higher intake of fruit (FET = 9.130, p=0.028) and fish/shellfish (FET = 12.551, p=0.004) compared with the control group. The experimental group significantly increased their restrictive intentions on eating as measured with the DEBQ subscale Restrained eating, but this change was not different from that of the control group (p=0.052). Both groups reduced their emotional relationship to eating and no difference between groups therefore emerged (p=0.409).
Table 4. Results from the analyses within group and between groups in Study IV, relating to change in physical activity (steps, low-intensity physical activity (LPA), moderate-to-vigorous-intensity physical activity (MVPA)), sedentary time, anthropometric data (weight, body mass index (BMI, kg/m^2) and waist circumference) from baseline to 6 months. Accelerometer data are presented in minutes and proportions of waking time (%). All data are presented as the mean ± standard deviation or median (minimum, maximum) and the corresponding p-values, effect sizes and 95% confidence intervals for differences between groups.

<table>
<thead>
<tr>
<th>Accelerometry</th>
<th>Experimental group (n=33)</th>
<th>Control group (n=30)</th>
<th>Difference between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>6 months</td>
<td>Change</td>
</tr>
<tr>
<td>Steps</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>LPA</td>
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<tr>
<td>Minutes</td>
<td></td>
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<td></td>
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<tr>
<td>Amount (%)</td>
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<td></td>
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<td>Baseline</td>
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<tr>
<td>7390 ± 2933</td>
<td>8582 ± 3748</td>
<td>1192 ± 3262*</td>
<td></td>
</tr>
<tr>
<td>187 ± 70.1</td>
<td>198 ± 61.8</td>
<td>11 ± 53</td>
<td></td>
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<tr>
<td>19.4 ± 7.6</td>
<td>20.2 ± 6.4</td>
<td>0.8 ± 5.7</td>
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<tr>
<td>MVPA</td>
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<tr>
<td>Minutes</td>
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<tr>
<td>Amount (%)</td>
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<tr>
<td>62 (5, 220)</td>
<td>77 (7, 272)</td>
<td>2 (-78, 193)</td>
<td>0.2 (-8, 19)</td>
</tr>
<tr>
<td>6.4 (1, 21)</td>
<td>7.9 (1, 27)</td>
<td>0.2 (-8, 19)</td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td></td>
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<td></td>
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<tr>
<td>Minutes</td>
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<td></td>
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<tr>
<td>Amount (%)</td>
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<tr>
<td>701 ± 145</td>
<td>690 ± 106</td>
<td>-11 ± 116</td>
<td></td>
</tr>
<tr>
<td>71.8 ± 11.5</td>
<td>70.5 ± 10.4</td>
<td>-13 ± 9.8</td>
<td></td>
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<tr>
<td>Anthropometrics</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>106.6 ± 19.1</td>
<td>104.5 ± 20</td>
<td>-2.1 ± 4.6*</td>
</tr>
<tr>
<td>BMI</td>
<td>35.2 ± 5.3</td>
<td>34.6 ± 5.7</td>
<td>-0.6 ± 1.5*</td>
</tr>
<tr>
<td>Waist</td>
<td>119.4 ± 13.9</td>
<td>116.4 ± 15.2</td>
<td>-3.0 ± 4.9**</td>
</tr>
</tbody>
</table>

Notes: * p < 0.05, ** p < 0.01
Effects on sedentary time and anthropometric values

**Sedentary time**
There was no significant reduction in sedentary time for the experimental group, whereas the control group reported a significant reduction of 37 minutes a day ($t(29) = -2.146$, $p=0.040$). When analysing sedentary time in relation to time awake, the reduction in sedentary time in the control group over time (from 71.5% at baseline to 69.2% at 6 months) was not statistically significant ($p=0.128$). There were no statistically significant between-group changes regarding sedentary time, neither in terms of daily average minutes nor proportion of time awake (Table 4).

