LIvES: Lifestyle, Energy Expenditure, and Sleep in Obstructive Sleep Apnoea

(A pilot study)

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Abstract

Background: Obesity is a major health issue, and one of the leading causes of Obstructive Sleep Apnoea (OSA). OSA occurs when the upper airway is repetitively obstructed, either entirely or partially, whilst sleeping. This causes reduced or lack of airflow into the lungs, commonly resulting in snoring or disturbed sleep that leads to daytime sleepiness, increased risk of motor or work-related accidents, and overall impaired quality of life. As rates of obesity increase, it can be expected that so too will cases of OSA. Previous overseas research has found that overnight energy expenditure (EE) is greater when OSA is untreated, whilst Continuous Positive Airway Pressure (CPAP), the “gold standard” treatment, has been linked to weight gain due to a decrease in overnight energy expenditure but mechanisms are not well understood. This means losing weight may become more difficult with CPAP treatment.

Objective: To determine if there is a decrease in overnight energy expenditure following the initiation of CPAP treatment in patients newly diagnosed with Obstructive Sleep Apnoea, who are living in the Wellington area.

Design: In this pilot study, participants were recruited prior to their scheduled sleep assessment by means of polysomnography (PSG) (a multi-component sleep assessment tool) at the WellSleep Sleep Investigation Centre at Bowen Hospital. Participants were also recruited following PSG confirming OSA, but prior to initiating CPAP treatment. The study was divided into three stages. In stage one, participants wore a SenseWear® device on an armband consecutively for three days and nights, whilst keeping a three day food record and three day sleep diary.
In stage two, participants initiated CPAP treatment following OSA diagnosis, and continued to receive treatment.

Stage three was identical to stage one, but whilst continuing CPAP treatment.

Data on EE and sleep patterns were collected from SenseWear® devices by exporting the data to the SenseWear® Professional 8.1 program by Bodymedia® on a computer. Sleep diaries confirmed sleep data. Kai-calculator (v 1.11), a University of Otago dietary analysis program, was used to calculate energy intake from food diaries.

The strength of the relationship between CPAP and EE was measured using Pearson correlation coefficient. EE and energy intake before and during CPAP treatment were compared using paired t-tests.

**Results:** Mean energy intake per day was 9629KJ (SD 3130) in stage one, and 9271KJ (SD 2107) in stage three, with no significant difference between each stage (p=0.89).

Mean EE per hour of total sleep time was 351KJ (SD 86) in stage one, and 340KJ (SD 82) in stage three, with no significant difference between each stage (p=0.36). CPAP use was strongly correlated with EE; EE decreased as hours of CPAP use increased (p=0.014, $R^2=0.485$).

**Conclusion:** The current study found a significant relationship between EE and CPAP; energy expenditure during sleep reduced with longer CPAP use. However, no overall differences in EE or EI were seen before and during initial CPAP use.

These results indicate there is the potential for weight gain to occur over time once initiated on CPAP treatment, particularly if energy intake remains unchanged. A longer term study with a larger sample size will help clarify the extent of this relationship.
Keywords: Obstructive Sleep Apnoea, CPAP, energy expenditure, sleep, diet record, sleep diary.
Preface

As part of this thesis, the candidate:

- Recruited participants via phone and/or email.
- Distributed the study information sheet and flow chart of project stages to participants via email, and to Respiratory specialist Doctors who refer patients to WellSleep.
- Booked appointments with participants via phone or email.
- Conducted appointments with participants before starting Stages one and three
  - Gave participants all materials required for the project (the food record, diet assessment photo book, sleep diary, and SenseWear® device with armband), and explained how to use the materials.
  - Collected demographic data from participant
  - Checked CPAP machine data at the end of stage two, with assistance from the primary supervisor Dr Angela Campbell.
- Downloaded data collected by the participants from the SenseWear® device to the SenseWear® computer program.
- Entered estimated diet record information into the web-based program Kai-calculator.
- Carried out statistical analyses with assistance from a biostatistician at the University of Otago Wellington campus, and interpreted the results.
- Designed the tables and graphs in the results section.
- Wrote the thesis under the supervision of Dr. Angela Campbell and Associate Professor Winsome Parnell.
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List of Abbreviations and Glossary

AHI – Apnoea-Hypopnoea Index
BMI – Body Mass Index
CIH – Chronic Intermittent Hypoxia
CPAP – Continuous Positive Airway Pressure
EE – Energy Expenditure
EI – Energy Intake
NZ – New Zealand
NZEO – New Zealand European and Other
OSA – Obstructive Sleep Apnoea
PSG - Polysomnography
PLMS – Periodic Limb Movements in Sleep
RCT – Randomised Controlled Trial
TST – Total Sleep Time
VST – Variation in Sleep Time

Apnoea-Hypopnoea Index: The number of times a person stops breathing, or has severely reduced breathing, for longer than 10 seconds in an hour long period. It is used to diagnose Obstructive Sleep Apnoea, as well as it's severity.
Body Mass Index: A measure used to classify underweight, healthy/normal weight, overweight and obesity in adults. It is an individual's body weight in kilograms divided by the square of their height in metres (kg/m²).

Chronic Intermittent Hypoxia: a long-term condition in which the body is repetitively deprived of oxygen, in between moments when oxygen levels are sufficient. In OSA patients, chronic intermittent hypoxia occurs when sleeping due to obstruction of the upper airway.

Continuous Positive Airway Pressure: The "gold standard" treatment for OSA, it is a machine that sits on the bedside and is worn by the patient during sleep. It pushes a continuous pressure of air from the machine, through a tube, and then into a nasal or facial mask worn by the patient. The pressure generated by the machine keeps the airway open, and is measured in centimetres of water.

Obstructive Sleep Apnoea: When the upper airway is repetitively obstructed, either entirely or partially, whilst sleeping. This causes a reduced or lack of airflow into the lungs, commonly resulting in snoring and disturbed sleep.

Polysomnography: Also known as a "sleep study", it is an overnight test which measures several physiological parameters to diagnose sleep disorders. These parameters include brain and skeletal muscle activity, eye movements, heart rate, oxygen saturation, nasal flow, thoracic and abdominal movements, limb movements, and body position. They
can occur in a laboratory with an attending technician or in the patient's home unsupervised. A split-night study, where the first half of the night is used to diagnose OSA, and the second half to begin CPAP treatment, can only occur in a laboratory with a technician. A study which is diagnostic only can be done in a laboratory or in the patient's home.

Sham-CPAP: the placebo method of CPAP used by control groups in randomised controlled trials.
1. Introduction

Obstructive Sleep Apnoea (OSA) is a sleep related breathing disorder which occurs when the upper airway is repetitively obstructed, either entirely or partially, whilst sleeping. This causes reduced or lack of airflow into the lungs, commonly resulting in snoring or disturbed sleep that leads to daytime sleepiness, increased risk of motor or work-related accidents, and overall impaired quality of life (Qaseem et al., 2014, bpac\textsuperscript{nz}, 2012.). Major risk factors identified for OSA include obesity (40-90% of patients are obese (bpac\textsuperscript{nz}, 2012.)), increasing age, and male sex (bpac\textsuperscript{nz}, 2012., National Institute for Health and Clinical Excellence, 2008).

Co-morbidities that contribute to cardiovascular disease such as hypertension, diabetes and insulin resistance are also associated with OSA (Murri et al., 2009, Coughlin SR, 2007, Marin et al., 2005, Gottlieb et al., 2014, Reichmuth et al., 2005).

In New Zealand (NZ), OSA is estimated to affect approximately 4% of adult males and 2% of adult females; the prevalence is higher than this amongst Pacific and Maori ethnic groups, who have more symptoms than New Zealand European and Other (NZEO) groups, and are more likely to suffer moderate or severe forms of OSA (Mihaere et al., 2009).

Continuous Positive Airway Pressure (CPAP) (the “gold standard” treatment) prevents the collapse of the upper airway by generating a continual pressure or airflow which passes
into the patient’s upper airway via a mask (Sullivan et al., 1981). CPAP improves sleep quality and overall quality of life (McMillan et al., 2014), and is a cost-effective way to manage the condition (National Health and Medical Research Council, 2000).

Interestingly, some studies have found that CPAP leads to weight gain (Quan et al., 2013, Garcia et al., 2011); A meta-analysis published in 2015 showed a significant increase in BMI and body weight with use of CPAP (Drager et al., 2014). OSA patients have higher metabolic rates than those without OSA (Phillips et al., 2000, Kezirian et al., 2008), and CPAP reduces overnight energy expenditure (EE) in OSA patients by decreasing restlessness and movement overnight (Stenlof et al., 1996).

Despite improved sleep quality and duration from using CPAP, research shows people do not change their diet or exercise habits; they do not experience a decrease in energy intake or an increase in energy expenditure (Ong et al., 2013). People appear to only lose weight when using intensive lifestyle interventions, which have been shown to be very effective for reducing severity of OSA and any other co-morbidities present (Chirinos et al., 2014, Hood et al., 2013, Thomasouli et al., 2013, Johansson et al., 2011). However, if overnight energy expenditure decreases upon initiation of CPAP treatment, this may make weight loss somewhat more difficult for OSA patients who struggle with weight management.

The overall aim of this project was to determine if newly or recently diagnosed OSA patients living in Wellington experience a change in overnight EE upon initiation and establishment of CPAP treatment.
2. Literature Review

2.1 Introduction and Methods

Relevant literature was searched for on databases “CINAHL” and “Medline”. The first keyword used to search both databases was ‘sleep apnoea’. This was then linked with other keywords using ‘and’ such as ‘CPAP’, ‘CPAP and weight changes’, ‘weight changes’, ‘weight loss’, ‘weight gain’, ‘energy expenditure’, ‘energy expenditure and weight changes’. Citations in the found articles were also used to find more relevant journal papers.

