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Physical activity in the severely obese

Studies on measurement and promotion

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To Joanna, Alex & Alicia

ABSTRACT

Background: The amount and quality of evidence on how to effectively promote physical activity (PA) is low compared to what is known about the health effects of regular PA, especially in obese individuals.

Aim: To evaluate the role of social support to promote walking in severely obese outpatients.

Methods: The main hypothesis (increased social support promotes walking) was tested through a randomised, 2-armed, prospective (18 weeks) intervention study in 42 severely obese outpatients (study III). Three preparative studies were carried out. Study I was a cross-sectional comparison of PA in severely obese outpatients and a normal weight population. Study II evaluated the digiwalker SW-701 pedometer against the more versatile and sensitive MTI 7164 (formerly CSA) accelerometer. Study IV evaluated the Tanita BC-418 bioelectrical impedance monitor for estimating body composition against dual x-ray absorptiometry (DXA).

Results: Study I found a clear inverse association between PA and BMI that was dependent on obesity status (strong correlation in the obese between PA and BMI, and weak or non-existent correlation in non-obese). Study II showed that the digiwalker pedometer was of sufficient quality to confidently detect changes in walking in the intervention study (study III). The Tanita BC-418 bioelectrical impedance monitor correlated well with DXA estimates of fatness, but underestimated both total and trunkal fatness (study IV). In the intervention study (study III) the group allocated to a more intensive support programme recorded 1794 more steps/d than the group allocated to standard support ($P < 0.01$).

Conclusions: Accelerometer data identified the need to promote PA in the severely obese. Pedometers were deemed sufficiently accurate to detect changes in walking. Finally, the intervention study provided support for the concept that social support promotes walking in the severely obese.

LIST OF PUBLICATIONS

- I. Hemmingsson E, Ekelund U. Is the association between body mass index and physical activity obesity dependent? *Int J Obes* (in press).
- II. Hemmingsson E, Ekelund U. Mixed abilities of a criterion pedometer to monitor real life physical activity in obese individuals. Submitted for publication.
- III. Hemmingsson E, Hellénus M-L, Ekelund U, Bergström J, Rössner S. Impact of social support intensity on walking in the severely obese: a randomised clinical trial. Submitted for publication.
- IV. Neovius M, Hemmingsson E, Freychuss B, Uddén J. Bioelectrical impedance underestimates total and truncal fatness in abdominally obese women. *Obesity* 2006;**14**:1731-8.

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LIST OF ABBREVIATIONS

BMI	Body mass index
DXA	Dual x-ray absorptiometry
MRI	Magnetic resonance imaging
MVPA	Moderate and vigorous physical activity
PA	Physical activity

INTRODUCTION

This thesis focuses on clinical methods for promoting physical activity (abbreviated PA, and defined here as any bodily movement produced by skeletal muscles that results in energy expenditure above basal requirements),¹ in severely obese adults. The main topics, and thesis rationale and aims are outlined below. The appendices show the individual thesis manuscripts.

OBESITY

The prevalence of obesity (BMI ≥ 30 kg/m²) is increasing. In Sweden, adult obesity prevalence has approximately doubled in the last two decades (Fig 1).² In young people there are data showing a quadrupled prevalence between 1971 and 1995.³

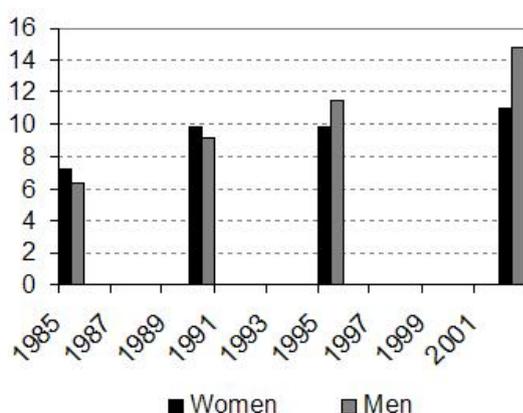


Figure 1. Prevalence (%) of obesity (y-axis) in men and women (25-64 year old) living in Gothenburg between the years 1985 to 2002, Sweden.²