**Anthropometric values**
The experimental group lost significantly more weight (-2.1 kg ± 4.6) and waist circumference (-3 cm ± 4.9) than the control group (-0.1 kg ± 3.3, -0.5 cm ± 4.1). Of the 23 participants losing weight, in the experimental group (63.9%), five lost 5% of their initial weight and two lost 10% of their initial weight. Of the 24 participants with a reduced waist circumference, in the experimental group (66.7%), five surpassed the upper cut-off value in the classifications of abdominal obesity. The participants in the experimental group also reduced their BMI, but the change was not significantly different from that of the control group ($p=0.074$), see Table 4.
Discussion

Summary of results
To the best of our knowledge, this is the first randomised behaviour change trial to implement a tailored behavioural sleep medicine intervention targeting physical activity and healthy eating in the treatment of patients with OSAS and overweight. Previous health outcome trials point to weight loss and/or enhanced physical activity being beneficial for the OSAS, but none has studied the impact on behavioural changes in the target behaviours per se.

We found that a behavioural sleep medicine intervention targeting physical activity and eating behaviours did not change physical activity or sedentary time during the first six months, but contributed to healthier eating, weight loss and reduction in waist circumference.

According to accelerometry, the participants had a large total amount of physical activity. However, one of the most important findings was that they spent a great deal of time while sedentary. Fear of movement explained some of the variation in sedentary time, which has not been previously recognised. Strong incentives for change were crucial for the adoption of physical activity behaviour according to patients’ conceptions. Perceived barriers and facilitators varied from overt and covert behaviours to external circumstances and physical symptoms, which were acknowledged in the tailoring of the behavioural sleep medicine intervention.

Changing physical activity and eating behaviours
The findings from Study I indicated that there are a range of factors that influence engagement in physical activity, whereof pain, exertion, low self-efficacy and a hard time prioritising and making time for physical activity are just some of them. When it came to eating behaviour change, the informants mentioned low susceptibility to health risks as a barrier for making a change in eating behaviour, together with the desire for food as a reward (121). If an individual’s self-image was challenged, however, it could function as a facilitator for change (121). These findings added important implications for treatment and were incorporated in the behavioural sleep medicine intervention provided in Study IV. The type and progress of physical activity and eating behaviours in the experimental group were therefore tai-
lored (3) according to personal goals, preferences, perceived expectations, barriers and facilitators and, in addition, out of the functional analyses of performed behaviour. Through proximal, achievable goals, identifying a behavioural change dose that was enjoyable and stepping up goals according to perceived capability and self-efficacy, the treatment was supposed to enhance self-efficacy (42) and thereby stimulate behavioural changes in eating behaviour and physical activity.

During the first six months of the intervention, the participants in the experimental group did not increase their median time spent at MVPA. One reason may be that the amount of physical activity was already high at baseline according to accelerometry and compared with the general Swedish population (48). A high baseline physical activity level may potentially leave less room for improvements. One hypothesis to the high accelerometry numbers might be the assessment itself since the mere assessment of physical activity may impact the observed physical activity, possibly as a result of raised awareness (122). Another reason for the large amount of MVPA may be that the participants kept moving to stay awake, which has been emphasised in a previous study of untreated individuals with OSAS (123). On the other hand, the amount of sedentary time was also high, which weakens these hypotheses. It has been reported that people with large amounts of occupational physical activity are generally more sedentary during their leisure time (124). Perhaps a high occupational physical activity level could be another explanation for the discrepancy between the self-reported low leisure time physical activity at inclusion and the accelerometer-assessed physical activity at baseline, as well as the contrast to the high amount of sedentary time. Nevertheless, according to the inclusion criteria, the participants were insufficiently physically active and expressed a need for enhanced leisure-time physical activity.

