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Cardiorespiratory Fitness, Insulin Sensitivity, and Perceptions of Obesity Treatment in Obese Children and Adolescents

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To obese children and
their caregivers

ABSTRACT

Background and Aims:
The childhood obesity epidemic is accelerating throughout the world and is associated with long-term medical and psychosocial consequences. To gain knowledge for clinical practice and further research, the overall aims of this thesis were to explore and describe obese children's and adolescents' physical fitness, participation in organized physical activity, and insulin sensitivity (SI). A further aim was to describe obese adolescents' perceptions of obesity treatment.
Material and Methods: Obese children and adolescents registered at a childhood obesity clinic, and age-matched reference groups participated. The following assessments were performed: a submaximal bicycle ergometry test, an interview regarding participation in organized physical activity, the frequently sampled intravenous glucose tolerance test (FSIVGTT), a dual-energy X-ray absorptiometry (DEXA), the six-minute walk test (6MWT), and a semi-structured interview regarding perceptions of obesity treatment.
Results: The obese children and adolescents had lower estimated relative maximal oxygen uptake (VO_2max), and participated less in organized physical activity, than the reference group did. Non-participation increased with age. Among the 14-16-year-olds 19% of the obese boys and 12% of the obese girls did not participate at all in physical education classes, compared to 2% in the reference group. Relative VO_2max was a stronger predictor of SI than body composition was. The six-minute walk distance (6MWD) performed by obese children averaged 86% of the distance normal-weight children walked. In test-retest of the 6MWT, the measurement error ($S_{w)}$ was 24 m, coefficient of variation (CV) 4.3%, and the intra-class correlation (ICC1.1) 0.84. The correlation between 6MWD and estimated VO_2max was low ($r = 0.34$). For the interview study, a phenomenographic research approach was chosen. The obese adolescents showed six qualitatively different ways of perceiving and responding to obesity treatment: a) personal empowerment, b) despair and disappointment, c) safety and relief, d) ambivalence and uncertainty, e) acceptance and realization, and f) shame and guilt. The categories had two contrasting internal structures regarding main focus and treatment objective: focus on the individual and focus on weight.
Conclusions: Obese adolescents, especially boys, were at risk of physical inactivity. This necessitates changes in the design of physical education programs in which obese adolescents participate. Relative VO_2max was a stronger predictor of SI than body composition was. Efforts to improve SI and prevent type 2 diabetes (T2DM) should include physical activity targeting cardiorespiratory fitness also in this population. The 6MWT showed good reproducibility and known group validity in obese children and adolescents, and can be recommended for use in clinical practice in the population studied. To evaluate individual outcomes after intervention, the 6MWD needs to have changed by > 68 m to be statistically significant. The correlation between 6MWD and estimated VO_2max was low, hence the 6MWT cannot replace a bicycle ergometry test. Adolescents at a pediatric obesity clinic varied broadly in how they perceived and understood the treatment program, how they related to the staff, and how they responded and reacted in the treatment process. Knowledge of such perceptions has relevance for health-care professionals seeking to accomplish successful treatment and interventions.

SAMMANFATTNING

Bakgrund och syfte: Andelen barn och ungdomar med fetma ökar med långsiktiga medicinska och psykosociala konsekvenser som följd. Det övergripande syftet med denna avhandling var att, för klinisk tillämpning och vidare forskning, få ökad kunskap om maximal syreupptagningsförmåga (VO_2max) hos barn och ungdomar med fetma, deras deltagande i organiserad fysisk aktivitet, insulinkänslighet (SI) samt gångförmåga. Vidare att beskriva ungdomars uppfattningar av att delta i fetmabehandling.

Material och Metod: Barn och ungdomar inskrivna på en specialistklink för barnfetma samt åldersmatchade referensgrupper deltog. Följande tester genomfördes: submaximalt konditionstest på ergometercykel, intervju angående deltagande i organiserad fysisk aktivitet i skolan och på fritiden, insulinkänslighetstest (FSIVGTT), mätning av kroppssammansättning (DEXA), sex-minuters gångtest (6MWT), samt semi-strukturerad intervju angående uppfattningar av att delta i fetmabehandling.

Resultat: Barnen och ungdomarna med fetma hade lägre estimerad relativ VO_2max och deltog i mindre utsträckning i organiserad fysisk aktivitet jämfört med en populationsbaserad referensgrupp. Icke-deltagandet ökade med stigande ålder. I åldersgruppen 14-16 år deltog 19 % av pojkarna och 12 % av flickorna inte alls i ämnet idrott och hälsa jämfört med 2 % i referensgruppen. Relativ VO_2max var starkare prediktor för SI än kroppssammansättning. Barnen och ungdomarna med fetma gick 86 % av sträckan de normalviktiga tillryggalade. Vid test-retest gick de 571 m första testet och 574 m det andra. Mätfelet (Sw) var 24 m, variationskoefficienten (CV) 4,3 % och intra-klass korrelationen (ICC1.1) 0.84. Korrelationen mellan sex-minuters gångsträcka (6MWD) och relativ VO_2max var låg ($r = 0.34$). I intervjustudien, som analyserades med fenomenografisk ansats, framkom sex olika uppfattningar av att delta i fetmabehandling: a) personlig empowerment, b) misströstan och besvikelse, c) trygghet och lättnad, d) ambivalens och osäkerhet, e) acceptans och insikt, f) skam och skuld. Kategorierna jämfördes, och två kontrasterande interna strukturer framträdde beträffande huvudsakligt fokus på behandlingen: fokus på individen och fokus på vikten.