A recent review of the global situation claimed that over 30 % of US adults were now obese, with Europe at about 20 %, and the Gulf states and Polynesian countries at 40-70 %.⁴ The increased prevalence of obesity are seen in most age groups in both men and women. Both education and income are inversely associated with an increased risk of becoming obese.^{5,6}

It is generally believed that an interaction between what has been called a thrifty genotype and changing environmental exposures has led to the increase in obesity prevalence.⁷ However, establishing exactly which environmental factors that have caused the global increase in obesity is difficult to determine.⁸

Furthermore, the observed variations in body weight change from both negative⁹ and positive energy balance,¹⁰⁻¹² demonstrates that genes plays a substantial part in determining weight gain, and that some individuals are more genetically susceptible than others.

The negative impact of obesity on health includes an increased risk of several chronic diseases such as type 2 diabetes,¹³⁻¹⁵ hypertension,¹⁶ dyslipidaemia,¹⁷ cardiovascular disease,¹⁸ stroke,¹⁹ Alzheimers disease and cancer.²⁰ Obesity is also associated with increased total mortality.²¹

Moreover, obesity is associated with an increased risk of discrimination and bias in situations concerning education, employment and health care.²² Disabilities such as back pain, mental disorders, arthritis, and learning problems are also more common in the obese compared to normal weight.^{23,24} The obese also have a lower social activity compared to normal weight people.²⁵

Economic analyses indicate that up to 9 % of the health service budget is currently due to obesity.⁴ One study of Finnish women found that 25 % of disability pensions were directly due to obesity.²⁶ Indeed, the social costs of obesity has been seen as a hindrance to economic development.⁴

PHYSICAL ACTIVITY

Similar to behaviours such as eating and sleeping, physical activity is a routine part of everyday life. When using the current definition of PA (see above) almost every individual is exposed, although the exposure varies according to frequency, intensity, volume, type, and duration.

Both randomised controlled experiments²⁷⁻²⁹ and prospective cohort studies³⁰⁻³³ have generally found changes in fatness after changes in PA, which tend to be dose-dependent. Since the association is also biologically plausible, there is some support for the hypothesis that increased PA leads to improved control of fat mass.

One observation, however, is that reduction in fat mass from PA tend to be larger in efficacy studies (effects of PA in controlled conditions, for example on a treadmill where strict rules apply about compliance to a pre-set PA protocol),^{9,28} compared to effectiveness studies (participants are instructed to increase PA in real-life, unsupervised settings, without strict criteria about compliance).^{27,34} The discrepancy between these two study designs in terms of fat loss suggests that compliance to advice on PA behaviour change is problematic.

Another part of the overall rationale for PA in the obese are the data implying that PA helps to prevent and treat several obesity comorbidities, such as the metabolic syndrome,³⁵ type 2 diabetes,³⁶⁻⁴¹ and cardiovascular disease.^{18,42-46}

In short, many of the diseases that PA reduces the risk for, are the same diseases that obesity increases the risk for. Furthermore, PA is also linked with reduced mortality,^{18,46-54} again similar to the opposite effect of obesity.

The mechanisms whereby PA influences its beneficial impact on health in the obese are also becoming clearer, such as increased insulin sensitivity⁵⁵ and reduced age-related decline in mitochondrial function.⁵⁶ The positive effects of PA on central obesity, and metabolic health aspects, such as insulin sensitivity, lipid profile and blood pressure,^{9,28,29,57} can therefore be of substantial help to sedentary, obese individuals with metabolic syndrome.⁵⁸

Since there is a general independent association between PA and health, regardless of body composition, combined with the inverse association between PA and BMI,^{57,59-68} it could be argued that PA is a key component for alleviating and preventing many of the negative health effects seen in obese individuals.^{69,70} Indeed, there is ample evidence supporting an independent association between cardiorespiratory fitness and reduced morbidity and related mortality.^{69,71,72}

CONFIDENCE IN PHYSICAL ACTIVITY AS A HEALTH ENHANCING EXPOSURE

PA is a complex behaviour with inherent measurement challenges, especially when data is collected in real-life, non-supervised conditions in large populations, e.g. surveys and prospective cohort studies.^{73,74} There is, for example, no standard definition of “physically active” or “sedentary lifestyle“ in the way an individual can be classified as obese or non-obese.