Another reason for the lack of physical activity change may lie in the intervention design. It is a challenge to tailor physical activity behaviour to individual prerequisites yet achieving the appropriate dose of physical activity, in this case 60 minutes of moderate physical activity five days a week. It is a matter of concern that the self-selected behavioural goals and progress might have been too modest an approach for any changes to appear at this time point. The tailored treatment design may have produced heterogeneity, especially regarding the progress and challenge in the physical activity behavioural goals. This could contribute to greater variability in progress and outcome. Further, another concern is that the performed functional behavioural analyses did not capture the most influential determinants of behaviour that would have benefited from being targeted. The action plan for the next week could therefore have been formulated using mismatched barriers and facilitators.

The importance of not only discussing but also writing down your goals and plans has been reported (18). The behavioural goals in the intervention
were agreed on and written down by the coaches, but the patients were not prompted to write them down. Likewise, in the maintenance/coping plan, the patients wrote down the risk situations they had encountered during their behavioural change process, but the strategies for overcoming them were only discussed and not written down. Self-monitoring was prompted and performed at least once, but it was not a requirement throughout the treatment. Since self-monitoring has been reported in several studies to facilitate physical activity (125) and sound eating habits (20), it is worth reflecting on whether a higher frequency of self-monitoring could have enabled an increase in physical activity.

The intervention in the main project is continuing for an additional nine months with an assessment three months after the last follow-up session. According to a review of study characteristics in intervention trials for enhanced physical activity or healthy eating, treatment periods of more than 24 weeks and the use of follow-up prompts have a higher maintenance rate than shorter interventions (126). It is therefore possible that a behavioural change in physical activity will not be evident until later in the study.

It is worth acknowledging that, during the six-month period, the participants in the experimental group targeted not only two behaviours but three; enhancing physical activity, improving eating behaviour and accommodating CPAP treatment. Perhaps this concurrent triad was too overwhelming, making physical activity less of a priority and eating behaviours more open to change. In a pilot study of the concurrent initiation of two behaviours, namely CPAP usage and dietary change, McDoniel & Hammond (32) reported positive results in both behaviours in terms of CPAP adherence and eating style. In our study, even though no changes were found in physical activity, the people participating in the behavioural sleep medicine intervention did change their eating behaviours, as measured by an increased intake of fruit and fish/shellfish, which are important indicators of a healthy diet (127). Treatment targeting increased fruit and vegetables has been reported to be efficient in also reducing the consumption of high-fat/high-sugar foods and to result in greater subsequent weight loss compared with treatment focusing on reducing the intake of high-fat/high-sugar foods (128). In order to elucidate what contributed to the changes in eating behaviour, it will be interesting to further study the intervention components or individual characteristics that may have moderated and mediated the behavioural changes.

**Sedentary time – sedentary behaviour**

Interestingly, the amount of sedentary time surpassed the sedentary time reported in the general population (48) and the reason for the contrast between high physical activity and high sedentary time remains unclear. Fear of movement emerged as the parameter explaining a part of the variation in both sedentary time and daily steps. However, what this fear comprises in
people with OSAS is elusive. In Study I, statements emerged regarding anticipation of pain and fear of eliciting symptoms from the heart while exercising. In addition, having OSAS increases the risk of cardiovascular diseases (129). These aspects may hypothetically contribute to fear of movement and activity avoidance. However, fear of movement has to be further explored among people with OSAS.

We included sedentary time as a secondary outcome, since, at the time the study was designed, the definition of sedentary was limited to “too little exercise”. During our studies, the importance of operationalising and defining sedentary time as a separate construct has grown. During the time we spend being sedentary, we engage in several different lying or sitting behaviours (130) such as screen activities (e.g. TV, computer), reading a book, or sitting at the dinner table, for example. In questionnaires, sedentary time so far has mainly been operationalised as sitting, e.g. IPAQ (104) and our study-specific log book. Future self-reports on sedentary time, such as logbooks, should comprise different types of sedentary behaviour performed while both sitting and lying. More recent accelerometers are able to capture all such activities with the lowest energy expenditure. However, depending on total sleep time, more or less waking time is available for physical activity and sedentary time. People who sleep longer at night have less time awake and the amount of MVPA and sedentary time may therefore well be analysed in relation to time awake. In Study IV, when using this type of analysis, the decrease in sedentary time noted in the control group was no longer statistically significant. Even though the Sensewear armband was not developed in order to perform sleep studies per se, it has been reported to have high sensitivity for estimating sleep (88.7%) compared with polysomnography (131). Future studies aiming to analyse daily activity patterns could therefore benefit from using a multiple physiological activity monitor in order to measure sedentary time and physical activity and to analyse these activities in proportion to time awake.