Konklusion: Ungdomar med fetma, i synnerhet pojkarna, visade sig vara en riskgrupp för fysisk inaktivitet. Skolidrotten behöver anpassas så den lämpar sig även för inaktiva barn och ungdomar med med fetma. För att öka insulinkänslighet och förhindra utvecklandet av typ 2 diabetes hos barn och ungdomar med fetma bör fysisk aktivitet som höjer relativ VO_2max ingå i rekommendationer och behandling. 6MWT visade god reproducerbarhet och validitet hos barn och ungdomar med fetma och kan rekommenderas för användning i klinisk praktik. För utvärdering av individuella resultat bör gångsträckan förändras med minst 68 m för att vara statistiskt signifikant. Korrelationen mellan 6MWD och relativ VO_2max var låg, följaktligen kan 6MWT inte ersätta ett konditionstest på ergometercykel. Kunskap om ungdomar med fetmas uppfattningar av fetmabehandling är av betydelse för behandlande personal, då behandlingsstrategier och interventioner bör ta i beaktande ungdomarnas egna motiv och mål för behandling och viktnedgång.

LIST OF PUBLICATIONS

I. Berndtsson G, Mattsson E, Marcus C, Evers Larsson U. Age and gender differences in VO_2max in Swedish obese children and adolescents. Acta Paediatr 2007; 96: 567-571.

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IV. Morinder G, Biguet G, Mattsson E, Marcus C, Evers Larsson U. Adolescents' perceptions of obesity treatment – an interview study. Submitted.

CONTENTS

LIST OF ABBREVIATIONS

AIR	Acute insulin response
BIA	Bioimpedance analysis
BM	Body mass
BMC	Bone mineral content
BMI	Body mass index
BMI SDS	Body mass index standard deviation score
CT	Computer tomography
CV	Coefficient of variation
CVD	Cardiovascular disease
DEXA	Dual-energy X-ray absorptiometry
DI	Disposition index
FFM	Fat-free mass
FM	Fat mass
FSIVGTT	Frequently sampled intravenous glucose tolerance test
$HOMA_{IR}$	Homeostasis model assessment index
HR	Heart rate
ICC	Intra-class correlation
ICF	International classification of functioning, disability, and health
IP	Interviewed person
MRI	Magnetic resonance imaging
PEC	Physical education classes
R	Repeatability
SDdiff	Standard deviation of the differences
SI	Insulin sensitivity
S_w	Measurement error
TTM	Transtheoretical model
T2DM	Type 2 diabetes mellitus
VO_2max	Maximum oxygen uptake
QUICKI	Quantitative insulin sensitivity check index
6MWD	Six-minute walk distance
6MWT	Six-minute walk test

1 INTRODUCTION

Since 1997 physical therapists at the National Childhood Obesity Centre, Karolinska University Hospital, Huddinge, Sweden have collected data about obese children's and adolescents' physical fitness and physical activity level. To gain knowledge for clinical practice and further research, the main objective of this thesis was to scientifically explore, describe, and present data from this large cohort of obese children and adolescents.

Childhood obesity is associated with morbidity and mortality in adulthood. Even though clinical symptoms of chronic diseases do not become apparent until later in life, the origin of many chronic diseases lies in early childhood. Lifestyles and activity patterns are often established during childhood and adolescence, and tend to follow into adulthood. Consequently, prevention of chronic diseases should start early in life. Enlarged information and knowledge of obese children's cardiorespiratory fitness, degree of participation in physical activity, and insulin sensitivity (SI) are important for planning prevention and intervention strategies.

The demand for clinical assessment tools to evaluate physical capacity and performance in obese children and adolescents is growing. The six-minute walk test (6MWT) is increasingly used in clinical practice and research in this population since it provides useful information on daily physical performance. The 6MWT is safe, simple, well-standardized and inexpensive, easy to use in clinical settings. For evaluation over time or after intervention, knowledge of the test's reproducibility is essential. This and its validity have not been determined in obese children and adolescents.

Numerous children and adolescents are today referred to medical and behavioral centers for treatment for obesity. It is important to increase empathy with and understanding of obese children and adolescents, since obese children from clinical samples reportedly have poorer quality of life and self-esteem than those studied in community samples. To understand and meet the needs of these children and adolescents, their perceptions of medical guidance and obesity treatment should be elucidated and taken into consideration. Knowledge of such perceptions has relevance for health-care professionals seeking to accomplish successful treatment and interventions.

1.1 CHILDHOOD OBESITY

1.1.1 Classification of obesity

An expert panel set up by the National Institutes of Health in 1998 recommended the use of the body mass index (BMI) to define and classify obesity (1). BMI is calculated as body weight in kilograms divided by height in meters squared ($kg \cdot m^{-2}$). The BMI is broadly used in measurement and classification of adult obesity, and forms the basis for classifying childhood obesity (2). In adults, overweight is defined as BMI > 25 $kg \cdot m^{-2}$ and obesity as BMI > 30 $kg \cdot m^{-2}$ (3). These definitions cannot be used in children since normative values for BMI are highly age-dependent (4). The most implemented classification of childhood obesity, adopted by the International Obesity Task Force (IOTF), was developed by Cole et al. (2) in 2000. This classification is based on backward extrapolation of gender-specific BMI percentile curves that at age 18 correspond to the widely used cut-offs for adults' BMI (2). BMI can also be expressed as a standardized age- and gender-dependent standard deviation score (SDS) (5, 6), also called the Z-score.

Although BMI is frequently used for clinical and research purposes in children, no universally accepted classification system for childhood obesity exists. Numerous international BMI-based systems are in use, however, and national variants also exist in many countries (7).

1.1.2 Prevalence of childhood obesity

Childhood obesity has reached epidemic levels in developed countries. More than one out of three children in the USA is now considered overweight or obese. Further, about 70% of obese adolescents grow up to become obese adults (8).