There are at least five components of PA:

- type (e.g. walking, running, and fidgeting)
- intensity (e.g. heart rate, perceived exertion, % $\dot{V}O_{2max}$)
- volume (e.g. energy expenditure, walked distance, activity counts)
- duration (e.g. min/d of walking, min/d of above light-intensity PA)
- frequency (e.g. number of exercise sessions/week).

Given these complexities, it is perhaps not surprising that there is currently no single measurement technique that can collect data on all aspects of the behaviour, and at the same time claim to be valid, reliable, accurate and practical.

To collect as much information about PA exposure as possible, it is therefore necessary to combine different techniques, preferably those that have been validated against gold standard methods such as doubly labeled water or maximal oxygen uptake.

Self-report data through questionnaire and diaries can be detailed and provide essential information (for example if exposure to a certain type of PA or the perceived exertion is of interest), but there are also known problems with recall and estimations.

The obese tend to over-estimate PA more than normal weight subjects,⁷⁵ but underestimation of PA also occurs, especially when women recall their lifestyle PA (e.g. walking, cleaning, house-work).⁷⁶

One development during the last couple of decades has been the validation of methods for collecting objective PA data, mainly from pedometers and accelerometers. These increase precision by eliminating problems with recall and subjective estimations. However, large scale studies with objective data on PA are still scarce.

Indeed, much of the evidence on PA and health still comes from relatively crude self-report measures of PA, or proximate measures such as cardiorespiratory fitness. The lack of large scale studies on health outcomes and objectively collected PA data, including adjustment for carefully measured covariates, is a general limitation in the field so far.

The use of a sedentary control group in an experimental design to investigate the relationship between PA and health (especially for analysing dichotomous outcomes such as disease or mortality, which often requires a long follow-up period), is problematic from an ethical point of view due to the adverse effects of a prolonged period of physical inactivity.

This means that much of the evidence on PA and health comes from non-experimental studies, such as longitudinal cohort studies with more or less appropriate adjustment for known confounders.

Advances in the measurement of PA, mainly by adding objective data to self-report, has facilitated the increased understanding of causal links between PA and health, and has also contributed to reduced confounding of PA in other studies (for example how diet impacts on the risk for cardiovascular disease).

Apart from problems with acquiring accurate and reliable data on PA, especially on a large scale, there are at least four other factors that can limit the confidence in studies of PA and health.

Firstly, PA is correlated to other healthy lifestyle exposures, such as diet and sleep,^{77,78} which means that there is risk for confounding. Studies of PA and health therefore require careful interpretation, unless statistical adjustment from carefully measured covariates has been carried out.

However, some of these confounders, such as diet, are also difficult to measure, which can lead to reduced confidence in the adjusted findings. As data on PA and related lifestyle factors increase in quality it will be easier to tease out the respective contribution of each exposure on health outcomes such as obesity.

Secondly, the association between PA and health can also be confounded by genetic factors, since genes play a part in regulating both PA levels and the benefit that PA can have on health.^{9,79,80}

Thirdly, many studies of PA and health require that participants volunteer. This means that participants in PA studies can be more favorably disposed than non-volunteers, which may lead to bias.

Fourthly, the direction of causality between PA and health is complex to determine. In terms of obesity and PA, several prospective studies show that having either a low level of PA or reduced PA during the follow up period increased the risk of becoming obese.³⁰⁻³³ However, there are also data indicating that obesity can precede low levels of PA.⁸¹ This implies that reverse causality also occurs.

RATIONALE

Despite these limitations when considering the quality of evidence on the health enhancing effects of regular PA, most national health authorities nevertheless recognize PA as a health enhancing exposure in those that are sedentary.