As a result of the knowledge of sedentary behaviour that has evolved in recent years, it was not surprising that sedentary time was not affected by the intervention targeting enhanced physical activity. Instead, sedentary behaviour has to be addressed separately in future behaviour change trials and dealt with in the same structured manner as other behavioural changes, e.g. by goal setting, self-monitoring and providing reinforcement (66). A recent study has reported the effects of four different intervention combinations of increasing physical activity, reducing sedentary time, reducing saturated fat and increasing the intake of fruit and vegetables (132). The results favoured the intervention arm targeting an increased intake of fruit and vegetables and reduced sedentary time. It generated the most improvements in outcome measurements of both sedentary time and the intake of fruit/vegetables and saturated fat, as well as an increase in physical activity (132). Given that sedentary behaviours are prevalent in many leisure-time activities (e.g. read-
ing, watching TV, playing computer games), these behaviours are perhaps more open to change in many populations. As low-intensity physical activities, such as standing up instead of sitting, are easily accessible and impose less exertion on the individual, such intervention strategies may be advantageous.

**Effects of behavioural changes on anthropometric values**

The behavioural sleep medicine intervention made it easier for the participants in the experimental group to reduce weight and waist circumference, albeit in small numbers. Previous randomized, controlled health outcome studies of the effect of weight loss on OSAS severity have reported larger weight losses of a mean of about 10 kilos (29-31) and they all showed clear improvements in AHI. However, these studies all used a low or very low calorie diet as a means of initial weight reduction. A diet of this kind is not an alternative for patients who are not willing to substitute normal food with liquid replacements. Instead, in our intervention programme, the behavioural change activities individuals could take part in varied depending on the aspect of eating habits the individual preferred to focus on and the needs the patient expressed. Some patients concentrated on meal structure (regardless of caloric intake), while others worked on reducing caloric intake by increasing the amount of vegetables to half the plate, for example. However, this approach may have led to heterogeneous types of eating behavioural change activity and to varying intensities in goal progression, which might explain the small yet significant improvements in weight and waist circumference. Nevertheless, the behavioural sleep medicine intervention targeting habitual eating patterns makes an important contribution to our understanding of how to facilitate weight loss in patients with OSAS.

**Methodological discussion**

This thesis took its starting point in the prevailing research field of behavioural sleep medicine where a gap had been identified regarding physical activity and eating behavioural changes in people with OSAS. As these kinds of health behavioural changes had been scarcely targeted in the field of behavioural sleep medicine, the project started with an explorative approach to uncover patients’ perceptions of prerequisites for behavioural change. We also studied agreement between measurement methods before the start of the RCT. As a consequence, the study protocol could be informed by the initial studies, which is an important strength regarding individual tailoring strategies for instance. The results from the interviews were incorporated, in addition to theory-based foundations of behavioural learning and principles of self-determination and self-regulation. The individual tailoring to the pa-
tient’s behavioural goal and functional behavioural analyses then aimed at changing behaviour through enhanced self-efficacy (42).