The prevalence of obesity in Swedish adults has doubled during the past two decades, and is now approximately 10% in both men and women, according to estimates based on self-reported weight and height (9). In Swedish children, according to a study including both rural and urban areas, the prevalence of overweight among 10-year-old children was 22% in both genders, and the prevalence of obesity was 4% in boys and 5% in girls (9, 10). Urban-rural differences have been reported, data from non-urban areas in northern Sweden estimating the prevalence of overweight in 10-year-olds to approximately 30% (9, 11).

Recent data indicates that obesity in 10-11 year olds may be declining in urban parts of Sweden. Sjöberg et al. (12) found that the obesity epidemic in 10-11-year-olds may possibly be leveling off in Göteborg, and reversing among girls. A similar study in Stockholm, found comparable trends during the same period: decreased prevalence of obesity among girls and no change in boys (12, 13).

During the past three years a decrease in overweight and obesity in four-year-old children has been observed in the county of Stockholm (14). Of 19 832 four-year-old children born in 2002, 9.3% were classified as overweight and 2.1% as obese. Corresponding figures in children born in 2000 (n=8882) were 11.6% and 2.7%. Both overweight and obesity were more frequent in girls than in boys. In addition large socioeconomic variations were found. In Vaxholm (high socioeconomic status), 4.6% of the children were overweight and 0% obese, compared to 14.3% overweight and 5% obese in Skärholmen (low socioeconomic status) (14).

1.1.3 Cause of childhood obesity

Body weight is regulated by numerous physiological mechanisms that maintain balance between energy intake and energy expenditure (15). Any factor that increases energy intake or decreases energy expenditure will in the long-term cause obesity (16).

Childhood obesity is a disease which has both genetic and environmental determinants (17-19). Genetic factors may have a large effect on individual predisposition, although environmental factors play a decisive role for the development of childhood obesity (16). Diet, physical inactivity, socioeconomic status, and family factors are all reported as important components for the development of childhood obesity (16).

1.1.4 Consequences of childhood obesity

Childhood obesity is associated with physical, psychological, and social consequences (20, 21). The grave character of obesity was demonstrated by Fontaine et al. (22), who found that 13 years of life for men, eight for women were lost due to obesity (BMI >45 $kg \cdot m^{-2}$). This represents a 22% reduction in expected remaining life span for men.

Childhood obesity is associated with increased overall mortality, and particularly with increased risk of cardiovascular disease (CVD) in adulthood (21, 23). CVD usually developes in adulthood, but reportedly has its origin as early as in childhood and adolescence (24, 25). The past two decades have seen a dramatic increase in the incidence of type 2 diabetes (T2DM) among children and adolescents (26, 27). This is most probably due to an increased prevalence of childhood obesity and associated increase in insulin resistance. Children and adolescents diagnosed with T2DM in the USA were predominantly overweight/obese, had a strong family history of T2DM, belonged to ethnic groups at high risk for T2DM, and were female (28). Despite increased prevalence of obesity in Swedish children and adolescents, T2DM is still unusual in Sweden (29).

Further physical comorbidities found to be related to childhood obesity are pulmonary (obstructive sleep apnea, asthma), and hepatic (nonalcoholic fatty liver disease, nonalcoholic steatohepatitis) (21). Regarding psychological and psychosocial consequences, depression, poor quality of life, isolation, poor self-esteem, and teasing have been reported to be associated with childhood obesity (20, 21).

1.1.5 The National Childhood Obesity Centre

The National Childhood Obesity Centre, Karolinska University Hospital, Stockholm, receives patients with severe obesity from all parts of Sweden. Age at referral varies from three to 18 years. The referral criteria are: children and adolescents with severe obesity where previous treatment has failed, children with obesity and clinically manifested co-morbidities such as T2DM, elevated blood pressure, elevated blood lipids, obesity-related syndromes, children and adolescents with obesity and strong family history of obesity and/or co-morbidities. The multiprofessional team at the clinic consists of dieticians, health promoters, nurses, physicians, physical therapists, and psychologists. Treatment includes a combination of diet, physical activity/exercise, behavior modification, summer camps, weight-loss drugs, and bariatric surgery. The method of treatment offered is individually adapted and depends on age, motivation, degree of obesity, presence of co-morbidities, previous weight-loss therapies and the relative success of each.

1.2 PHYSICAL ACTIVITY

1.2.1 Definitions and assessments

Physical activity is defined as "any bodily movement produced by skeletal muscles that results in energy expenditure" (30). Physical exercise is defined as "a subset of physical activity that is planned, structured and repetitive bodily movement done to improve or maintain one of more components of physical fitness" (30). In contrast, physical inactivity is time spent in behavior that does not markedly increase physical energy expenditure.

Physical activity is a broadly-used term, and its heterogeneous nature makes it very difficult to assess and quantify (31). To describe and assess physical activity, intensity, frequency, and duration, should be taken into account. Sometimes also mode (refers to the type of specific activity, e.g. cycling to school) and continuity (refers to the period during which the activity has been performed (cycle to school four days a week for three months) are of importance. Various methods are available for assessing physical activity in children, and all have strengths and limitations (31, 32). Self-reporting of physical activity (questionnaires, interviews, and activity diaries) is the most widely used method in epidemiological research due to its simplicity and low costs (32). Objective measures (doubly labeled water, indirect calorimetry, direct observation, heart-rate monitoring, pedometry, accelerometry) are more expensive and time-consuming. Pedometers are devices that count steps, some models also calculate steps taken per minute (33). Accelerometers are devices that measure body movement in terms of acceleration. They can be used to estimate the intensity of the physical activity over time (34). Pedometry and accelerometry are increasingly used in epidemiological and intervention studies in children and adolescents (33, 35, 36), even though they are unable to assess activities such as swimming and bicycling.