2.2 What is Obstructive Sleep Apnoea?

Obstructive Sleep Apnoea occurs when the upper airway is repetitively obstructed, either entirely or partially, whilst sleeping, causing reduced or lack of airflow into the lungs. This commonly results in snoring and disturbed sleep (Qaseem et al., 2014). A by-product of OSA is daytime sleepiness, which impairs overall quality of life and is a potential hazard for motor or work-related accidents (Qaseem et al., 2014, bpac\textsuperscript{nz}, 2012.).

Major risk factors identified for OSA include obesity, increasing age, and male sex. Enlarged tonsils or tongue, or craniofacial abnormalities are also risks for OSA (bpac\textsuperscript{nz}, 2012., National Institute for Health and Clinical Excellence, 2008).

Co-morbidities that contribute to cardiovascular disease such as hypertension, diabetes and insulin resistance are also associated with sleep apnoea (Coughlin SR, 2007, Murri et al., 2009, Marin et al., 2005, Gottlieb et al., 2014, Reichmuth et al., 2005). This may in part be due to the chronic hypoxia producing reactive oxygen species that lead to oxidative stress, as well as these co-morbidities being associated with obesity, and
sympathetic stress from arousals (Murri et al., 2009, Gottlieb et al., 2014). It is important for OSA to be diagnosed so appropriate management and treatment can be given; this may aid in reducing these co-morbidities for the individual, as well as health care costs associated with these health issues (Mihaere et al., 2009).

2.2.1 Tools to assist diagnosis

The Epworth Sleepiness Scale (Johns, 1991) is often used to assess a patient’s degree of daytime sleepiness if they are suspected of having OSA. It is a subjective self-assessment tool, which gives a person a numerical score based on likeliness of falling asleep in eight different situations (Johns, 1991). The score indicates whether sleepiness is an issue. The Scale has been shown to have both high reliability and validity (Smyth, 2012). A score >10 is considered to mark excessive daytime sleepiness (Gander et al., 2005) and is often used in conjunction with other measures to prioritise patients for clinical review (bpac\textsuperscript{nz}, 2012.).

The Mallampati Score is a tool also used by health professionals (bpac\textsuperscript{nz}, 2012.). It identifies the degree of airway obstruction, by asking the patient to protrude their tongue to determine the visibility of the tonsils, uvula and soft palate (bpac\textsuperscript{nz}, 2012.). Scores are ranked from class one (complete visibility) to class four (no visibility). A score of class three or four indicates likely severe obstruction (bpac\textsuperscript{nz}, 2012.).

2.2.2 Diagnosis

Following the above assessment and clinical history, Polysomnography is used to confirm a diagnosis of OSA. A multi-component sleep assessment tool, it measures and records a number of parameters; Electroencephalography (brain activity), electromyography
(skeletal muscle activity), electro-oculography (eye movements), heart rate, oxygen saturation, nasal flow, thoracic and abdominal movements, limb movements, and body position. A level 1 study is one carried out in a laboratory with an attending technician. A level 2 study has no attending technician and is often performed at the patient’s home (bpac\textsuperscript{nz}, 2012.).

In New Zealand, there is currently no agreed criteria for referring patients for sleep studies, although there are Australasian Guidelines on how and when to conduct sleep studies (Chai-Coetzer et al., 2014). People with co-morbidities such as cardiovascular disease or Type II diabetes, who suffer daytime sleepiness, or who have a motor or machine-operating related occupation are considered by experts to be of high priority for sleep studies (bpac\textsuperscript{nz}, 2012.).

During a sleep study, the Apnoea-Hypopnoea Index (AHI) is used as a severity indicator, and OSA is classified as mild, moderate or severe depending on the number of times a patient stops breathing per hour for longer than 10 seconds. An AHI of 5-15 is considered mild, 16-29 moderate, and >30 severe (bpac\textsuperscript{nz}, 2012.).

Partial sleep studies, also known as level 3 or 4 studies, can be carried out in a patient’s home by a trained technician (bpac\textsuperscript{nz}, 2012.), (Chai-Coetzer et al., 2014). This is an alternative to a Sleep Study in a clinic or laboratory, and useful only in selected populations (Chai-Coetzer et al., 2014). Partial studies do not include all the measurements of a polysomnography. A type 3 partial study would include measuring airflow, respiratory effort, blood oxygenation and heart rate. This is considered the minimum standard for a sleep study when diagnosing OSA (bpac\textsuperscript{nz}, 2012., Chai-Coetzer et
al., 2014). Type 4 only involves two measures (heart rate or airflow and blood oxygenation typically), which makes it difficult to differentiate between OSA and other sleep disordered breathing issues. Other information from the patient such as presence of snoring and sleep time can help compliment the data collected (Chai-Coetzer et al., 2014).

2.2.3 Prevalence of OSA in New Zealand and overseas

A survey by Mihaere et al. found that in NZ, OSA affects approximately 4% of adult males and 2% of adult females; the prevalence is higher in Pacific and Maori ethnic groups compared to NZ European and Other ethnic groups. Maori and Pacific people also appear to have more symptoms than Non-Maori or Non-Pacific, and are more likely to suffer moderate or severe forms of OSA (Mihaere et al., 2009).

Qaseem et al. estimated that between 10% and 17% of North Americans suffer from OSA. The estimate is not precise due to variation in criteria used to define OSA, and the number of individuals who may have a mild form of the disease but have not sought a diagnosis (Qaseem et al., 2014). In the UK, it is estimated that 4% of middle-aged men and 2% of middle-aged women have OSA; a similar prevalence to NZ (National Institute for Health and Clinical Excellence, 2008, Mihaere et al., 2009).

2.2.4 Summary

OSA is frequently associated with obesity, older age, and male sex. It is a full or partial obstruction in the upper airway, leading to snoring and disturbed sleep as a result of reduced or no airflow into the lungs. There are negative health outcomes if left untreated. The Epworth Sleepiness Scale, which has demonstrated reliability and validity, is used to determine the extent of a patient’s daytime sleepiness if they are suspected of having
OSA. The Mallampati score can also be used to clinically identify the degree of obstruction. This should be followed by Polysomnography (a multi-component sleep assessment tool) to diagnose OSA. These can be carried out in a clinical setting, or in an individual’s home if appropriate. From these, the AHI is determined, which classifies as an individual as having ‘mild’, ‘moderate’, or ‘severe’ OSA. There are differences in prevalence between genders and ethnicities. If left untreated, OSA can contribute to conditions such as hypertension and cardiovascular disease, and consequent healthcare costs.

2.3 Treatment for OSA

The primary treatment option for moderate to severe OSA is Continuous Positive Airway pressure (CPAP) (National Institute for Health and Clinical Excellence, 2008). There are several treatment options available for those with mild OSA, and which can also complement CPAP treatment (bpacnz, 2012.).

2.3.1 Continuous Positive Airway Pressure

Sullivan et al first showed the effectiveness of CPAP in a small clinical trial (Sullivan et al., 1981). CPAP is recommended for people with moderate or severe OSA; the National Institute for Health and Clinical Excellence (NICE) Guidelines recommend it is only to be used in mild cases if other treatment has failed, and if quality of life is affected by symptoms (National Institute for Health and Clinical Excellence, 2008). CPAP is administered via a mask which the patient wears at night while sleeping. The device generates a continual pressure or airflow, which passes into the patient’s upper airway via the mask. This prevents the collapse of the upper airway (Sullivan et al., 1981).
“Compliance” to CPAP is classified as using it for at least 4 hours/night (National Institute for Health and Clinical Excellence, 2008). It is considered the “Gold Standard” treatment, but compliance is suboptimal for several reasons (National Institute for Health and Clinical Excellence, 2008). The mask can be uncomfortable if it fits poorly, or nasal dryness, bleeding or throat irritation may occur, resulting from pressure intolerance (bpacnz, 2012).

In both middle-aged and older adults, CPAP has been shown to improve sleep quality and overall quality of life (McMillan et al., 2014). It is also a cost-effective way to manage and treat the condition (National Health and Medical Research Council, 2000). Observational and intervention studies have also found that CPAP reduces blood pressure over several months, is associated with reduced risk of both fatal and non-fatal cardiovascular events (Coughlin SR, 2007, Marin et al., 2005, Gottlieb et al., 2014), and reduces glycated haemoglobin and cholesterol levels (Sharma et al., 2011). A Meta-analyses of prospective observational studies published in 2013 also found CPAP treatment was associated with decreased cardiovascular mortality (Ge et al., 2013). A recent international study found that CPAP was effective in reducing blood pressure in patients with cardiovascular disease or multiple cardiovascular risk factors (Gottlieb et al., 2014). Many studies have frequently found weight gain occurring following CPAP treatment. This will be discussed further in Section 2.5.

2.3.2 Other Treatments for OSA

Other treatments for OSA include weight loss, dental devices, surgery, reducing alcohol intake, sleep position advice and drug treatments (bpacnz, 2012).
As obesity is a major risk factor for OSA, it would make sense that in theory weight loss should improve OSA or even completely treat the patient.

Trials have shown weight loss to be effective in reducing severity and hence improving quality of life through reduced daytime sleepiness (Chirinos et al., 2014, Hood et al., 2013, Thomasouli et al., 2013, Johansson et al., 2011). In a follow-up to a weight-loss trial, Johansson et al. found that one year later, weight loss as the result of a low energy diet had been maintained by the majority of participants. Obese men who had lost the most weight or at baseline had the most severe OSA experienced the biggest decrease in OSA severity (Johansson et al., 2011). Bariatric surgery is also an option for morbidly obese people as it will reduce obesity, and potentially improve or cure OSA (Lanfranco et al., 2010).

Dental devices may be useful for those suffering mild to moderate OSA, by increasing upper airway size to allow greater airflow into the lungs. Consequently, long-term use of the devices has been shown to reduce AHI and blood pressure (Marklund et al., 2012).

Surgery is sometimes considered appropriate if OSA is caused by enlarged tonsils or tongue, or craniofacial abnormalities. This is of little use to those who are obese and suffering from other co-morbidities (bpacnz, 2012.).
Reducing alcohol intake, especially in the hours before bedtime, is helpful because alcohol promotes relaxation of the upper airway muscles, leading to a higher likelihood of collapse (Wettach et al., 2007).