However, there are some methodological aspects that are important to bear in mind when interpreting the results of the studies. The severity of OSAS increases with increasing BMI (7) and, the larger the weight loss, the greater the improvement in OSAS severity (133). In order to address those patients in the greatest need of changes in eating and physical activity, the inclusion criterion for BMI at the time of Studies I-II was \( \geq 30 \), i.e. obesity. When launching the intervention trial some years later, gastric by-pass was conducted to a larger extent and for lower BMI classes, which could have jeopardised study recruitment. To counteract this, the criterion for BMI was set at \( \geq 25 \), i.e. overweight. This may have had an impact on the variability in progress and anthropometric outcome. Despite the lowering of the inclusion criterion for BMI, the recruitment progressed slowly and the intervention study was closed before a sufficient sample size was obtained in terms of MVPA (\( n=132 \)). This might have increased the risk of type II errors. However, for two of our secondary outcomes, it was estimated that a sample size of 26 participants would be enough to detect a difference between groups of 2,000 steps and that 52 participants would be sufficient to detect a difference between groups of a 10% weight loss.

As we did not use a food diary, we do not know whether the participants altered their calorie intake, their meal structure, or their choice of food. We did not choose this method since we did not want to introduce the risk of enhanced dietary awareness in the control group. The items on the questionnaire from NBHW are, however, indicators of importance of healthy eating (127).

The accelerometer data on sleep were handled in different ways in Study II and Studies III-IV and might have contributed to discrepancies between the results for physical activity and sedentary time in these studies. In Study II, we removed 7.5 hours from all the participants’ sleep, which could have led to a misinterpretation of more sedentary time in those who sleep longer than 7.5 hours/night and less physical activity in those who sleep less than 7.5 hours. In Studies III-IV, however, we analysed the visual time axis of every participant’s accelerometer data and removed those time periods of prolonged sleep (several consecutive hours) as recognised by the software. Despite being different from Study II, it was hypothesised that this procedure would provide a more reliable pattern of daily activities and it was thus regarded as an improvement and progress in data management.

A total of 20 participants declined CPAP treatment during the first six months of the RCT. Trouble using CPAP and maintained OSAS severity could have impacted on internal validity as a result of hampered behavioural changes. However, the attrition was equally distributed between groups and the risk should therefore have been evenly disseminated.
During this period, one of the participants who dropped out of the experimental group was referred for investigation for potential gastric surgery. Another two participants in the experimental group were subsequently (after the first six months) referred for screening of this kind. This process may have influenced their motivation to make behavioural changes in either a positive or a negative direction.

Randomised, controlled trial is a potent design for evaluating the effect of treatments. One drawback, however, is being allocated to the control group. Some study participants in the control group were reluctant to attend the assessment at six months, due to dissatisfaction with the study conditions and embarrassment about weight gain. This contributed to some of the missing values for accelerometry and anthropometric data.

**External validity**

The results of the studies are valid for patients on CPAP treatment or referred for first-time CPAP treatment and for those willing to participate in studies of behavioural changes in physical activity and eating behaviours. The vast majority of the participants were men, but this unevenly distribution between genders is in line with previous reports on prevalence of OSAS (5, 134). However, future studies are needed to develop interventions including more women and addressing those that declined due to perceived lack of time and incentives to change and those on other OSAS treatment modalities.
Conclusions

- A tailored behavioural sleep medicine intervention targeting physical activity and eating behaviours combined with first-time CPAP treatment facilitated eating behaviour change and subsequent weight loss and reduction in waist circumference. It did not enhance physical activity.

- Patients with OSAS expressed that strong incentive for change is necessary to engage in a physical activity behavioural change. It is challenging to tailor treatments according to perceived barriers and facilitators for physical activity engagement, since the great variation requires patient-specific assessments and behavioural analytic strategies.

- When measuring physical activity and sedentary time in patients with OSAS, an accelerometer is the preferred measurement method. Using a logbook combined with accelerometry enables the correlation of duration, type and exertion of physical activity and may contribute to specifying current physical activity behaviours.

- Patients with OSAS and overweight, scheduled for first-time CPAP treatment may, according to accelerometry, fulfil recommendations for physical activity although they report not being enough physically active in leisure time.