Indeed, in the scientific literature the claims for the impact of PA on health are now quite specific. For example, one analysis recently concluded that in Canada physical inactivity increased the risk of coronary artery disease by 45 %, stroke by 60 %, hypertension by 30 %, type 2 diabetes by 50 %, and osteoporosis by 59 %.⁸²

Therefore, even when considering the many above-mentioned factors that may limit the confidence in the evidence of PA and health, there still exist reasonable claims that 30 min/d of moderate intensity PA would improve the health of most sedentary individuals.⁸³

The rationale for PA promotion for sedentary individuals is founded on the increasing volume and quality of evidence supporting the hypothesis that regular PA enhances health in a plausible, dose-response manner. Likewise, there is ample evidence on the adverse effects of a sedentary lifestyle on health and mortality.

Such evidence, coupled with the on-going reduction of PA through increasing numbers employed in sedentary occupations and greater exposure to labour saving devices, strengthens the case for PA promotion.^{67,84-89} Furthermore, the adverse effects of PA are neither sufficiently frequent nor serious to reduce the confidence in the overall beneficial effects of increased PA.⁹⁰

Given the general efficacy of PA to promote health, combined with the proportion of the population who are insufficiently exposed, the population attributable risk of a sedentary lifestyle can be assumed to be high.⁹¹⁻⁹⁴

The last point of the thesis rationale is the general lack of quality controlled methods for promoting PA, especially in the severely obese.⁹⁵ Subsequently, the understanding of how to promote PA is disproportionate compared to the level of understanding about the efficacy of PA to enhance health.

AIMS

Primary aim

- to evaluate the role of social support intensity for promoting PA (walking) in severely obese adults.

Secondary aims

- to compare PA in a sample of severely obese outpatients with normal weight adults
- to scrutinise the digiwalker SW-701 pedometer when used on individuals with severe obesity
- to scrutinise the relatively simple, quick, safe and cheap Tanita BC-418 bioelectrical impedance machine for assessing body fatness in abdominally obese women

METHODS

The establishment of the primary aim to generate information on how to promote PA in the obese led to a series of linked investigations (Fig 2). The information from these then helped to design of the intervention study. Specific information on methodology can be found in the individual manuscripts (see appendix I-IV). Below is a more general description of the thesis material and methods.