Drug treatments for daytime sleepiness can be an option, if sleepiness is still an issue despite CPAP compliance. Modafinil has been shown to be very useful alongside CPAP at reducing daytime sleepiness, and use does not affect an individual’s compliance to CPAP (bpacnz, 2012.) (Black, 2003).

2.3.3 Summary
The “gold standard” treatment for OSA, CPAP, has been shown in both observation and intervention studies to reduce co-morbidities and reduce cardiovascular mortality. Compliance may be affected if the mask does not fit properly, or nasal dryness, bleeding, or throat irritation occur from pressure intolerance. Other effective treatments include weight loss, changing sleeping positions, dental devices, surgery, reducing alcohol intake, and drug treatments.

2.4 Current evidence for weight change following CPAP initiation in OSA patients
No studies have been conducted in NZ looking at weight changes resulting from CPAP. Most have been conducted in the US, where obesity is a significant health issue, and a major risk factor for OSA. These studies classified use of CPAP at least 4 hours per night for at least 70% of nights as “compliant”, and all only used subjects who had an AHI >15 (“moderate” OSA). A retrospective cohort, a randomised controlled trial (RCT), and a clinical trial, all found that CPAP was associated with weight gain (Quan et al., 2013, Redenius et al., 2008, Garcia et al., 2011). However there were limitations which may have affected the outcomes.
The multi-centre RCT of Quan et al. had the largest sample size and provides the strongest evidence of the three studies. Eight hundred and twelve participants were randomised to receive either CPAP (intervention) or Sham-CPAP (control) over 6 months. It was concluded that CPAP adherence may lead to some weight gain in OSA patients. However, adherence was suboptimal in both groups (only 35% adherence in entire cohort) (Quan et al., 2013). The primary aim of Garcia et al.’s clinical trial was to investigate the metabolic effects of CPAP in 20 obese subjects, specifically looking at changes to insulin, insulin resistance, and ghrelin. Weight changes were associated with these factors. After using CPAP for 6 months nearly half of the participants had experienced weight gain. It is difficult to know if CPAP was responsible for this given the lack of data on any lifestyle changes participants may have made which could affect body weight. Weight change was also not a primary outcome in this study (Garcia et al., 2011).

Conclusions drawn from Redenius et al.’s 2008 retrospective study stressed that Physicians should not assume CPAP alone will help obese patients with OSA lose weight, and that CPAP may affect weight in ways not measured in the study. The study found that BMI had significantly increased in women and non-obese subjects within one year of successfully using CPAP; no groups lost a significant amount of weight (Redenius et al., 2008).

In 2014, a meta-analysis which included 25 RCT’s and over 3000 participants was published. It showed that there was a significant increase in both BMI and body weight with initiation of CPAP treatment, by 14% and 17% respectively. This result occurred
even after controlling for any diet and exercise counselling, and other potential confounders such as OSA severity, differences in study design, baseline BMI, and CPAP compliance. BMI however was influenced by baseline weight (Drager et al., 2014).

As was explained in Section 2.4, weight gain may occur because CPAP normalises breathing, and so decreases energy expenditure whilst sleeping.

A prospective study with a follow-up period of four to five years concluded that CPAP may facilitate short-term weight loss in overweight or obese people, but that they should be encouraged to lose weight through dietary measures (Loube et al., 1997).

Other studies have found that weight loss in overweight or obese OSA patients has only occurred when participants have had to make a conscious effort to lose weight. Four different studies have found that if participants make a conscious effort to lose weight then this helps lower their AHI and risk factors for co-morbidities (Chirinos et al., 2014, Thomasouli et al., 2013, Johansson et al., 2011, Hood et al., 2013). The RCT published by Chirinos et al. found that a weight loss intervention combined with CPAP had a greater effect on blood pressure and other markers of metabolic syndrome than either intervention alone. It is not certain if CPAP had any role in weight loss (Chirinos et al., 2014). Hood et al. found a possible association between CPAP and weight loss, as participants randomised to a weight loss intervention lost more weight with increased CPAP adherence. However, the overall low CPAP adherence in both groups in this study limited the validity of these results and relevance to the wider population (Hood et al., 2013).
The systematic review and meta-analysis of Thomasouli et al. found that CPAP and diet combined had the greatest effect on weight loss than either intervention alone. Studies which used intensive lifestyle interventions had a greater effect on weight loss than the trials which used intensive dietary intervention and CPAP only (Thomasouli et al., 2013).

As mentioned in Section 2.3.2, Johansson et al. found improvements in the AHI of participants treated with CPAP when intentional weight loss through dietary intervention occurred, and this weight loss was able to be maintained one year after the intervention had ended (Johansson et al., 2011).

The current evidence shows that CPAP contributes to weight gain, and that weight loss only occurs with intensive lifestyle intervention. Studies conducted in this area do have significant limitations. For example, the majority of participants are white males; results may not be relevant to females or relevant to New Zealand’s multi-ethnic society. Poor adherence to CPAP treatment is also an issue.

2.4.1 Summary

Studies led by Quan, Garcia, and Redenius concluded that CPAP was associated with weight gain. However, these studies were potentially affected by poor CPAP adherence, lack of data on lifestyle change, and retrospective design, respectively (Quan et al., 2013, Garcia et al., 2011, Redenius et al., 2008). People with OSA appear to only lose weight when making a conscious effort or using intensive lifestyle interventions. Weight loss appears to be effective in reducing a person’s AHI.
2.5 Proposed mechanisms of how OSA and CPAP might influence weight changes

Understanding mechanisms of how OSA and CPAP may affect body weight can give insight into why weight gain may occur.

It is proposed that when untreated, OSA leads to increased overnight EE in at least two different ways: Chronic Intermittent Hypoxia (CIH), and increased work of breathing due to upper airway resistance.

CIH causes increased sympathetic nerve activity. This leads to an increase in blood pressure, increased muscle activity (Lusina et al., 2006), and possibly endocrine abnormalities (Garcia et al., 2011) through altered release of hormones (Phillips et al., 2000).

Garcia et al. state this may lead to disruption of appetite and weight regulation hormones in people with OSA, which can be corrected through preventing hypoxia via CPAP use. They hypothesised that CPAP will increase levels of hormones that induce weight loss and reduce appetite; specifically that it would reduce insulin resistance and ghrelin levels, and increase adiponectin levels. Leptin levels were also examined for any change. After 6 months of CPAP use, participants’ leptin and ghrelin levels were unchanged, and insulin and insulin resistance surprisingly increased only in those who experienced weight gain. Forty percent of participants who experienced weight loss showed a decrease in insulin and insulin resistance, whilst ghrelin changes were inversely correlated with insulin and insulin resistance (Garcia et al., 2011). While CPAP improved or even eliminated
hypoxia, only body weight changes affected participant’s hormones, meaning OSA doesn’t independently lead to weight or appetite dysregulation.

Phillips et al. found OSA patients had significantly higher muscle sympathetic nerve activity than control subjects, and higher levels of leptin. They hypothesised that because muscle sympathetic nerve activity would likely be higher in OSA patients, that leptin levels would be lower due to suppression of its production (Phillips et al., 2000). This would explain obesity and tendency to gain weight in OSA patients. Higher levels of leptin are produced as a result of increased adipose tissue. It helps weight loss by mediating satiety and leading to excess fat stores being used as energy (Myers et al., 2008). However, the researchers found that both sympathetic nerve activity and leptin levels were higher in OSA patients compared to healthy controls. The study therefore suggests that OSA may be associated with resistance to the effects of leptin, resulting in weight gain. “Leptin resistance” has been suggested to be an underlying mechanism in continuing obesity in sleep apnoea patients, but not involved in the initiation of obesity (Myers et al., 2008).

In a review of OSA and endocrine function, Lanfranco et al summarised leptin resistance. The serum levels or secretory patterns of many hormones are altered in response to obesity, but this alteration is exacerbated when OSA exists. There is evidence that insulin and leptin show increased levels in obesity with OSA, along with decreased levels of adiponectin and insulin-like growth factor-1 (Lanfranco et al., 2010).
Indirect calorimetry with eight OSA subjects and 86 control subjects has found that as hypoxia increased, sleeping metabolic rate decreased (Hins et al., 2006). This also meant that as hypoxia decreased in response to CPAP, sleeping metabolic rate and hence EE increased. However, this result perhaps should not be taken as conclusive due to the low number of OSA subjects. In 2008 Kezirian et al. also used indirect calorimetry to assess EE of 212 OSA patients. Higher resting EE was independently associated with increased AHI and hence increased severity of OSA (Kezirian et al., 2008).

Overnight EE also increases in OSA due to increased work of breathing, as a result of upper airway resistance (Stenlof et al., 1996, Marcus et al., 1994). The increased respiratory effort is also associated with restlessness or “tossing and turning”, as well as excessive perspiration which is also a symptom of OSA (Guilleminault and Abad, 2004).

Energy expenditure (EE) in OSA patients has been measured to try to better understand the effect of OSA and CPAP on weight. Stenlof et al. conducted a small pre- and post-treatment comparison trial with eleven subjects, which found over a period of 3 months that 24-hour EE and sleeping EE was higher for patients with OSA. CPAP normalised breathing and decreased overall restlessness and movement at night, and so decreased EE (Stenlof et al., 1996). Prior to this, Marcus et al. found that young children with untreated OSA had increased EE, which caused faltering growth (Marcus et al., 1994). When OSA is untreated, lethargy and daytime tiredness lead to less physical activity and higher consumption of energy-dense foods (Ong et al., 2013). Booth et al. found that sleep duration is the strongest predictor of daily physical activity (Booth et al., 2012). It has also
been observed that subjective hunger and appetite ratings increase with sleep restriction, as well as favour of high carbohydrate, energy-dense foods; this occurs in proportion to an increase in ghrelin and decrease in leptin (Spiegel et al., 2004).