- The amount of sedentary time during waking hours was remarkably high. Sedentary behaviours were not affected by an intervention targeting physical activity, which confirm sedentary being a construct necessary to separate from the lower end of a physical activity continuum. This highlights the need to develop more comprehensive measurements for sedentary behaviours and for interventions specifically targeting sedentary behaviour.

- Daytime sleepiness, BMI, exercise self-efficacy, fear of movement and depressive symptoms explained some of the variation in sedentary time. Fear of movement, in particular, appears to play an important role in sedentary time.
Clinical implications

- As the vast majority of patients with OSAS are overweight, treatments for healthy eating, enhanced physical activity and reduced sedentary time have to be incorporated in the field of behavioural sleep medicine.
- Various, multifaceted incentives, barriers and facilitators for health behaviour changes in patients with OSAS point to that the standardised advice and treatments should be replaced with treatments incorporating patient-specific measures.
- A shift in focus from treatments aimed at enhancing physical activity to treatments aimed at reducing sedentary behaviours is indicated

Future research

The results imply several suggestions for future studies and the following are some of the more urgent research questions that need to be answered.

- Further health outcome analyses will conclude whether or not the relatively small anthropometric changes have had any impact on OSAS severity.
- Analyses of duration of physical activity in relation to bouts of physical activity and additional information from logbooks will enhance the knowledge on physical activity behavioural change.
- Further analyses of the performed behavioural changes and the potential mediating variables will help filtering out the aspects that may have contributed the most to the effects.
- Patients’ conceptions of sedentary behaviours have to be studied, as well as predictors of sedentary behaviours in OSAS in order to elaborate tailored interventions accordingly.
- The impact of fear of movement or activity avoidance on sedentary behaviours in patients with OSAS has to be studied and measurement methods of fear of movement have to be developed for this population.
- It is also important to develop treatments that appeal to those that decline participation in comprehensive treatment programmes.
Sammanfattning på svenska

Bakgrunden till avhandlingen var att det i början av 2000-talet konstaterades att det behövdes fler studier om hur förändringar i matvanor och fysisk aktivitet påverkar svårighetsgraden av obstruktivt sömnapnésyndrom (OSAS). Det fanns dessutom inga studier avseende själva beteendeförändringarna hos patienter med OSAS, dvs. hur förändringar i fysisk aktivitet och matvanor initieras, förändras och bibehålls genom behandlingar som riktas mot dessa beteenden.

Under senare år har flera randomiserade, kontrollerade studier visat att Viktminskning har positiv inverkan på sömnapnésyndromet men det saknas fortfarande studier om beteendeförändringarna av fysisk aktivitet och matvanor. Vad vi vet finns hittills endast en pilotstudie om hur åtbeteendet förändras under en behandlingsperiod. Syftet med denna avhandling var att utveckla och utvärdera en skräddarsydd beteendemedicinsk behandling för att öka fysisk aktivitet och sunda matvanor hos personer med OSAS och övervikt. Genom förstudier integrerades patienternas egna uppfattningar om drivkrafter och influerande faktorer för beteendeförändring med teoribase-rade principer om beteendeinlärning och beteendeförändring.