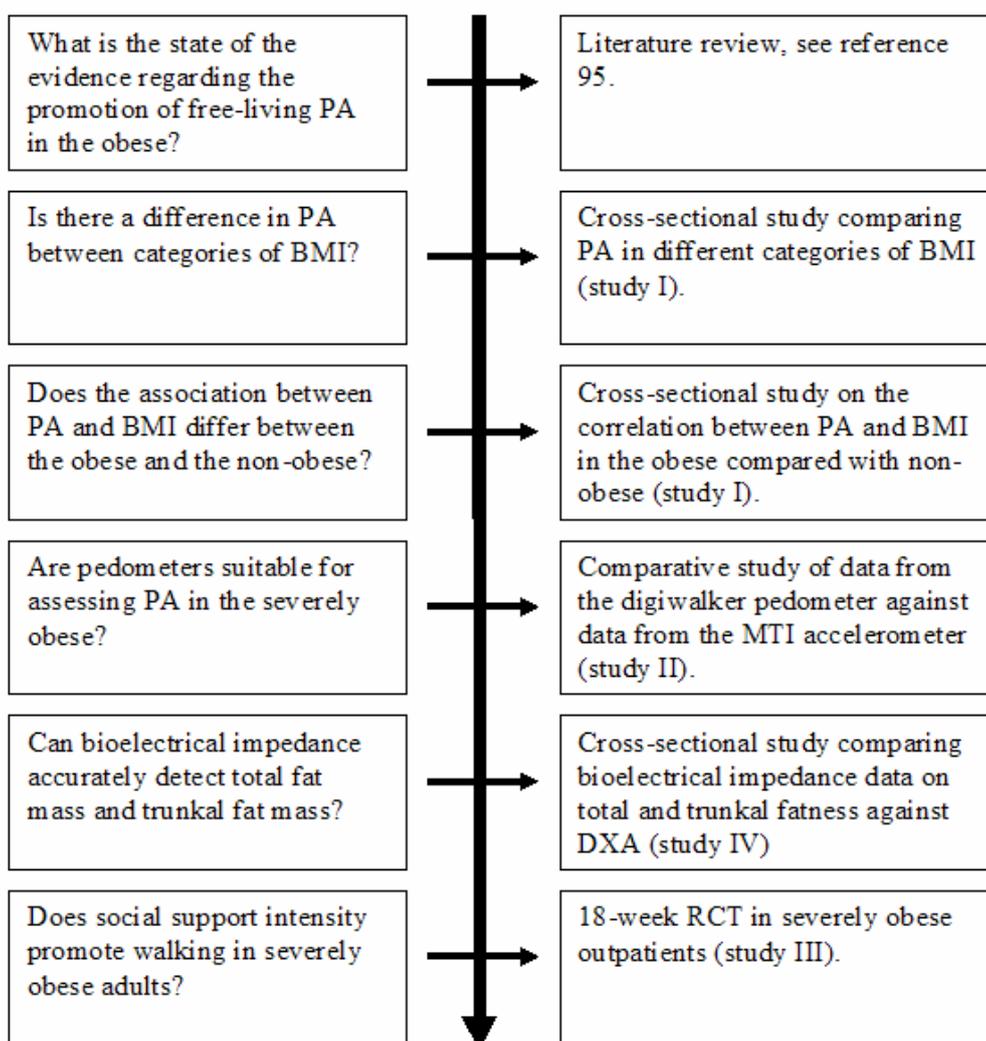


Figure 2. Overview of research questions and thesis structure.

STUDY POPULATIONS

The severely obese outpatients at the Obesity Unit, Karolinska university hospital, Stockholm, have a central role in this thesis. Studies II and III are comprised entirely of outpatients from the Obesity unit, and about half the study population from study I.

Firstly, the severely obese deserve to be studied in their own right. However, studying those with severe obesity, as opposed to overweight or class I obese, may also lead to more insight into obesity-related problems. A concrete example is skin-chafing on the thigh insides when walking, and other mechanical problems, that are likely to increase proportionally to BMI.

The outpatients were referred for weight loss by other parts of the Stockholm county health services. Severe obesity with minimum one co-morbidity is common. At the time of data collection, the outpatient programme was two years long. During the first 12 weeks patients met weekly for a whole day.

Group meetings were thereafter held monthly two hours sessions for the remainder of the programme. The programme was designed to help the outpatients change their diet and exercise habits, for the purpose of weight reduction and general health promotion, mainly metabolic aspects and sleep apnea.

Study IV was the only study that did not include any severely obese outpatients. Instead the participants in study IV were recruited by newspaper advertisements to take part in an 18-month randomised, clinical trial on lifestyle PA promotion (walking and bicycling) in unfit women with abdominal obesity (waist circumference ≥ 88 cm). Study IV includes baseline data from that intervention study, but no prospective data.

This means that all participants in the thesis were volunteers.

DATA COLLECTION

Physical activity

The Yamax Digiwalker pedometer SW-701 (New Lifestyles, Missouri, USA) and the MTI/CSA accelerometer (7164, version 2.2, Manufacturing Technology Inc., Fort Walton Beach, FL, USA) were used for measuring PA.

The Yamax digiwalker pedometer was used in study II, III and IV (data not shown in study IV) and the MTI accelerometer was used in study I and II. The Yamax digiwalker is the cheaper and easier to use of the two, whereas the MTI accelerometer has greater versatility, sensitivity and cost. Both monitors have been validated against energy expenditure (commonly measured with a portable metabolic unit), $\dot{V}O_2$ peak and heart rate.⁹⁶⁻¹⁰²

Pedometer steps correlate with accelerometer steps in free-living conditions ($r=0.74$ to 0.86), with a significant difference in steps between monitors (about 15-20 %).¹⁰³ Pedometers particularly underestimate walking at slow speeds, and they are not sufficiently accurate for detecting PA energy expenditure or walked distances.¹⁰⁴ Neither the accelerometer nor the pedometer are suitable for detecting upper-body PA.