Perhaps with CPAP, people will make better choices around diet and activity as a result of improved sleep patterns. However, it has been shown that despite improved sleep quality and duration, participant’s dietary habits and activity levels do not substantially change (Ong et al., 2013, Batool-Anwar et al., 2014). Although participants had improved sleep and hence less energy expenditure at night, there was no change in energy expenditure during the day following CPAP initiation (Ong et al., 2013). Quan et al. also propose that there is a reduction in overnight EE when compliant with CPAP, which may lead to some weight gain if energy intake is not modified (Quan et al., 2013).

2.5.1 Summary

EE is higher when OSA is not treated, compared to treatment with CPAP. This has been seen in both children and adults. Changes to endocrine function also occur due to hypoxia, potentially leading to “leptin resistance” and impaired regulation of weight management. Daytime sleepiness and short sleep duration are strong predictors of lower activity levels, increased subjective hunger scores, and favour of energy-dense foods.

CPAP treatment normalises breathing and so reduces EE whilst sleeping. If lifestyle factors remain unchanged after CPAP treatment begins, then weight gain may likely occur.
3. Objective Statement

Obesity is a major cause of OSA. As rates of obesity increase, it can be expected that so too will cases of OSA. Unfortunately, current overseas evidence suggests losing weight may become more difficult when using CPAP, likely due to a decrease in overnight energy expenditure. To the knowledge of the candidate and the Supervisor, no studies have been conducted in New Zealand looking at energy expenditure and CPAP. Therefore the major aim of this pilot study was to determine if a decrease in overnight energy expenditure following the initiation of CPAP treatment in adults with OSA who live in the Wellington area, could be detected.

The primary objectives were to:

- Determine if there are differences in overnight EE before and after initiating CPAP treatment.
- Determine if there is any difference in EI before and after initiating CPAP treatment.
- Determine if there are differences in Total Sleep Time (TST), before and after initiating CPAP treatment.
4. Subjects and Methods

4.1 Study Design

The aim of the study was to determine if there is a decrease in overnight EE upon initiation of CPAP treatment. The study protocol had three stages. In stage one, baseline data were collected for three consecutive days. This included continually wearing the SenseWear® device and completing food and sleep diaries.

In stage two, participants diagnosed with OSA initiated CPAP treatment.

Stage three repeated stage one, while using CPAP treatment and took place at least two weeks after stage two.

4.2 Recruitment of participants

The Human Ethics Committee of the University of Otago approved the study (Ethics Committee reference number H15/018). Prior to participating in the study, written informed consent was obtained from each participant.

23 participants were approached between July and September 2015, using WellSleep referrals and consent to research participation while under WellSleep’s care. Potential participants were contacted by phone and/or email either at least one week prior to a scheduled split night PSG (combined diagnostic test for OSA and CPAP titration), or following diagnostic-only PSG confirming OSA but prior to initiating CPAP.

Participants had to be at least 18 years of age, living within the Wellington area, and have enough literacy and numeracy skills to fill in the food and sleep diaries. Exclusion criteria included having a job involving shift work, having Periodic Limb Movements in Sleep (PLMS), or currently following a specific weight loss programme.
Participant information sheets (PIS) (Appendix A) were given to the WellSleep registrar and other doctors who refer patients to the WellSleep Clinic for suspected OSA, so that patients could have some time to think about participating before they were approached. Participants who were sent an email (Appendix D) also received an attached copy of the Flow chart of the different stages of the study (Figure 4.1) and the PIS, asking them to consider participating in the study and notifying them that the candidate would telephone them later in the week to discuss possible participation.

At the end of the study, participants who had come into the clinic to pick up and drop off the equipment were given a $20 MTA gift voucher to reimburse travel costs to and from the clinic. Contact for appropriate dietetic advice was provided if requested. SenseWear® reports were sent to participants who were interested in seeing their results at the end of the data collection period.
Study flow chart for patients in the Energy Expenditure Study:

Prior to starting the study:
- Meet with Stacey (Masters Student) to have explanation of study.
- Explanation of how to use armband and food diary.

Day 1-3:
- Wear armband continuously.
- Complete a food diary at each meal/snack (including drinks).
- Complete sleep diary at the end of each night.

Day 4 (evening):
- Have Sleep Study at WellSleep Clinic to confirm OSA diagnosis.

Next 4 weeks:
- If OSA diagnosed; use CPAP each night aiming for at least 4 hours/night.

After 4 weeks, Day 1-3:
- Wear armband continuously.
- Complete a food diary at each meal/snack (including drinks).
- Complete sleep diary at the end of each night.
- Continue using CPAP each night.

If you have any questions you can contact Stacey on (04) 9208819 or edwst898@otago.ac.nz

Figure 4.1: Flow chart of the different stages of the study and approximate time period of each stage.
**4.3 Data Collection**

Once participants had been contacted and expressed interest in participating, they attended the clinic at least four days prior to their scheduled split PSG or CPAP initiation. During this visit they were taught how to wear the SenseWear® device (Appendix H) and how to complete the food and sleep diaries. If they were unable to come into the clinic, the candidate arranged to visit the participant in their home.

The candidate allocated each participant an identification code to use for all data entry and analysis. Demographic information (age, sex, ethnicity (self-designated)), BMI, and existence of co-morbidities were collected using participant’s medical notes upon recruitment. Any missing or unclear data was obtained from the participant during their clinic visit. NZ Deprivation Index was assigned according to the 2013 Statistics New Zealand Census data. Each participant’s address was entered into the Statistics New Zealand Classification Coding System (v 4.0.2), using the ‘manual search’ option followed by ‘Geographic – Streets MB13’. A score out of 10 was assigned for each address, in which 1 indicated the lowest level of deprivation and 10 indicated the highest level.

In the appointment, the participant was asked to read and sign the consent form (Appendix C) once they had read the information sheet and had any questions answered. They were given a folder containing a Sleep Diary with instructions (Appendix G), a food record and diet assessment photo book (Appendix F) and the SenseWear® device with armband (Appendix H).
At the end of Stage one, the participants returned the diaries and the SenseWear® device to WellSleep. They then collected their CPAP/Auto-PAP machine, or had their scheduled split PSG.

If undergoing a ‘diagnostic only’ study, initially this was performed either at WellSleep or at home. A study carried out in an individual’s home had all the same measurements as one carried out at WellSleep except for video recording. Polysomnography consisted of the following measurements: Electroencephalogram, Electromyogram, Electro-Oculogram, heart rate, Nasal and oral airflow, respiratory effort, leg movements, body position, sound (to hear snoring), and oxygen saturation. If the participant was put on CPAP treatment during the night (a ‘split night’ study), then CPAP pressure, mask leak and airflow were also assessed as per WellSleep study protocol.

Following a ‘split night’ study, participants began CPAP use at home the following night (stage two). After home or diagnostic only studies, the participant initiated CPAP treatment as soon as convenient once OSA diagnosis was confirmed by the Sleep Physician responsible for the area. An appointment was made for the participant to return to the clinic to begin stage three once they had been on CPAP for at least 14 nights.

For stage three, the participants picked up a second food and sleep diary, and the SenseWear® device. They were asked to collect data on the same days of the week as they did in stage one, and to keep using their CPAP machine for this time.
When the participants returned their materials at the end of stage three, they were also asked to bring in their CPAP data card, so usage data could be downloaded per participant and use of CPAP determined. CPAP compliance in this study was defined as use of the machine for at least four hours on average during stage three. Usage data from CPAP and Auto-PAP machines was downloaded from the machines data card using the appropriate company software. This generated a report of how many nights the machine had been used and average number of hours of use each night, both during stage two and three.

4.3.1 SenseWear Device®

The participants were instructed to wear the SenseWear® device consecutively for three days and nights, and to remove the device only when showering or bathing. In the initial appointment, the device was trialled on the non-dominant arm to ensure the armband was the right fit and to show participants how it was to be worn; on the mid upper arm, so that the device had contact with the triceps muscle. It was explained that SenseWear® was for assessing EE and total sleep times (TST). The participants’ name, birthday, sex, handedness, weight and height (self-reported or measured) were entered into the SenseWear® program and loaded onto the device to aid EE monitoring.

The SenseWear® device gives accurate and continuous data for monitoring sleep and activity patterns in a person’s own environment (Sunseri et al., [No date]). SenseWear® has high reliability and validity, is accurate at detecting differences between sleep and sedentary activity, and can detect sleep onset, wake time, and total sleep time (Sunseri et al., [No date]).
The SenseWear® device has several different sensors to assess multiple physiologic changes that mark changes in EE, making it more reliable and precise compared to other available instruments for assessing a person’s lifestyle (Liden et al., [No date]). It has an accelerometer which measures the wearer’s motion and steps; a thermistor-based sensor which measures skin temperature; a near-body ambient temperature sensor which measures the air temperature immediately around the armband, to detect the environment conditions the wearer is in; a galvanic skin response sensor to assess skin conductance, which is affected by sweat from physical activity and emotional stimuli; and a heat flux sensor which measures heat being dissipated by the body (Sunseri et al., [No date], Liden et al., [No date]). BMI, handedness (left or right handedness), smoking status, age and sex data are programmed into the device via computer to help calculate EE of the Wearer (St-Onge et al., 2007).

Using a variety of subjects with different medical conditions (for example, Type Two Diabetes and Chronic Obstructive Pulmonary Disease), SenseWear® has been found to have correlated well against indirect calorimetry in many laboratory tests. An average error of 3% was found compared to indirect calorimetry during exercise periods (Andre et al., 2006). The armband also provides day-by-day data to calculate EE, unlike indirect calorimetry methods such as Doubly Labelled Water (St-Onge et al., 2007).