1.2.2 Health effects

Regular physical activity is essential and necessary for normal growth and the development of functional qualities such as cardiorespiratory fitness, muscle strength, flexibility, and motor skills (37). Physical activity is effective in preventing diseases such as CVD, diabetes, cancer, hypertension, obesity, depression and skeletal ill-health (38-40). Even though clinical symptoms of chronic disease do not become apparent until later in life, the origin of many chronic diseases lies in early childhood (24, 25). Consequently it is often argued that prevention of chronic diseases should start early in life (41). Lifestyles and activity patterns are often established during childhood and adolescence, and tend to follow into adulthood (42, 43). It is therefore important to establish a physically active lifestyle in childhood that can be maintained throughout life. In adults it has been suggested that the effect of physical activity on health-related outcomes and morbidity and mortality operates largely through improvements in cardiorespiratory fitness (39, 44). This topic had been less studied in children and adolescents. However, recent studies have verified the importance of cardiorespiratory fitness for health also in children and adolescents (45-48).

A physically active everyday life, not just vigorous physical exercise, has been emphasized (49). Recent research suggests that the health benefits associated with physical activity in children may possibly be more closely related to its intensity rather than its duration (48, 50). For prevention and treatment of childhood obesity, vigorous physical activity seems more important than moderate physical activity (48, 51, 52). Not just increased physical activity is of importance, but also reduced physical inactivity and sedentary behavior such as television viewing (53, 54). According to Epstein et al. (55) reduced television viewing/computer use contributed to prevention of obesity and lower BMI in young children, but these changes were more related to changes in energy intake than to changes in physical activity. Further, Hancox el al. (56) found that television viewing for more than two hours a day in childhood and adolescence was associated with overweight, poor fitness, smoking, and raised cholesterol in adulthood.

Several recent studies in children and adolescents have found physical activity important for preventing and treating insulin resistance and T2DM (57-60). Shaibi et al. (60) found that overweight adolescent boys with previously diagnosed T2DM did approximately 60% less moderate-to-vigorous physical activity than age- and body-mass-matched non-diabetic controls. In addition, the diabetic youths exhibited significantly lower cardiorespiratory fitness levels than the controls (60). As regards type of physical activity to improve SI, positive effects on SI through aerobic exercise training and circuit-based exercise training have been reported in overweight and obese children and adolescents (57, 58). In those studies improvements in SI and cardiorespiratory fitness appeared despite absence of changes in body composition. On the other hand, Shaibi et al. (59) found that resistance training in overweight adolescent males improved SI. Alterations in body composition such as increased lean tissue mass and decreased percent body fat were found, but no improvement in cardiorespiratory fitness (59).

There is consistent evidence that boys are more physically active than girls in the general population (61-64). Whether this gender difference is similar in obese children is unclear. Stratton et al.(65) found that overweight boys and girls were equally active: further, that overweight boys were significantly less active than their normal-weight male counterparts, but this difference did not hold true for girls (65).

More research concerning the effects of physical activity on cardiorespiratory fitness in children and adolescents is required, mainly because of the complexity of assessing physical activity (66). However, Ruiz et al. (48) found that both total and at least moderate-to-vigorous physical activity improved cardiorespiratory fitness in 9-10-year-olds. Further, Gutin el al. (52) found in adolescents that a higher index for cardiorespiratory fitness was associated with higher amounts of moderate and vigorous physical activity, and that more variance was explained by vigorous activity than by moderate. In both studies, physical activity was measured by accelerometry.

1.2.3 Secular trends in physical activity

While there is a general concern nowadays that the level of physical activity in children is declining, there is remarkably little scientific evidence to substantiate this popular perception (67). This is mainly due to previous lack of objective assessment methods for physical activity, and thereby suitable baseline data (68). However, recently Dencker et al. (69) found in Swedish children (8-11 years), that all participants in the study reached the recommended level of 60 minute or more per day of moderate physical activity (measured by accelerometry).

Riddoch et al.(63) found, in a population of 5595 English 11-year-old children, that a majority were insufficiently physically active (measured by accelerometry), according to current recommended levels of 60 min in moderate-to-vigorous physical activity each day. Only 2.5% of the children (boys 5.1%, girls 0.4%) met the current recommendations. Boys were more active than girls, and the children were most active in the summer and least active in the winter. In a study by Metcalf et al. (70), physical activity measured by accelerometry on four annual occasions (5, 6, 7 and 8 years), 42% of the boys and 11% of the girls met the guidelines. Mean physical activity did not change over time in either sex. However, these two studies exemplify the difficulty of comparing results since different thresholds for 'at least moderate' intensity were applied, making the results difficult to interpret and compare.

Raustorp et al. (35) found in 7-9-year-old Swedish children that the level of pedometer-determined physical activity (steps per day) during school weekdays was higher in 2006 than in 2000. Enhanced focus on physical activity in society and at school was believed to have had influenced the result. The proportion of girls and boys meeting the preliminary weight control recommendations of 12000 and 15000 steps per day respectively (71) was significantly higher in 2006 among girls (90% compared to 75% in 2000) and non-significantly higher in 2006 among boys (67% compared to 60% in 2000).

According to Westerståhl et al. (64), 16-year-old Swedish adolescents were more active in leisure-time sport in 1995 than in 1974. The difference was more pronounced in girls. In both cohorts more boys than girls participated in leisure-time sports and were members of a sports club. Both genders also felt more satisfied with their sports performance in physical education in 1995 than in 1974. However, girls in 1995 felt more anxious about physical education than girls in 1974 did.

1.2.4 Guidelines and recommendations

In adults physical activity recommendations for general health have recently been updated by the American College of Sports Medicine (72). The recommendations advise adults to do 30 minutes of at least moderate-intensity physical activity on at least five days per week. This 30 minutes can be replaced by three occasions of 20 minutes of vigorous intensity activity per week. Moderate-intensity physical activity can be accumulated toward the 30-minute minimum from bouts lasting ten or more minutes. In addition ten strength-training exercises twice a week are recommended.