I Studie I genomfördes semi-strukturerade individuella intervjuer med patienter med måttlig eller svår OSAS (apné-hypopné-index, AHI ≥ 15) och fetma och som behandlades med kontinuerligt positivt luftvägstryck (continuous positive airway pressure, CPAP) under sömnen. Intervjuerna analyserades med kvalitativ innehållsanalys. Patienterna beskrev att det krävs en stark drivkraft för att förändra sin fysiska aktivitet och att man kan behöva stöd för att finna sådan drivkraft. De beskrev att kroppsliga symptom såväl som omgivningsfaktorer, tankar och känslor inverkar på deltagandet i fysisk aktivitet. I Studie II analyserades överensstämmelsen mellan tre metoder för mätning av medel-till-högintensiv fysisk aktivitet och stillasittande; en accelerometer (Sensewear Pro 3 Armband), en studiespecifik loggbok och ett frågeformulär (International Physical Activity Questionnaire, IPAQ). Resultaten visade att deltagarna överskattade sin fysiska aktivitet jämfört med värdena från accelerometern och underskattade mängden tid i stillasittande. I Studie III studerades medel-till-högintensiv fysisk aktivitet och inaktivitet samt det multivariata sambandet med två sjukdomsrelaterade faktorer (dag-sömnighet och body mass index, BMI) och tre psykologiska faktorer (tilltro till att vara fysiskt aktiv, rörelserädska samt nedstämdhet). Resultatet av regressionsanalyser visade att BMI förklarade 9 % av variationen i daglig
mängd medel-till-högintensiv fysisk aktivitet medan rörelserädsla förklarade 6.3 % av variationen i dagligt antal steg. Alla fem faktorer tillsammans förklarade 22.9 % av variationen i inaktivitet. Utav dessa hade rörelserädsla den största förklaringsgraden (14.3 %) för variationen i inaktivitet. I Studie IV studerades effekter på fysisk aktivitet och åtbeteende efter en 6-månaders skräddarsydd beteendemedicinsk behandling för ökad fysisk aktivitet och sunda matvanor i kombination med förstagångsbehandling med CPAP, jämfört med enbart CPAP-behandling och råd från sköterska eller läkare om betydelsen av viktnedgång. De patienter som erhöll den beteendemedicinska interventionen ökade sitt intag av frukt och fisk/skaldjur och de minskade mer i både vikt och midjeomfång. Den fysiska aktiviteten förändrades inte av behandlingen.

Fynden från den randomiserade studien (Studie IV) var att den skräddarsydda interventionen som påbörjades samtidigt som CPAP-behandling underlättade för patienterna att ändra sina matvanor vilket också gav positiv effekt på vikt och midjeomfång. Behandlingen bidrog inte till förändring av fysisk aktivitet. Intervjusträff (Studie I) visade på en stor variation av faktorer som påverkar det fysiska aktivitetsbeteendet. Denna mångfald tydliggör behovet av att behandlingar skräddarsyas enligt de hinder och underlättande faktorer för beteendeförändring som den enskilde individen upplever. Detta kan göras utifrån patientspecifika mätningar, självskattningar och beteendeanalyser.

Fysisk aktivitet och inaktivitet rekommenderas att mätas med accelerometer och loggbok (Studie II), men eftersom inaktivitet inbegriper olika beteenden behöver loggböcker och andra mätmetoder utvecklas för att omfatta fler beteenden än enbart stillasittande. Resultaten från Studie III visade att den dagliga mängden inaktivitet var påtagligt hög. Rörelserädsla förefaller vara en förklarande faktor och behöver utforskas mer i denna population. Mängden inaktivitet påverkades inte av interventionen för ökad fysisk aktivitet vilket bekräftar att inaktivitet måste ses som eget begrepp och ett separat beteende och inte som ”otillräcklig mängd fysisk aktivitet”. Behandlingar särskilt riktade mot inaktivitetsbeteenden behöver därför utvecklas och utvärderas.
Acknowledgements

Nu är jag färdig med min forskarutbildning och ni är många som under årens lopp hjälpt mig att ta mig dit jag är idag. Därför vill jag rikta mitt stora tack till alla er men vill nämna särskilt några här.


Jag vill också rikta mitt stora tack till:

…alla studiedeltagare. Alla ni som lät er intervjuas och delade med er av era uppfattningar och alla ni som tagit er till sjukhuset för upprepade mätfallen och besök på dietistmottagningen, i tillägg till alla besök på CPAP-mottagningen. Tack för ert engagemang!

...dietist Hanna Andersson för alla år som vi nu har arbetat ihop. Tänk vad mycket vi har varit med om, utvecklat och lärt oss under årens lopp! Tack till alla dietister på Dietistmottagningen, Akademiska sjukhuset! Ni har varit så tillmötesgående och berett plats för vårt forskningsprojekt.