Gait problems (slow walking) and abdominal obesity (tilted monitors) are factors known to increase the error in the detection of steps from the digiwalker pedometer that are not seen in data collected by accelerometers.^{101,105-107}

Body composition

Obesity is currently defined by body mass index (BMI), where body weight (kilograms) is divided by body height squared (meters). Table 1 shows the different BMI classifications according to the World Health Organisation criteria.

*Table 1. Body mass index ranges and classifications of obesity.*¹⁰⁸

Classification	BMI-range
Underweight	<18.5 kg/m ²
Normal weight	18.5-24.9 kg/m ²
Overweight	25-29.9 kg/m ²
Obese grade I	30-34.9 kg/m ²
Obese grade II	35-39.9 kg/m ²
Obese grade III	>40 kg/m ²

The advantages of BMI are that it is cheap, safe, quick and easy. These are traits that make BMI an attractive choice in large scale studies, such as surveys. The cons of BMI are several, where the main limitations are inability to discriminate between fat and muscle, and the location of fat tissue.

Indeed, these limitations of BMI maybe the reason why BMI does not add predictive power of obesity-related risk when waist circumference is already included in the model.¹⁰⁹ Waist circumference is therefore a more suitable anthropometric fat proxy measure due to its close correlation with both insulin resistance and abdominal fatness.¹¹⁰

Radiation techniques such as computed tomography (CT), magnetic resonance imaging (MRI) and dual x-ray absorptiometry (DXA) offer even further improved ability to

detect harmful adipose tissue, such as located in the abdomen, in skeletal muscle and liver fat. Cons include radiation exposure and cost.¹¹¹

Another technique for acquiring objective data on fatness and body composition is bioelectrical impedance. This is a relatively quick, low-cost and easy way of detecting fatness, although estimates of fatness are less accurate than radiation techniques.¹¹²

INTERVENTION

A review on the promotion of PA in obese adults was carried out, and published in 2001.⁹⁵ The conclusions from the review led to the decision to test the hypothesis that social support promotes walking in the severely obese.

To further increase the chances of increased PA it was decided to add a written information booklet on changing exercise habits and an electronic pedometer (Yamax digiwalker, SW-701), i.e. the same pedometer that was tested in study II. The pedometer was included for data collection purposes, but also as a feed-back tool and to promote the behaviour change. More specific information on the intervention in study III can be found in the Methods section of the manuscript.

RESULTS

STUDY I

This study compared the association between PA, measured with the MTI accelerometer, and BMI in two groups: obese and non-obese. The obese sample consisted mainly of severely obese outpatients. In the total sample, the association between BMI and PA was significant in all PA categories except for time spent sedentary ($P=0.68$). However, in subgroup analyses, the association between BMI and PA in non-obese was only significant for activity counts/day ($r=-0.16$, $P<0.05$) and vigorous intensity PA ($r=-0.15$, $P=0.05$).

After adjustment for age, vigorous PA remained significantly associated with BMI in the non-obese ($r=-0.17$, $P<0.05$). In obese individuals, significant associations between BMI and PA were found for all six PA categories (age adjusted), sedentary time ($r=0.26$, $P=0.05$), light PA ($r=-0.30$, $P<0.01$), moderate PA ($r=-0.35$, $P<0.01$), vigorous PA ($r=-0.39$, $P<0.001$), activity counts/day ($r=-0.50$, $P<0.001$) and steps/day ($r=-0.54$, $P<0.001$). The association between PA and BMI was weak in non-obese individuals. In contrast, BMI was significantly associated with PA in obese individuals.