4.3.2 Sleep Diary

Participants were also given sleep diaries to self-measure periods of sleeping and waking. Instructions with an example night were attached to help participants fill in the diaries. The diary was one used regularly by WellSleep for all patients.
4.3.3 Estimated food record

Participants were given a food diary with instructions and a ‘Diet Assessment Photo’ book, both created by the University of Otago Human Nutrition department. The book was to help participants with estimating portion sizes; it contains photos of different portion sizes of commonly consumed foods, including meat, rice, mixed vegetables, and cornflakes, and differing thickness of spreads on bread. Circles of different diameters are included to measure round foods such as apples, and a graph with measurements to measure square foods, such as slices of cheese. Each book also contained a sheet stating the weight of each portion size of every food shown in the book, for the candidate’s use. Food diaries were to be filled out according to the instructions provided with them, for the period the participants were wearing the SenseWear® device. If a participant forgot to take their food diary with them somewhere, or it was inconvenient to do so, they were instructed to record the data as best as they could on their cellphone using a note-taking app such as Evernote, and/or take a photo of the food to help them fill in the food diary later in the day.

Estimated food records are one of several methods of dietary assessment.

The participant records all food and beverages as they are consumed, the estimated amount, and other details of the food or beverage such as brand and method of preparation or cooking if applicable. A combination of the following can be used to determine portion sizes of foods: cup, spoon, or ruler measurements; labels on packaging; and photos of foods of various portion sizes. However, underreporting can occur due to incorrect
quantifying of portion sizes, lack of detail about food or beverage items, and undereating due to the burden of recording (Gibson, 2005).

4.4 Data Entry

At the end of both stage one and stage three for each participant, data from the SenseWear® devices were exported to a computer via USB cable for analysis in the SenseWear® Professional 8.1 program by Bodymedia®.

At the end of stage one, information on the three sleep periods of each participant (according to their sleep diary) were downloaded as graphs, and from this kilojoules expended per hour of sleep was calculated.

At the end of stage three, energy expenditure during the hours of sleep when CPAP was used was determined. From this, the kilojoules expended per hour of CPAP use were calculated.

In both stage one and three, TST was also collected from SenseWear® data.

Data from food diaries was analysed using the program Kai-culator (Version 1.11), developed by the University of Otago’s Department of Human Nutrition. Kai-culator uses the New Zealand Plant and Food Research FOODfiles to analyse dietary information. It includes information on the composition of foods available in New Zealand.

Diet records were entered under the participant’s identification code, and the amounts of foods and beverages were entered using grams or millilitres. If anything in the diet records
was unclear or in not enough detail, the participant was emailed and asked for clarification about the specific items in order to improve energy intake estimation. Kilojoule intake for two 24 hour periods was measured, and the average of the two periods recorded.

4.5 Statistical Analysis

All data collected was then recorded into a Microsoft Excel 2010 spreadsheet for further analysis. The statistical program SPSS (v. 22) was also used for analysis. Means and standard deviations were calculated using both programs. Percentages were calculated for categorical characteristic variables. Paired t-tests were used to calculate differences in both EE and EI before and after use of CPAP. Variables were checked for normality by producing histograms and box and whisker plots.

Comparisons between stage one and stage three EE, EI, TST, and SenseWear wearing time were calculated using Paired samples t-tests, assuming normal distribution.

The average hours of CPAP use between those who experienced an increase in EE and those who experienced a decrease was calculated using Independent samples T-test, using Levene’s test for Equality of Variances. A Mann-Whitney Test was also used in case of non-normal distribution.

The strength of relationship between CPAP use and change in EE was assessed using the Pearson correlation coefficient. Due to the very small sample size, EE and CPAP use could not be analysed for association with gender, ethnicity, or co-morbidity.
5. Results

In total, 15 participants were recruited between July and September 2015. Of these, four were excluded from the study; one participant did not have an OSA diagnosis after their PSG, one chose not to complete the study, and two did not use their prescribed CPAP treatment. Completion rate was therefore 73%.

5.1 Participant and Demographic data

Table 5.1 summarises participant characteristics. Participants were predominantly male, and New Zealand European (90.9%). Mean ESS score was 9.1/24 ± 5.9. The majority of participants were in quintiles 1-3 (out of 10) of the NZ Deprivation Index (least deprived). All participants had a BMI classified as overweight or obese. 41.6% had one or more co-morbidity, the most common of which was hypertension.

<table>
<thead>
<tr>
<th>Table 5.1: Participant characteristics a (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years</td>
</tr>
<tr>
<td>Male (%)</td>
</tr>
<tr>
<td>Ethnicity (%)</td>
</tr>
<tr>
<td>NZ European</td>
</tr>
<tr>
<td>NZ Maori</td>
</tr>
<tr>
<td>NZ Deprivation Index (/10) (%)</td>
</tr>
<tr>
<td>1-3</td>
</tr>
<tr>
<td>4-6</td>
</tr>
<tr>
<td>7-10</td>
</tr>
<tr>
<td>ESS (/24)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
</tr>
<tr>
<td>Co-morbidities present (%)</td>
</tr>
<tr>
<td>Hypertension</td>
</tr>
<tr>
<td>Type II Diabetes</td>
</tr>
<tr>
<td>Hypercholesterolaemia</td>
</tr>
</tbody>
</table>

a Results are presented as mean (SD) for continuous values and % for categorical values.
5.2 Dataset Completion

Sunday and Saturday were the most common days of the week of which data were collected (Table 5.2). No data were collected on a Wednesday in stage one, but in stage three they were as one participant forgot to start collecting on the right day.

<table>
<thead>
<tr>
<th>Day of week</th>
<th>Frequency of recording</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stage one</td>
</tr>
<tr>
<td>Sunday</td>
<td>8</td>
</tr>
<tr>
<td>Monday</td>
<td>6</td>
</tr>
<tr>
<td>Tuesday</td>
<td>4</td>
</tr>
<tr>
<td>Wednesday</td>
<td>0</td>
</tr>
<tr>
<td>Thursday</td>
<td>4</td>
</tr>
<tr>
<td>Friday</td>
<td>6</td>
</tr>
<tr>
<td>Saturday</td>
<td>8</td>
</tr>
</tbody>
</table>

Oxygen desaturation and AHI were assessed during PSG, as part of OSA diagnosis. Mean oxygen desaturation associated with respiratory events was 6.36% ± 3.1. Most subjects were diagnosed with severe OSA (AHI>30). Mean AHI was 41 ±18.5 (Table 5.3).

<table>
<thead>
<tr>
<th>AHI</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;16/hour</td>
<td>0</td>
</tr>
<tr>
<td>16-29/hour</td>
<td>3</td>
</tr>
<tr>
<td>30+/hour</td>
<td>8</td>
</tr>
</tbody>
</table>

Mean Oxygen Desaturation associated with a respiratory event (%) 6.36%

5.2.1 Use of SenseWear

During stage one, SenseWear devices were worn on average for a total of two days 20 hours.

In stage three, the average time was a total of two days 19 hours.
There was no significant difference between the duration of the two wear times (p=0.61).

5.2.2 Sleep Diary and Estimated Diet Record Completion

All participants recorded sleep and wake times for at least three consecutive nights for both stage one and stage three, with the exception of one participant who forgot to complete the diary in stage three.

All participants completed at least three consecutive days of estimated diet records in stage one and stage three.

5.2.3 CPAP use

Average CPAP pressure, average length of stage two, and mean hours that CPAP was used by participants over the three nights of stage three are shown in Table 5.4.

The mean length of stage two (CPAP initiation) was 30.8 days ± 15.1.

During stage three, CPAP was used on average for over five hours each night. Of the 11 participants, only two used CPAP for less than 4 hours per night on average.

In the three nights recorded in stage three, six of the participants had at least one night where they used CPAP for less than 4 hours.

<table>
<thead>
<tr>
<th>Table 5.4: CPAP use and machine pressure a</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPAP pressure (cm H$_2$O)</td>
</tr>
<tr>
<td>Mean length of stage two (days)</td>
</tr>
<tr>
<td>Mean CPAP use in stage three (hours/night)</td>
</tr>
</tbody>
</table>

aResults are presented as mean (SD).
5.3 Differences in sleep time, EE, and EI.

Table 5.5 below shows differences in: \( \text{TST}_{\text{SW}} \) (period that SenseWear determined participant was sleeping); \( \text{TST}_{\text{SD}} \) (period that participant was asleep, according to subjective sleep diary); kilojoule consumption (EI); and kilojoule expenditure (EE) per hour of sleep, both before and during CPAP. There was no significant difference between stages one and three for any of these variables.

Table 5.5: Summary of Total Sleep Time, Energy Intake, and Energy Expenditure before and after initiation of CPAP

<table>
<thead>
<tr>
<th></th>
<th>Before CPAP (Stage 1)</th>
<th>After CPAP (Stage 3)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{TST}_{\text{SW}} ) (hours)</td>
<td>5.73 (1.2)</td>
<td>5.87 (1.2)</td>
<td>0.77</td>
</tr>
<tr>
<td>( \text{TST}_{\text{SD}} ) (hours)</td>
<td>7.95 (0.93)</td>
<td>7.96 (1.15)</td>
<td>0.98</td>
</tr>
<tr>
<td>Kilojoule consumption per 24 hour period</td>
<td>9629 (3130)</td>
<td>9271 (2107)</td>
<td>0.74</td>
</tr>
<tr>
<td>Kilojoule expenditure per hour TST</td>
<td>351 (86)</td>
<td>340 (82)</td>
<td>0.36</td>
</tr>
</tbody>
</table>

\( \text{TST}_{\text{SW}} \) = Total Sleep Time according to SenseWear data (objective). \( \text{TST}_{\text{SD}} \) = Total Sleep Time according to Sleep diary data (subjective). * Results are presented as mean (SD).

5.3.1 Energy Expenditure

Overall, six participants experienced a decrease in EE (mean % change), all of whom used their machine on average for over four hours each night.

Five experienced an increase in EE (mean % change), three of whom used their machine more than four hours a night on average.

Between these two groups there was no significant difference in hours of CPAP use (p=0.275). However a significant correlation was found between hours of CPAP use per
nights, and change in overnight energy expenditure; EE between stage one and stage three decreased more with greater CPAP compliance (p=0.017). A very similar result was found for percentage decrease in EE (p=0.014).

Figures 5.1 and 5.2 respectively show the correlation between average hours CPAP use, with percentage change in EE, and change in EE, per hour of CPAP use.