...personalen vid CPAP-mottagningen på Sömn- och Andningscentrum, Akademiska sjukhuset samt all personal i verksamhetsområdet Logopedi, Sjukgymnastik och Arbetsterapi, Akademiska sjukhuset, för mycket gott samarbete genom åren.

...Institutionen för Neurovetenskap, Sjukgymnastik, vid Uppsala Universitet, som gett mig möjlighet att genomföra mina doktorandstudier i en så stimulerande arbetsmiljö, både vad gäller forskning och undervisning. Tack alla nuvarande och tidigare arbetskamrater på Sjukgymnastprogrammet för alla upplyftande och kreativa samtal och alla pedagogiska samarbeten vi haft genom åren.

...forskargruppen Beteendemedicin och sjukgymnastik som, under ledning av Pernilla, i nuvarande form består av Annika Bring, Ingrid Demmelmeier, Christina Emilson, Catharina Gustavsson, Sara Holm, Birgitta Jönsson, Magnus Lindberg, Pelle Lindberg, Susanne Pettersson, Cecilia Rastad, Åsa Revenäs, Maria Sandbohr och Sören Spörndly-Nees. TACK för alla inspirerande och utvecklande diskussioner!

...alla doktorander vid Institutionen för Neurovetenskap, Sjukgymnastik; Mikael Andersson, Christina Emilson, Carina Hagman, Sara Holm, Henrik Johansson, Åsa Revenäs, Sören Spörndly-Nees, Susanna Tuvemo Jonsson och Birgit Vahlberg. Jag vill gärna skriva Annika Bring och Charlotte Urell här också, trots att ni nyligen doktorerat! Doktorandgruppen är enastående dynamisk och har hela tiden genomsyrats av kreativitet, öppenhet, givmildhet - och humor! Tack för alla lärorika och roliga år!

...Sara Holm (igen), min rumscompis under åren på BMC. Tack för att du genom åren varit bollplank för textformuleringar, forskningsfrågor och vetenskapsmetodik men framför allt för att du är sådan medmänniska.

...Birgitta Lindmark, professor emerita, som genom att rekrytera mig till forskningsprojektet på Strokeenheten fick mig att rikta blicken mot forskarutbildningen. Tack också till Therese Hellman, arbetsterapeut och numera Fil. Dr, för de där inspirerande åren när vi arbetade tillsammans, både på avdelningen och i projektet.

...mina vänner som finns där för mig, trots att jag på grund av arbete inte alltid kunnat tacka ja till middagar eller utflykter, och som har hjälp till när
vardagslogistiken inte blivit som planerat. Jag ser fram emot att umgås mer med er framöver!

..mina svärföräldrar Torgärd och Stellan, för en droppe andlighet i det vetenskapliga havet.

…hela min härliga ursprungsfamilj! Ett särskilt tack till min mamma Agneta som alltid stöttat mig och mina syskon i vått och torrt. Du har en sådan enorm medmänsklighet och har alltid betonat varje individs unika värde! Och mina härliga syskon som jag växte upp med; Johan, Anna, Tixi och Andreas - tack för att ni är de ni är! Det är svårt att sätta ord på hur glad jag är över att jag har er.

…min älskade Martin för all din kärlek och ditt stöd under alla våra års tillsammans! Under doktorandstudierna har du fått stå ut med att agera både översättare, datasupport och bollplank för allehanda forskningsidéer men du har hela tiden varit enastående uppmuntrande för mig och mitt arbete.


Denna avhandling har delfinansierats med anslag från Vetenskapsrådet, Hjärt- och Lungsjukas Riksförbund, Uppsala Läns Landsting, Medicinska fakulteten vid Uppsala universitet, Uppsala läns förening mot hjärt- och lungsjukdomar samt Svensk Förening för Sömnforskning och Sömnmedicin.


Acta Universitatis Upsaliensis

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