In 2002, the International Association for the Study of Obesity (IASO) (73) suggested that prevention of weight regain in formerly obese adult individuals requires 60-90 minutes of moderate-intensity activity or lesser amounts of vigorous-intensity activity.

Further, moderate-intensity activity of approximately 45 to 60 minutes per day is required to prevent the transition to overweight or obesity (73).

The amount and type of physical activity needed in childhood and adolescence is still a matter of debate (74). According to Andersen et al.(75) the current recommendation of 60 minutes a day of moderate-to-vigorous exercise (76) appears to be insufficient. To prevent clustering of cardiovascular-disease risk factors, approximately 90 minutes (116 min per day in 9-year-olds and 88 min per day in 15-year-olds) is required. Previous physical activity recommendations for children have relied mainly on subjective measures. Andersen at al. (75) assessed physical activity by accelerometry. Wittmeier et al. (77) found that lower durations of both moderate and vigorous physical activity are associated with increased odds of overweight and adiposity in young children. Since 45 minutes of moderate and 15 minutes of vigorous physical activity daily were found to be associated with reduced body fat and BMI, those authors recommend these amounts to develop minimum physical activity intensity guidelines for the prevention and treatment of obesity in children.

1.3 CARDIORESPIRATORY FITNESS

1.3.1 Definition and assessments

There are many different definitions of physical fitness (78). The one used in the present work, "a set of attributes that individuals possess or achieve that relates to their ability to perform physical activity" includes several components such as muscular, skeletal, metabolic, morphological, and cardiorespiratory fitness (30). The latter is one of the most central health-related fitness components. This is due to its ability to provide oxygen for the aerobic energy supply, the basis for all activities. Maximal oxygen uptake, VO_2max, is the maximal amount of oxygen that an individual can consume in a defined period, and is the point at which the body can no longer increase the amount of oxygen it uses despite increasing the intensity of the exercise (79). VO_2max is an important determinant of cardiorespiratory fitness, and quantifies the cardiorespiratory level (80).

Cardiorespiratory fitness can be assessed with either direct or indirect methods, and maximal or submaximal tests can be used. In laboratory settings VO_2max can be measured with indirect calorimetry (analysis of oxygen and carbon dioxide concentrations). However, this requires advanced equipment: hence, maximal and submaximal tests for estimation of VO_2max have been developed. The Åstrand and Rhyming test (81) is a submaximal test frequently used in research (82-86). When no consideration is taken of body weight, VO_2 max is expressed in absolute terms ($l \cdot min^{-1}$). When body weight is considered, VO_2 max is expressed in relative terms ($ml \cdot kg^{-1} \cdot min^{-1}$). In studies with reference to obesity, body composition is often considered, and VO_2max is then expressed in relation to fat-free mass (FFM) instead of body mass (BM). The way VO_2max is expressed, in absolute or relative terms, can influence the interpretations of the results (66, 87).

1.3.2 Health effects

In adults, persistent evidence exists that low cardiorespiratory fitness levels predicts CVD and all-cause morbidity and mortality (88-90). Cardiorespiratory fitness is consequently nowadays considered to be one of the most important health markers and predictors of future morbidity and mortality in adults. Until recently, knowledge of the health effects of cardiorespiratory fitness in children has been limited and uncertain. However, numerous studies have now verified its importance for health in children and adolescents as well (45-48, 66, 91). Cardiorespiratory fitness in children is reportedly associated with total and abdominal obesity (92, 93), DVD risk factors such as blood pressure, fasting glucose, insulin sensitivity, fasting insulin, triglycerides and low and high lipoprotein cholesterol, grade of inflammatory markers (57, 58, 91, 94-96), and skeletal health (97). Only a limited number of studies have been performed regarding cardiorespiratory fitness and insulin sensitivity in obese children and adolescents (45, 98, 99), and the results vary. No studies have previously been performed in a large cohort of severely obese children and adolescents.

In children, cardiorespiratory fitness is influenced by several factors such as age, gender, physical maturity, body composition, status of health, and genetics (100, 101). Recent studies, with objectively measured physical activity, have verified that physical activity pattern is of significance for cardiorespiratory fitness in children and adolescents (48, 52, 75). Data from the European Youth Heart Study (EYHS) indicate that cardiorespiratory fitness relates more strongly to cardiovascular risk factors than to components of objectively measured physical activity in children and adolescents (94). Further, in a population of 2859 adolescents, those with high cardiorespiratory fitness performed better in all other fitness tests such as 4x10 m shuttle-run test, seat and reach test, standing broad jump test, bent arm hang test, and handgrip strength test than those with lower cardiorespiratory fitness (102). In the study mentioned, cardiorespiratory fitness was assessed by a 20-meter shuttle-run test.

1.3.3 Secular trends in cardiorespiratory fitness

Since the importance for future health of cardiorespiratory fitness in children and adolescents has been demonstrated (45-48), there is a rationale for monitoring trends in this population in order to create early preventive strategies against CVD and other diseases. Ekblom et al. (103) found in Swedish adolescent boys significantly lower cardiorespiratory fitness (-9.2%) when values from two separate cross-sectional samples collected in 1987 and 2001 were compared. In girls no change was found. A similar study in 9-year-old Danish children compared cardiorespiratory fitness in 1985-86 and 1997-98 (104). Boys were less fit in 1997-98 than in 1985-86. In girls, no overall change in fitness was found. In the study by Wedderkopp et al. (104), a polarization in fitness and obesity was found since the children with low fitness were less fit than their counterparts 12 years previously, and the obese children were generally more obese at the second time point.

Westerståhl et al. (105) explored muscular and cardiorespiratory fitness in a representative sample of 16-year-old girls and boys in Sweden from 1974 to 1995. In 1995, both genders had higher body mass index (BMI) than in 1974.

Cardiorespiratory fitness was assessed by a run–walk-test. A decrease was found in both genders, but after adjustment for body dimensions, there were no differences in performance between 1974 and 1995.