Figure 5.1: Correlation between average hours of CPAP use per night, and percentage (%) change in Energy Expenditure per hour of CPAP use
Figure 5.2: Correlation between average hours of CPAP use per night, and change in Energy Expenditure per hour of CPAP use

Both body weight (kg) and BMI (kg/m²) had a positive correlation with EE per hour of sleep before beginning CPAP (Figure 5.3 and 5.4). BMI did not have a significant correlation with change in EE during CPAP use (p=0.58).
Figure 5.3: Correlation between Energy Expenditure and body weight (Kg) before beginning CPAP treatment

Figure 5.4: Correlation between Energy Expenditure and BMI (kg/m²) before beginning CPAP treatment
BMI did not have a significant correlation with change in EE during CPAP use (p=0.577) (Figure 5.5).

Figure 5.5: Correlation between BMI, and change in Energy Expenditure per hour of CPAP use
Figure 5.6 shows EE per hour of sleep both before and during CPAP use for each of the 11 participants.

Figure 5.6: Energy Expenditure per hour of sleep before and during CPAP use for each participant

Energy expenditure at baseline (before CPAP) ranged from 205 KJ/hour to 516 KJ/hour. Three control subjects who trialed the SenseWear devices overnight had an average EE of 254.1kj/hour. Two subjects had an EE/hour value lower than this before CPAP. This is shown in Figure 5.7. The horizontal line shows the average EE of the three controls.
5.3.2 Energy Intake

Average EI was 9629 KJ per day in stage one, and 9271 KJ per day in stage three. As was shown in Table 5.5, there was no significant difference between these two values. Some participants however did show a dramatic change in EI between the two phases. This can be seen below in Figure 5.8, which shows the EI of each participant in each phase. Takeaways and fast food were consumed more often during the phase where the participant had a larger EI.
Figure 5.8: Energy Intake of each participant over 24 hours, before and after initiating CPAP
6. Discussion and Conclusion

Main findings

This study was the first in New Zealand to attempt to measure energy intake and energy expenditure in OSA before and after CPAP treatment initiation. Some results of this study are inconsistent with results of previous overseas studies (Hins et al., 2006, Stenlof et al., 1996); we found for this group of subjects no significant difference between the energy expended overnight before and after initiating CPAP, but that decreased EE was associated with greater CPAP use. There is evidence from this study that CPAP has a role in decreasing energy expenditure in people with OSA, particularly in those who are more compliant with the treatment. The implications are that in the long-term, this could result in potentially significant weight gain if energy intake and/or daytime energy expenditure remain unchanged.

Though this study was only of short duration, the average energy intake of participants did not significantly change before and after CPAP initiation. This adds to the body of evidence that people with OSA do not necessarily change their eating habits or lifestyle upon diagnosis of OSA and initiating CPAP treatment. Therefore structured intervention and guidance by a Health professional is needed for this to happen, as noted in previous research. (Johansson et al., 2011, Chirinos et al., 2014, Hood et al., 2013, Thomasouli et al., 2013).

Individuals with a higher BMI have a higher metabolic rate, as they have greater fat-free mass than those with a lower BMI. If an individuals’ energy intake decreases (drastically
and suddenly, or gradually over time), loss of fat-free mass will occur and their metabolic rate will consequently decrease (Prentice, 2012). In this study, changes in overnight energy expenditure are attributed to CPAP use, as there was no significant change in EI. Other studies have not measured EI directly so it is uncertain if participants changed their diet at all during the study period. In terms of diet and exercise counselling, the meta-analysis by Drager et al. found that CPAP alone was associated with change in body weight, regardless of the counselling (Drager et al., 2014). However, as EI was not measured it is difficult to know if participants experienced any change in EI.

This study had several limitations which may have contributed to the lack of statistically significant difference between EE per hour of sleep, before and after CPAP initiation. Firstly, sample size was smaller than anticipated, as four of the fifteen subjects did not complete the protocol. The study by Stenlof et al. also had only 11 participants, but the study ran for three months (Stenlof et al., 1996), possibly allowing further time for adaptations to occur compared to the current study. Participants in the current study used CPAP on average for less than one month before the next stage of data collection. The reason for this is that this study was designed as a pilot and was constrained by the candidate’s research period of five months.

A second limitation of this study was CPAP compliance. Only four participants used CPAP for at least four hours or more for all three nights. Three further participants used CPAP for over four hours, during one night only. Previous studies have defined CPAP compliance as over four hours per night (Quan et al., 2013, Redenius et al., 2008, Garcia
et al., 2011). Therefore almost two thirds of participants in this study were not compliant with CPAP. Some participants explained when returning materials at the end of stage three that they had used their machine “very little” due to being unwell. Given this study involved the use of CPAP while measuring energy expenditure, the level of compliance may not have been high enough to show significant differences in the small sample. The proposed ways in which EE increases during OSA (Chronic Intermittent Hypoxia and increased work of breathing) would still have been an issue during this period. Even though BMI was not significantly related to EE, there is a trend for participants with the higher BMI’s to have greater overnight EE (before initiating CPAP) compared to subjects with lower BMI’s. Those with higher BMI’s (>30kg/m²) tended to experience a greater decrease in EE with CPAP treatment than participants with lower BMI’s. If the current study was repeated with a larger sample size, this might show significance, and demonstrate that those with a higher BMI are at a greater disadvantage for attempting to lose weight when they begin CPAP treatment.

Data collection success rate was high, as only 15 minutes of data were lost during sleep from one participant while wearing the armband, due to the SenseWear® being too loose on his arm. This also happened in a study in adolescents published this year by Roane et al, which also used SenseWear® devices (Roane et al., 2015). No more than 2-3 minutes of data were lost from other participants during sleep in the current study. Our results showed no difference in Total Sleep Time between stages one and three. This was measured subjectively via sleep diary, and objectively via SenseWear. Therefore we conclude the participants did not decrease their sleep time with CPAP use. This was not
surprising due to the poor CPAP compliance. Roane et al also measured variability in Total Sleep Time (TST), but only did so objectively through use of SenseWear® and other actigraph devices.

Several of the participants overnight EE recordings were within the range of control subjects, therefore it is likely that they had less room to decrease their overnight EE to start with i.e. a floor effect was seen, and this would have contributed to the lack of statistical significance.

Despite these limitations, there were major strengths in the study design. A major strength was the use of the SenseWear® device to assess sleep patterns. SenseWear® has high reliability and validity when detecting sleep parameters (Sunseri et al., [No date]). A recent study in a group of 20 US adolescents showed that SenseWear® was accurate in estimating sleep duration for groups of people. Compared to PSG, there were no significant differences for any of the sleep parameters measured (Roane et al., 2015). An internal company SenseWear® research paper found that sleep data from SenseWear® had a 91.9% similarity to PSG data (Sunseri et al., [No date]). The participants sleep and wake times for stage one and two of data recording that were detected by the device were close to those recorded in the sleep diaries.

Diet records are a validated method of measuring energy intake and considered the “Gold Standard” in diet assessment (Gibson, 2005). Estimated records are not as reliable as weighed records due to greater risk of under- or over-estimation of portion sizes. However
weighed records would not have been appropriate for this population due to the high level of respondent burden. The diet records were checked for completeness when handed in, and participants were asked via email or in person during a clinic visit about any potentially incomplete data to ensure the diet data collected was as accurate as possible.

A further limitation of the study is that SenseWear® may not be completely accurate in measuring EE in the current study’s population. In terms of EE data, it has been found in previous trials that SenseWear® provides valid and reliable EE estimates for men and women of healthy body weight, but that individual error is large (Fruin and Rankin, 2004), and that SenseWear® is not the most accurate method of measuring EE in obese people (Papazoglou et al., 2006). SenseWear® has been shown to be reliable when used with subjects with varied medical conditions (Andre et al., 2006). However O’Driscoll et al point out that SenseWear has not specifically been validated for EE in OSA patients (O’Driscoll et al., 2013). As this was a pre- and post- trial on individuals, it is possible that this error was low as data was paired.

The days of the week where data were collected may not be representative of usual energy intake or sleep pattern. For most participants two weekend days were included as part of the three days of recording. This was often because their PSG was scheduled for a Sunday or Monday evening and so they were required to come into the clinic on Thursday or Friday to collect the diaries and SenseWear. Weekends are a time of the week when EI is greatest and EE lower, compared to weekdays (Racette et al., 2008, Gibson, 2005). Some participants had a large variation in EI between stage one and three; for example, one
participant had a high EI in stage one due to a high intake of alcohol. Takeaway and fast food consumption that occurred during one recorded weekend, but not during the other weekend, also account for some difference between the two stages. Another participant had a very low energy intake in stage one (2540KJ/day) as he had decided at the time to severely restrict food intake to try and lose weight. However in stage three his EI was much higher (9205KJ/day). To ensure equal comparison between stage one and stage three, the days of the week recorded in each stage were the same.

The present study had no control group of overweight/obese patients without OSA, or OSA patients not using CPAP, also due to time constraints and availability of equipment. In particular there would not have been enough SenseWear® devices available to include a control group.

**Implications for further research**

A larger sample size and a longer study period would allow further time for changes to manifest. A longer study period may allow changes in metabolism to become established, and compliance with treatment to be more consistent. Another factor to consider would be carrying out the study during a time of year when illness from the cold virus is not so prevalent, as this was cited by participants as a major reason for not using CPAP at least four hours per night.

A study which involved a gold standard measure of energy expenditure may also yield different results. This would involve admitting patients to a metabolic chamber each night for sleep with the use of an indirect calorimeter to provide accurate EE data. This would
be a far more burdensome and expensive study, and would provide data in a controlled clinical setting rather than a free-living one. Incorporating Sham-CPAP into the study would provide evidence for changes in EE over time. This technology was not available to the current study. A control group of overweight/obese subjects without OSA is also something to be considered for future research. This would allow comparison of energy expenditure between the two groups, and further determine the extent to which EE is increased in OSA, and how much it decreases with CPAP treatment.