STUDY II

Steps from the pedometer correlated significantly with all five PA variables calculated from the accelerometer data (Pearson $r=-0.38$ for time spent sedentary, $r=0.60$ for light intensity PA, $r=0.87$ for MVPA, $r=0.88$ for activity counts, and $r=0.94$ for steps_{acc} ($P<0.05$ for all)).

However, the pedometer recorded 16.5 % fewer steps than the accelerometer ($P<0.001$). This difference was independently associated with both waist circumference ($P=0.033$) and sex ($P=0.025$). The difference between monitors was 3.4 times greater for women with above-median waist circumference than for men with below-median waist circumference.

STUDY III

The group allocated to additional support (AS) recorded 1794 more steps/d than the standard support (SS) group ($P=0.0074$) during the 18 weeks. The odds ratio for adherence to the 10 000 steps/d recommendation, was 6.0 (95 % CI: 1.1 to 31.6, $P=0.04$), favoring the AS group. However, the difference in walking between groups did not increase as the intervention progressed.

STUDY IV

Compared with DXA, the bioelectrical impedance equipment significantly underestimated total % body fat (5.0; 3.6 to 8.5 [mean; 95% CI]), fat mass (3.6; 3.9 to 3.2), and % trunkal fat (8.5; 9.1 to 7.9).

The discrepancies between the methods increased with increasing adiposity for both % total body fat and trunkal % body fat (both $P < 0.001$). Variation in BMI explained 28% of the variation in % total body fat from the DXA and 51% of % total body fat from the bioelectrical impedance equipment.

DISCUSSION

For a more detailed discussion of the individual studies, the reader is advised to read the manuscripts in the appendices. This section of the thesis will instead discuss the thesis as a whole, the interpretation of the findings, and suggestions on how to move the field of PA promotion in the obese forward.

STUDY POPULATIONS

Arguably setting the thesis studies aside from much of the available literature on PA and obesity, was the inclusion of the severely obese. The severely obese are rarely studied in terms of PA, which may be unfortunate.

For example, by including the severely obese in the intervention study (study III), it was possible to gain additional insight into obesity-related problems with PA promotion, for example as opposed to promoting PA in grade I obese. Since the primary aim was to provide proof of concept that social support intensity promotes walking in the severely obese, the study was not powered to detect group differences in health outcomes, such as BMI or waist circumference. Such findings would require a larger sample size to detect, which was deemed unfeasible.

Furthermore, inclusion of severely obese in the cross-sectional study of PA and BMI (study I) also helped to gain insight the association between PA and BMI in the obese compared to the non-obese. Future studies aiming to establish the direction of causality between PA and body fatness would probably benefit from including the severely obese.

DATA COLLECTION

Since the emphasis of the thesis was on PA, it was critical that this data would be of high quality. And since over-reporting of PA increases with BMI,⁷⁵ it was important to use objective techniques. The choice of using the MTI/CSA accelerometer and the Yamax digiwalker pedometer seems justified since they have been scrutinized in a number of conditions and populations (see the Methods section). They also meet the criteria of being sufficiently easy to use, and the pedometer is also reasonably affordable.

Using the MTI accelerometer to study the PA and BMI association (study I) provided detailed insight into several aspects of PA, including sedentary time, which the pedometer is unable to do.

However, an accelerometer protocol for collecting PA in the intervention study (study III) was deemed unfeasible, due to a more time-consuming process of data collection and handling (more time consuming calibration, initialization, downloading, data cleaning, and finally separation into different variables).

By using the pedometer to collect data on walking it was possible to collect up to ten observations per participant. This data collection frequency was deemed unfeasible with the accelerometer. Although less detailed than accelerometer data, the pedometer data was still of sufficient quality to provide insight into the behaviour change process.

Self-report could have added additional information on PA behaviour (types, frequencies, intensity, and duration). Participants were indeed instructed to fill in 7-day activity diaries during the same weeks they reported their step tallies. Compliance with the diaries was too low for any meaningful analyses.

With hindsight, it seems that the pedometer protocol with data collection every other week provided acceptable balance between compliance and detailed information. An extended PA data collection protocol, by adding accelerometers and diaries, would have gained more information, but probably at the expense of compliance.