1.4 BODY COMPOSITION

In obesity-related research, body composition is highly interesting and important. Since no direct method is available, indirect methods have been developed (31). These include basic measurements of height and weight for BMI calculation, waist circumference, skin-folds, bioimpedance analysis (BIA), dual-energy X-ray absorptiometry (DEXA), computer tomography (CT), and magnetic resonance imaging (MRI).

BMI is only a predictor and approximate measurement of body fat, and has limitations at individual level (106). In children, the relationships between BMI and fat mass and fat-free mass are further complicated by changeable growth rates and levels of physical maturity (107). DEXA is commonly used in childhood obesity research (31). The advantages are the relatively quick scan time (< 20 minutes) and minimal radiation dose. In addition, information is obtained about whole-body as well as regional measurements of bone mass, lean mass, and fat mass (31). A further advantage of DEXA is that several studies have demonstrated validity (31, 108).

1.5 INSULIN SENSITIVITY

T2DM affects more than 5% of the world's population and is increasingly affecting younger populations (109). Available data regarding young onset of T2DM indicate that the microvascular complications of diabetes (retinopathy and nephropathy) are as severe and frequent as in type 1 diabetes (109). The prevention of T2DM has become an urgent matter especially for children and adolescents, since if T2DM is established they have to face a lifetime of therapy and complications in young adulthood.

Insulin sensitivity is the degree to which cells respond to a particular dose of insulin by lowering blood glucose levels. Insulin resistance is a condition in which the cells no longer respond well to insulin (109). As a result, the body secretes more insulin into the bloodstream in an effort to reduce blood glucose levels. The ability of muscle cells and the liver to remove glucose from the bloodstream is also called glucose tolerance. Insulin resistance is strongly associated with the cardiovascular risk factors of obesity: hypertension, elevated triglycerides and low levels of high-density lipoprotein cholesterol (110, 111).

Methods for measuring SI have been developed over the past 15 years (112). These methods can be divided into two groups; invasive and precise methods such as the euglycemic clamp and the frequently sampled intravenous glucose tolerance test (FSIVGTT) (113), and more uncomplicated methods based on fasting samples such as the homeostasis model assessment index ($HOMA_{IR}$) (114) and the quantitative insulin sensitivity check index (QUICKI) (115). The FSIVGTT is a well-validated method (112, 116), but since it is expensive and time-consuming, alternatives such as $HOMA_{IR}$

and QUICKI (115) are frequently used in studies in children and adolescents (45, 47, 99). However, these surrogate measures have been found not fully reliable in obese children and adolescents (112, 116).

Physical activity and physical fitness level predict future risk of T2DM in adults, and exercise improves insulin sensitivity in this population (117-120). Regarding children, knowledge of the association between physical activity/cardiorespiratory fitness and insulin sensitivity has been incomplete and divergent. In recent years, an increasing amount of research on cardiorespiratory fitness and health in children and adolescents has been published, indicating that cardiovascular fitness is associated with insulin sensitivity in this population as well (45, 47). The mechanisms responsible for improvement in insulin sensitivity associated with exercise have been studied extensively, but are complex and not fully clear (119). Numerous factual explanations have been suggested (121-123), such as: a) improvement in insulin action through an increase in GLUT-4 (glucose transporter) concentration in skeletal muscle (124), b) increase in skeletal muscle capillarization and enhancement of muscle blood flow (58, 125), c) increase in highly oxidative and insulin-sensitive type I muscle fibers (58, 122), d) change in body composition, fat-mass loss and increased fat-free mass (muscles) (121, 123).

1.6 SIX-MINUTE WALK TEST

Several walking tests for clinical or research purposes have been described (126, 127). The American Thoracic Society published in 2002 guidelines for the six-minute walk test (6MWT) (128). The test was introduced in 1976 (129) as a 12-min walk test to determine exercise capacity for patients with respiratory disease, and later developed into the 6MWT (130). Solway et al. (131) performed a qualitative systematic overview of the most commonly used walk tests, and found the 6MWT to be easy to administer, better tolerated, and reflected activities of daily living better than other walk tests. Apart from lung and heart diseases, several other states of ill-health might result in reduced six-minute walk distance (6MWD) (128). Consequently the test could be used to assess any problem affecting walking capacity, and it is increasingly used in clinical practice since it provides useful information on daily physical performance (132, 133). The 6MWT is a safe, simple, well-standardized, and inexpensive test easy to use in clinical settings (134). Apart from information about 6MWD, heart rate (HR), and perceived exertion, the test gives valuable information about the child's movement pattern, posture, joint position in ankle and knee, degree of pain, endurance etc. This is important information in clinical practice in obese children and adolescents, since these aspects might influence the recommendations that will be given about physical activity.

The 6MWT has reportedly been found to be a reliable and valid test in healthy children (135), in children with cystic fibrosis (136), and in those with congenital heart disease (137). Li et al. (135) determined concurrent validity (138) between 6MWD and maximum oxygen uptake (VO_2max) in healthy children. Further, Calders et al. (133) recently studied predictors that contribute to the variance in 6MWD in obese children and adolescents, and the influence of treatment on the distance covered by this population. BMI z-score was reported to be the most dominant predictor, and 6MWD significantly increased after three months of multi-component treatment. The reproducibility and validity of the 6MWT have recently been determined in adults with obesity (139), but not in obese children.

1.7 VALIDITY AND RELIABILITY

The concepts of validity and reliability are central to the research process (140). Validity relates to the extent to which an instrument measures what it is intended to measure (140). Known group validity refers to a validation process where two distinctive groups are compared (141). Reliability refers to the accuracy of a given measurement, either performed by the same operator (intra-rater reliability) or by different operators (inter-rater reliability) (140). Reproducibility concerns the extent to which a test or an instrument yields the same measurement on repeated uses (140).