**Conclusions**

This study found that CPAP treatment significantly decreased both the change and percentage change in EE between stage one and stage three (before and during CPAP treatment, respectively) when controlling for CPAP use. There was no change in participants TST or EI between stage one and three. These findings indicate there is the potential for weight gain to occur on CPAP treatment, particularly if EI and daytime EE remain unchanged.

Limitations of this study were poor CPAP compliance and small sample size. However some individual results show a drastic reduction in EE upon establishing CPAP, with average compliance over four hours per night. These subjects are at significant risk of weight gain.

This study highlights the need for further studies, which have a longer time frame and greater number of participants, to provide more evidence on the relationship between CPAP and its effect on EE. It also shows the need for a multidisciplinary approach to the use of CPAP for the treatment of OSA. Specific dietary input in this group is likely to be the best intervention to prevent the possibility of CPAP use induced weight gain.
7. Application to Dietetic Practice

As the proportion of overweight and obese New Zealanders increases, so too will the proportion of our population with OSA. Currently, newly diagnosed patients are advised by their Doctor to lose weight as this can help improve OSA severity; however no specific nutrition and lifestyle advice or intervention is necessarily given to patients to help encourage and motivate lifestyle change.

This study provides some evidence toward the need for intensive lifestyle intervention to be administered to people with OSA who are overweight or obese. Treatment with CPAP alone will not lead to lifestyle change or weight reduction for OSA patients. Patients need to be targeted for nutrition and lifestyle intervention shortly after OSA diagnosis, so that along with CPAP, there is further improvement in quality of life.

Firstly, there should be promotion of OSA as a health issue and co-morbidity of obesity to increase awareness amongst Dietitians.

Continuing to advocate for, and implement, public health policy and legislation to tackle rising rates of overweight and obesity is a major way Dietitians can help prevent people from developing OSA. They can also work with stakeholders to help implement community initiatives, for example Fruit and Vegetable co-ops, which in turn Dietitians can promote to their clients.
Dietitians can give evidence-based nutrition and weight loss advice and interventions to help clients with weight loss or weight maintenance, to prevent OSA from developing or to improve severity for current OSA patients. This will also importantly aid in prevention of other co-morbidities that may be seen alongside OSA, such as hypertension and Type II Diabetes.
8. References


SMYTH, C. 2012. The Epworth Sleepiness Scale (ESS), The Hartford Institute for Geriatric Nursing, New York university, College of Nursing.


SUNSERI, M., LIDEN, C. B., FARRINGDON, J., PELLETIER, R., SAFIER, S., STIVORIC, J., TELLER, A. & VISHNUBHATLA, S. [No date]. The SenseWear Armband as a sleep detection device.


9. Appendices

A. Participant Information Sheet (PIS)
B. Ethics form
C. Consent form
D. Email sent to participant if it was the first form of contact
E. Email sent to participant if first contact made via phone
F. University of Otago 4 day Food Record with instructions
G. WellSleep Sleep diary and instructions
H. Photo of SenseWear® device on armband
I. Example of 24 hour EE graph produced by SenseWear Professional program by BodyMedia (from participant ID 102 in phase 2)
Appendix A

Participant Information Sheet (PIS)
Participant Information Sheet

Study title: Activity levels and food intake in people with obstructive sleep apnoea

Principal investigator: Dr Angela Campbell, WellSleep, Department of Medicine, Laboratory Manager

Contact phone number: (04) 9208819

Introduction

Thank you for showing an interest in this project. Please read this information sheet carefully. Take time to consider and, if you wish, talk with relatives or friends, before deciding whether or not to participate.

If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you and we thank you for considering our request.

What is the aim of this research project?

The aim of this study is to look at energy changes in people with Obstructive Sleep Apnoea (OSA) before and after treatment (CPAP machine). We know that some people when they start using the CPAP device lose weight and some gain weight. The study hopes to understand more about how this change occurs and hopefully provide information to assist with weight loss after treatment with this device (CPAP) has been started.

Who is funding this project?

The study is being undertaken as part of a student Masters in Dietetics project. We have some money from the Wellington Medical Research Foundation to cover the costs of the device you will wear during the study.

Who are we seeking to participate in the project?

We wish to recruit subjects who are suspected of having Obstructive Sleep Apnoea (OSA) for this study. If your referring Doctor thinks there is a high chance of you having Obstructive Sleep Apnoea and needing treatment with the CPAP machine then you may be eligible to take part.

If you participate, what will you be asked to do?

If you agree to take part in this study, you will be asked to wear a small device on your upper arm for 3 days and nights before your sleep study and for 3 days and nights after your sleep study, once you have been using CPAP for a month and while using your CPAP machine during sleep. During these times we will also ask you to keep a record of the food that you eat. Your participation in this study is voluntary and you can stop taking part at any time – this will not affect your care in any way.
Is there any risk of discomfort or harm from participation?

The device that is worn on your arm is comfortable and we do not see any risks associated with taking part in this study.

What specimens, data or information will be collected, and how will they be used?

Information from your sleep study will be used in this study to tell us how many times you stop breathing during the night and also how well the CPAP machine is working for you. The device you wear on your arm will tell us how much physical activity you get during the day and how much sleep you get at night. This device has a soft material cover and slides on and off from your upper arm. The sensor built into the soft cover is a little larger than the size of a standard watch and therefore can sit easily under your shirt during the day.

What about anonymity and confidentiality?

Once you have agreed to take part in the study your information will be assigned and stored only under a code which means you will not be able to be identified. No results will include any information that would lead to you being identified.

If you agree to participate, can you withdraw later?

You may withdraw from participation in the project at any time and without any disadvantage to yourself.

Any questions?

If you have any questions now or in the future, please feel free to contact either:

<table>
<thead>
<tr>
<th>Name: Angela Campbell</th>
<th>Contact phone number:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position: Principal Investigator</td>
<td>......(04) 9208819......</td>
</tr>
<tr>
<td>Department: WellSleep</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Name: Stacey Edwards</th>
<th>Contact phone number:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position: Masters Student</td>
<td>......(04) 9208819......</td>
</tr>
<tr>
<td>Department: WellSleep and Dietetics</td>
<td></td>
</tr>
</tbody>
</table>

This study has been approved by the University of Otago Human Ethics Committee (Health). If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (phone +64 3 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.
Appendix B

Ethics approval
Dr A Campbell  
Department of Medicine (Wgnt)  
Faculty of Medicine  
University of Otago, Wellington

25 February 2015

Dear Dr Campbell,

I am again writing to you concerning your proposal entitled "Energy expenditure in obstructive sleep apnoea", Ethics Committee reference number H15/018.

Thank you for your letter of 23rd February 2015 addressing the issues raised by the Committee.

The Committee thanks you for providing the documentation that was sent to the Wellington Medical Research Foundation (W MRI) as part of the funding application alongside copies of the peer reviews conducted for the study.

The Committee appreciates the clarification given in respect of how informed consent will be obtained and notes the revisions made to the Information Sheet. The Committee accepts the use of the lay title ‘Activity levels and food intake in people with obstructive sleep apnoea’ on the Information Sheet.

On the basis of this response, I am pleased to confirm that the proposal now has full ethical approval to proceed.

The standard conditions of approval for all human research projects reviewed and approved by the Committee are the following:

Conduct the research project strictly in accordance with the research proposal submitted and granted ethics approval, including any amendments required to be made to the proposal by the Human Research Ethics Committee.

Inform the Human Research Ethics Committee immediately of anything which may warrant review of ethics approval of the research project, including: serious or unexpected adverse effects on participants; unforeseen events that might affect continued ethical acceptability of the project; and a written report about these matters must be submitted to the Academic Committees Office by no later than the next working day after recognition of an adverse occurrence/event. Please note that in cases of adverse events an incident report should also be made to the Health and Safety Office:

http://www.otago.ac.nz/healthandsafety/index.html
Advise the Committee in writing as soon as practicable if the research project is discontinued.

Make no change to the project as approved in its entirety by the Committee, including any wording in any document approved as part of the project, without prior written approval of the Committee for any change. If you are applying for an amendment to your approved research, please email your request to the Academic Committees Office:

gary.witte@otago.ac.nz

to.farronediaz@otago.ac.nz

Approval is for up to three years from the date of this letter. If this project has not been completed within three years from the date of this letter, re-approval or an extension of approval must be requested. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing.

Yours sincerely,

[Signature]

Mr Gary Witte
Manager, Academic Committees
Tel: 479 8256
Email: gary.witte@otago.ac.nz

c.c. Assoc. Prof. S Mann Head of Department and Associate Professor of cardiovascular medicine Department of Medici
Appendix C

Consent Form
LlVES Study – Lifestyle and sleep in OSA

Principal Investigator: Dr Angela Campbell wellsleep@otago.ac.nz (04) 9208819

CONSENT FORM FOR PARTICIPANTS

Following signature and return to the research team this form will be stored in a secure place for ten years.

Name of participant: ..................................................

I have read the Information Sheet concerning this study and understand the aims of this research project.

1. I have had sufficient time to talk with other people of my choice about participating in the study.

2. I confirm that I meet the criteria for participation which are explained in the Information Sheet.

3. All my questions about the project have been answered to my satisfaction, and I understand that I am free to request further information at any stage.

4. I know that my participation in the project is entirely voluntary, and that I am free to withdraw from the project at any time without disadvantage.

5. I know that as a participant I will:

   Wear an energy sensing device on my arm for 3 days and nights on two occasions. I will during these two occasions also keep a food diary and a sleep diary.

6. I know that when the project is completed all personal identifying information will be removed from the paper records and electronic files which represent the data from the project, and that these will be placed in secure storage and kept for at least ten years.

7. I understand that the results of the project may be published and be available in the University of Otago Library.

8. I know that there is no remuneration offered for this study, and that no commercial use will be made of the data.

Signature of participant: ___________________________ Date: ___________________________
Appendix D

Email sent to participant if it was the first form of contact
Dear XXX,

My name is Stacey Edwards and I am a Master of Dietetics student at the University of Otago. I am doing my thesis at the Wellsleep Clinic at Bowen Hospital.