In study IV the aim was to scrutinize the 8-electrode Tanita BC-418 bioelectrical impedance machine for assessment of body composition. If such simple, safe, cheap, and easy to use machines provide accurate data on body composition, this would have a beneficial impact for clinicians, researchers and patients.

To compare estimates of fatness from bioelectrical impedance against dual x-ray absorptiometry seems justified in that DXA has been validated against hydrostatic weighing,¹¹³ Bod Pod,¹¹⁴ and magnetic resonance imaging (MRI).¹¹⁵

It must be stressed, however, that whilst most techniques for measuring fatness usually have acceptable correlation with each other, there can be substantial differences in body fatness. Data on body fatness, even from radiation techniques, are only estimates of true fatness.

INTERVENTION

Social support has been a cornerstone in the Obesity Unit's treatment programme for facilitating healthy eating and exercise habits for over 20 years. Support has mainly been provided by a group leader and from other patients. Whilst there are ample anecdotal indications that social support can help with lifestyle change and weight loss, the scientific foundation for using social support is surprisingly weak.

Nevertheless, in the initial literature review of PA promotion in the obese, social support was one of few salient exposures linked to behaviour change.⁹⁵ It therefore made sense to test the hypothesis that social support would promote walking.

The choice of walking as the main type of PA was founded on studies showing that this is a form of PA that people prefer, and that also can confer meaningful health benefits.^{34,47,116-121} Moreover, the use of pedometers for collecting data meant that participants could also receive objective feed-back on progress and form their own plan for increased walking in suitable increments.

In addition, the aim was not to try to increase exercise levels and fitness, but rather to help the patients reduce sedentary time and adopt lifestyle PA (walking, cycling, gardening, avoiding labour saving devices, etc)¹²² that could be maintained long-term.

Hopefully, this would lead to increased prevalence of PA at or above current recommendations of either walking 10 000 steps/d¹²³ or accumulating 30 min of moderate intensity PA on most days of the week.⁸³ Lifestyle PA, where change of clothing is not necessary, can also be a particularly suitable alternative for the obese, compared to exercise sessions where a change of clothes is necessary.⁹⁵

Psychosocial challenges to PA promotion in the obese, such as social physique anxiety and low self-efficacy, need to be considered.^{95,124} Recommendations to increase PA can probably be more successful if stressful situations, such as changing clothes in front of others, are minimized.

FUTURE RESEARCH

If study III can be interpreted to provide tentative proof of concept that social support leads to increased walking in the severely obese, then it makes sense to progress to a more detailed randomized dose-response study on the impact of social support on PA.

For example, this could be done through a three-armed design where all participants receive the same type of support, only in different degrees. This design would have the potential to provide a more confident answer to the role of social support intensity for PA promotion.

Another variation on the same theme would be to provide the same type of support in a three-armed study, but to have support programmes of different duration. This may also be of greater clinical relevance, since adherence to improved lifestyles is critical for long-term health benefits.

Pedometers, with 7-day observations every two to four weeks (depending on study duration and resources) could provide sufficient data quality of lifestyle PA, such as walking, to confidently conclude whether real behaviour change occurred.

A third variation on the same theme would be to design support programmes according to cost, to see whether increased cost yields a proportionally greater outcome. Since resources for obesity treatment are finite, the cost of the different support programmes could be matched to the cost of other types of intervention, such as drugs or surgery.

CONCLUSIONS

- There was an inverse association between PA and BMI (study I). However, this association was dependent on obesity status. The correlation between BMI and PA was stronger in the obese compared to the non-obese.
- The Yamax digiwalker pedometer was deemed to be of sufficient quality, when compared against the MTI accelerometer, for detecting changes in walking in the intervention study (study II).
- The Tanita BC-418 underestimated both total and trunkal fatness compared to DXA in obese women (study IV).
- Social support intensity may lead to increased walking in the severely obese, although additional studies are needed to verify this (study III).

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