1.8 PHENOMENOGRAPHY

The use of qualitative methods is growing in health-care research, since some research questions cannot not be answered by quantitative methods. Qualitative research methods are valuable in providing rich descriptions of complex phenomena (142). To understand how people respond and act in different situations it is essential to understand how they perceive, conceptualize and apprehend the situation studied (143, 144). Different methods are used in qualitative research e.g. content analysis, focus groups, grounded theory, phenomenology, and phenomenography.

Phenomenography was first described by Marton (145), and is defined as the empirical study of a limited number of qualitatively different ways in which various phenomena in, and aspects of, the world around us are perceived, conceptualized, and apprehended (143). In phenomenography, distinctions are made between the first-order perspective and the second-order. The former aims to explain how things really are, or what can be observed from outside: the latter describes how people experience and perceive their world (143). Phenomenography is concerned with the second-order perspective, and does not seek to formulate general principles about how things are or appear. Semi-structured interviews are the preferred method of data collection in phenomenographic research (143, 144).

To distinguish between phenomenography and phenomenology - while both are interested in human experience they differ in purpose. In phenomenology, the search for essence or the central meaning of a phenomenon is crucial, while phenomenography seeks the variation of the world as it is experienced (144).

1.9 PHYSICAL THERAPY

The World Confederation for Physical Therapy (WCPT) (146) describes physical therapy as “providing services to individuals and populations in order to develop, maintain and restore maximum movement and functional ability throughout the lifespan. This includes providing services in circumstances where movement and function are threatened by ageing, injury, disease or environmental factors.

Functional movement is central to what it means to be healthy. WCPT also emphasizes that physical therapy is concerned with identifying and maximizing quality of life and movement potential within the spheres of promotion, prevention, treatment/intervention, habilitation and rehabilitation. This encompasses physical, psychological, emotional, and social well-being." (146).

Physical therapists at the Swedish National Childhood Obesity Centre are involved in both surveying and assessing the child's and adolescent's physical fitness and physical activity level, as well as in their treatment. To survey and assess the child's physical fitness and physical activity level the physical therapists carry out submaximal bicycle ergometry tests, six-minute walk tests, accelerometry assessments (not included in this thesis), and semi-structured interviews. Physical therapist treatment at the clinic consists of both individual guidance and treatment, and group treatment such as pool exercise therapy, resistance training, and summer camps. The physical therapists at the clinic also collaborate with physical therapists close to the child, physical education teachers, and sport organizations.

The relationship between a health condition and the background and surrounding of an individual is complex and multifaceted. To understand and chart the conditions, a standardized language for classification of disability has been developed, the International Classification of Functioning, Disability, and Health (ICF). The ICF is the World Health Organization's (WHO) framework for measuring health and disability at both individual and population levels (147) (Figure1). In 2004, definition of ICF Core Sets for obesity were defined by twenty-one international experts from different backgrounds at a consensus conference (148). Altogether 109 categories were included in the Comprehensive ICF Core Set, while a Brief ICF Core Set consists of nine (148).

In 2007, the WHO published its International Classification of Functioning, Disability and Health for Children and Youth (ICF–CY) (147). This is the first internationally agreed-upon classification code for assessing young people's health in the context of their stages of development and the environments in which they live.

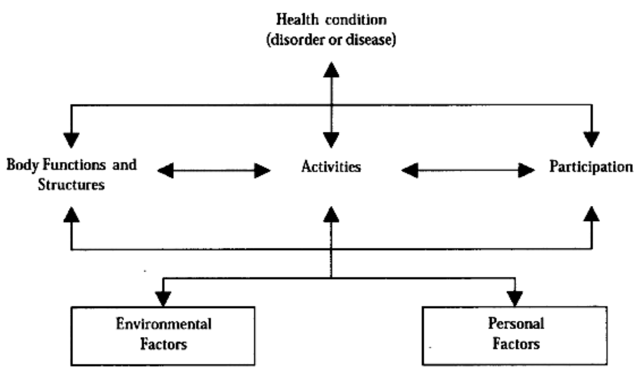

Figure 1.The interaction between health conditions and the components of the International Classification of Functioning, Disability and Health (147).

2 AIMS

General aims

The overall aims of this thesis were to gain knowledge of obese children's and adolescents' cardiorespiratory fitness, participation in organized physical activity, insulin sensitivity, and walking ability. A further aim was to describe obese adolescents' perceptions of obesity treatment.

Specific aims were

- to describe cardiorespiratory fitness and participation in organized physical activity in obese children and adolescents, and to compare the results with those of an age-matched reference group representative of the general population (Study I)

- to determine how far insulin sensitivity correlates with cardiorespiratory fitness and body composition in obese children and adolescents (Study II)

- to determine the reproducibility and known group validity of the six-minute walk test in obese children and adolescents. An additional aim was to describe the correlation between six-minute walk distance and a submaximal bicycle ergometry test (Study III)

- to describe variations in obese adolescents' perceptions of obesity treatment (Study IV)

3 MATERIAL AND METHODS

3.1 PARTICIPANTS

The obese children and adolescents in Studies I-IV were all registered at the National Childhood Obesity Centre at Karolinska University Hospital, Huddinge, Sweden, and on referral were classified as obese according to the international age- and gender-specific BMI cut-off points defined by the International Obesity Task Force (2), Table I.

Table I. Participants in Studies I-IV .