I am currently looking for people willing to participate in my research. The study is looking at energy (calorie) expenditure changes in people with Obstructive Sleep Apnoea (OSA) before and after starting treatment with a CPAP machine. Some people when they start using the CPAP device lose weight and some gain weight. The study hopes to understand more about how this weight change occurs and hopefully provide information to assist with weight loss after treatment with this device (CPAP) has been started.

I have attached a Participant Information Sheet, and also a flowchart that shows the timeline of events over the course of the study. Please have a read over these and think about whether or not you would be interested in participating. The study would require you to briefly come into the clinic for approximately 20 minutes to have a debrief with me and explanation on using the armband and food/sleep diaries (the first box on the flow chart). We will reimburse you with a $20 petrol voucher if you do manage to complete 3 full days of food/sleep diaries.

I will give you a call later this week to have a chat and ask if you would be interested in participating. It is entirely up to you whether or not you want to participate. If you do agree to participate but later change your mind, you can drop out of the study at any time you choose with no disadvantage or consequence for yourself.

Alternatively, you can reply to my email to let me know of your decision, and if you wish to participate we can sort out a time for you to come in to see me. If you have any questions then don’t hesitate to get in touch.
I look forward to talking to you soon.

Kind regards,
Stacey Edwards
Master of Dietetics Student
Appendix E

Email sent to participant if first contact made via telephone
Dear XXX,

Thank you for taking the time to chat to me today. As I said on the phone, my name is Stacey Edwards and I am a Master of Dietetics student at the University of Otago. I am doing my thesis at the Wellsleep Clinic at Bowen Hospital.

The study is looking at energy (calorie) expenditure changes in people with Obstructive Sleep Apnoea (OSA) before and after starting treatment with a CPAP machine. Some people when they start using the CPAP device lose weight and some gain weight. The study hopes to understand more about how this weight change occurs and hopefully provide information to assist with weight loss after treatment with this device (CPAP) has been started.

I have attached a Participant Information Sheet, and also a flowchart that shows the timeline of events over the course of the study. As we discussed, the study would require you to briefly come into the clinic (for approximately 15-20 minutes) to have a debrief with me and explanation on using the armband and food/sleep diaries (the first box on the flow chart). We will reimburse you with a $20 petrol voucher if you do manage to complete 3 full days of food/sleep diaries.

If later you change your mind about participating, you can drop out of the study at any time you choose with no disadvantage or consequence for yourself.

If you have any questions then don’t hesitate to get in touch.
I look forward to seeing you on (day of week). Don't hesitate to email me back if you are unable to come in or do not want to participate in the study.

Kind regards,
Stacey Edwards
Master of Dietetics Student
Appendix F

Scanned copy of University of Otago 4 day Diet Record with instructions
4-Day Diet Record

Department of Human Nutrition
University of Otago
Estimating the quantity of food or drink consumed

Because describing amounts can be difficult, here are some tips to make it easier for you to estimate the amount of each food or drink you consume.

- If you have **kitchen scales** it is helpful to weigh foods and record these amounts.

- For **mixed food dishes** it may be easier to list the total ingredients, then describe the proportion of this recipe you consumed.
  
  *e.g. 1 third of recipe 1*

- If you do not have scales or you are not at home, here are some **hints** to help you estimate the amounts.

**Household measures.**

* e.g. 2 rounded teaspoons of white sugar

**Weights marked on packages.**

* e.g. 150g Fresh n Fruity yogurt

**Comparison with other objects.**

* e.g. Tasty cheese size of a match box

**Rulers and circles printed on the last page of this book.**

* e.g. Orange, peeled 10 cm circle

**Photos of different serving sizes of popular food and drink items.**

* e.g. Pams Plum jam, spread B
  
  * e.g. Watties frozen green peas (boiled), serving size C
Sample record sheet

Please record all food and drink consumed during the whole day, including snacks and water. Remember to report any additions to each food or drink such as milk, sugar, salt, sauce or spreads.

<table>
<thead>
<tr>
<th>Time</th>
<th>Food or Drink</th>
<th>Brand and details</th>
<th>Preparation/ Cooking</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10am</td>
<td>Muffin</td>
<td>Bought-banana</td>
<td></td>
<td>C size</td>
</tr>
<tr>
<td></td>
<td>Coffee</td>
<td>Bought-Cappuccino</td>
<td></td>
<td>Large cup</td>
</tr>
<tr>
<td>12pm</td>
<td>Creamy tuna pasta</td>
<td>Homemade-recipe 1</td>
<td></td>
<td>1/3 recipe</td>
</tr>
<tr>
<td></td>
<td>French bread stick</td>
<td>Bought-New World</td>
<td></td>
<td>6 cm cir., 6 cm long</td>
</tr>
<tr>
<td></td>
<td>Margarine</td>
<td>Pams-Canaia low salt</td>
<td></td>
<td>2 x spread B</td>
</tr>
<tr>
<td></td>
<td>Chicken breast</td>
<td>Skin &amp; bone removed</td>
<td>fried in oil</td>
<td>76 g</td>
</tr>
<tr>
<td></td>
<td>Olive oil</td>
<td>Luppi</td>
<td>fried</td>
<td>1/2 tbsp</td>
</tr>
<tr>
<td></td>
<td>Tomatoes</td>
<td></td>
<td>raw</td>
<td>2 x 5 cm diameter</td>
</tr>
<tr>
<td></td>
<td>Spring onions</td>
<td></td>
<td>raw</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Vinegar</td>
<td>Red wine</td>
<td></td>
<td>1 tbsp</td>
</tr>
<tr>
<td></td>
<td>Banana</td>
<td>Yellow</td>
<td></td>
<td>16 cm</td>
</tr>
<tr>
<td></td>
<td>Orange juice</td>
<td>McCoy, unsweetened</td>
<td></td>
<td>200 ml</td>
</tr>
</tbody>
</table>

Record brand names, e.g. McCoy

Use household measures to describe amounts of food such as margarine, butter and milk e.g. teaspoons (tsp), tablespoons (tbsp), cups (cp).

Use photos to estimate the serving size for foods such as muffins or spreads e.g. C size muffin

Use rulers/circles to estimate the dimensions. e.g. french bread stick, 6 cm circle & 6 cm length
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<th>Quantity</th>
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Appendix G

WellSleep Sleep diary and instructions
Filling in your SLEEP-WAKE DIARY

This diary has seven days. Each day is a line. Each line is a 24-hour period.

It is a little different to normal diaries because the day starts in the evening at 6pm. You then sleep overnight and the rest of the graph is filled out for the following day.

There is a system for filling out your sleep diary. It is described below. If you are unsure please contact WellSleep on 920 8819 and a Sleep Technician will be happy to run through it with you. When filling out your sleep diary you will use letters, lines and arrows. The day is separated into vertical bars for each half hour. Here is an example of what a whole day might look like:

```
6 7 8 9 10 11 12 1 2 3 4 5
F, C       AL F, C  F, C  NB NE
```

This person had dinner and a coffee at 6pm. Turned the lights out at 10:30pm. Was asleep at 11:30pm. Woke at 5am. Was back asleep by their alarm at 8:35am. Had breakfast at 7am. Had lunch at 11:30pm. Had an afternoon nap from 5pm – 6pm.

Filling Out Your Diary

Start filling in your diary an hour before bedtime on the first day listed. Fill it in for everything up until bedtime that day (F, C, A, N).

Fill your diary in again when you get up in the morning (Sleep ↑, ↓, Column A, Column B).

The next day at bedtime fill in your whole day. This is from wake up time that morning until bedtime that day. You will see that your day starts on one line of the graph and ends on the next line down. (F, C, A, N)

| F | Food | Put an F next to the time in the diary that you eat any food. This includes all meals and snacks.
| C | Tea or Coffee | When you have a cup of tea or coffee put a C in your diary for each cup. Write the C next to the time you drank that cup.
| A | Alcohol | If you have an alcoholic drink put an A in your diary for each drink. Write the A next to the time you had each drink.
| N | Nap | Did you nap during the day? If yes, then write NB for ‘Nap Begin’ on the graph next to the time you fell asleep. Write NE for ‘Nap End’ when you wake up. Join these two times up with a thick line for sleep.
| ↑ | Lights Out | When you go to bed and turn the lights out draw a ↑. When you get out of bed in the morning draw a ↓.
| ↓ | Lights On | When you go to bed and turn the lights out draw a ↓. When you get out of bed in the morning draw a ↑.
| Sleep | | Fill in your sleep time when you get out of bed in the morning. Draw a thick line from the time you fell asleep until the time you got up. If you woke up during the night, leave a gap in the line for the time you were awake. Have a look at the example above.

You need to tell us how you woke up. Write AL for Alarm if you needed an alarm clock or someone to wake you up, or if noise woke you. If you woke up by yourself write S for Spontaneous. Remember that ↑ is for when you get out of bed. AL and S are for the time you woke up. These may be different times.

Column A | | Fill in this column when you get out of bed in the morning. How many minutes do you think it took you to get off to sleep after you turned the light out?

Column B | | Fill in this column when you get out of bed in the morning. Did you wake up one or more times after you went to sleep? If yes, how many minutes (in total) did you spend awake?

Comments | | Is there anything you think we should know? Was this week better or worse than normal? Give a quick explanation. For example, stresses at work, family staying, change in medication, illness etc are all important things you should tell us. You may have sleep better than usual. If so, tell us what normally happens.
Appendix H

Photo of SenseWear® device on armband
Image sourced from:
Appendix I

Example of 24 hour EE graph produced by SenseWear Professional program by BodyMedia (from participant ID 102 in phase 2)
The yellow lines show energy expenditure (measured in KJ), and blue lines show activity and sleep. The top blue row is ‘sedentary’; second row is ‘light’ activity; third row is ‘moderate’ activity. The last two lines are ‘lying down’ and ‘sleep’ respectively. All occurred within a 24 hour period.

Total energy expenditure, step count, total sleep time etc. are displayed along the bottom in white type.