	Participants	Girls	Boys	Age, years	BMI, kg·m^{-2}
	n	n (%)	n (%)	range	range
Study I					
Obese children	219	117 (53)	102 (47)	8-16	24.3-57.0
Reference group[a]	1351	643 (48)	708 (52)	8-16	18.6-22.0[x]
Reference group[b]	1975	970 (49)	1005 (51)	8-16	
Study II					
Obese children	228	119 (52)	109 (48)	8-16	23.2-57.0
Study III					
Obese children[c]	49	19 (39)	30 (61)	8-16	24.9-52.1
Obese children[d]	250	124 (50)	126 (50)	8-16	23.2-57.0
Reference group[d]	97	49 (50)	48 (50)	8-16	13.3-23.2
Study IV					
Obese adolescents	18	12 (67)	6 (33)	14-16	25.0-47.4

[a] Reference group regarding VO_2max, [x] range of BMI means.
[b] Reference group regarding participation in physical activity, no data regarding BMI available.
[c] Test-retest study.
[d] Comparative study.

3.1.1 Study I

In Study I, 219 obese children and adolescents, 117 girls and 102 boys, aged 8-16 years participated, having been included consecutively, Table I. Children with syndromes and disabilities were excluded. Eight children did not complete the bicycle ergometry test since they were too short for the bicycles, or achieved a heart rate (HR) during the test that was too high to fit the table for calculation of VO_2max. Three adolescents attended schools that did not offer scheduled physical education.

Reference data regarding VO_2max and participation in PEC and in organized physical activity in leisure time were taken from “Skolprojektet 2001” (82, 149, 150), a multi-disciplinary project at the University College of Physical Education and Sports in Stockholm. The aims of that project were to describe and explore Swedish children’s participation in physical activity, their physical capacity and health conditions. Approximately 2000 children and adolescents from 48 schools from different parts of Sweden were randomly selected from a national register and invited to participate (82, 149). The participating children attended the third, sixth or ninth grades, and took part in several different projects. The children in the third grade participating in “Skolprojektet 2001”, are in this thesis referred to as 8-10-year-olds, those in the sixth grade as 11-13-year-olds, and those in the ninth grade as 14-16-year-olds.

Reference data on estimated VO_2max were available from 1351 children (643 girls and 708 boys) (82), range of BMI means 18.6-22.0 $kg \cdot m^{-2}$, Table I. Reference data in this thesis regarding participation in physical activity, were the earliest published data from “Skolprojektet 2001” (149, 150). Values from 1975 children (970 girls and 1005 boys) regarding participation in physical activity were available (149), Table I. In 2002 no data about these children’s BMI was published. Since 2002, further results from “Skolprojeket 2001” have been published or are accessible (150).

3.1.2 Study II

In Study II, 228 obese children and adolescents, 119 girls and 109 boys, aged 8-16 years were consecutively included, Table I. They represented all boys and girls in the age group aged 8-16 years for whom data from the FSIVGTT were available when the data set was defined in 2004. Children with syndromes, disabilities and T2DM were excluded from the study.

3.1.3 Study III

In the test-retest study, data were collected from a convenience sample of 49 obese children and adolescents, 19 girls and 30 boys, aged 8-16 years, Table I. The children were consecutively asked to participate in the study when they visited a physical therapist at the clinic.

In the comparative study, 250 obese children, 124 girls and 126 boys, aged 8-16, represented all boys and girls in the age group 8-16 years for whom data from both the 6MWT and the submaximal bicycle ergometry test were available, Table I. Five children had missing data regarding HR during the 6MWT, and were not included. In 18 children who performed the 6MWT, perceived exertion according to the Borg RPE scale (151) was missing. These children were included since perceived exertion was not the main issue.

Reference values for the 6MWT were collected from a convenience sample of age-matched children from four schools in different parts of Sweden, 49 girls and 48 boys (152), Table I. The children in the reference group were all classified as normal-weight (2).

3.1.4 Study IV

Different professional categories at the National Childhood Obesity Centre were asked to nominate (153) registered obese adolescents. The inclusion criteria were: at referral classified as obese according to the international age- and gender-specific BMI cut-off points established by the International Obesity Task Force (2), age 14-16 years, ability to speak and understand the Swedish language, and registered at the clinic for at least six months. Individuals with defined syndromes, mental retardation, and or neuropsychiatric diagnoses were not included. The nominating team members received a letter of information asking them to select suitable participants. The first author also attended a team meeting to give information about the study and the selection criteria. To ensure a widespread selection of variation in perceptions, the team members were instructed to consider variation regarding age, gender, degree of obesity, weight loss achievement, ethnicity, time of registration, and socioeconomic status. No other selection criteria were recommended. Forty adolescents, 22 girls and 18 boys, were nominated. Eighteen agreed to participate, 12 girls and six boys, Table I. They varied in age, degree of obesity, weight-loss achievement, ethnicity, time of registration, and socioeconomic status.

3.2 MEASUREMENTS

3.2.1 Cardiorespiratory fitness

Study I, II and III

Cardiorespiratory fitness was estimated by a submaximal bicycle ergometry test according to Åstrand and Ryhming (81). The work rate on the bicycle (Monark, 864, Varberg) was adjusted depending on the child's gender, age and physical activity level. HR was registered every minute with a Polar watch (Polar, Polar Oy. Kempele, Finland). If necessary to reach the required HR above 120 beats, the work rate was increased during the first minute of the test. If the HR during the first minute exceeded 170 beats the test was terminated and continued at a lower work rate after at least 30 minutes of rest. The obese children cycled for six minutes at the final workload in order to reach steady state. The mean value of the HR at the fifth and sixth minute designated the working pulse for the load in question. If the difference between these last two HRs exceeded five beats per minute the test time was prolonged by one minute or more until a constant level was reached. Extrapolated absolute VO_2max ($l \cdot min^{-1}$) was estimated from the measured HR and workload using the nomogram provided by Åstrand and Ryhming (81). Relative body mass (BM) VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) was calculated from absolute VO_2max in $l \cdot min^{-1}$ and measured body weight (kg). In Study I no correction factor for max HR or age was applied so as to have comparable measurements according to "Skolprojektet" data. In Study II, relative fat-free mass (FFM) VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) was calculated from fat-free mass (kg) measured by DEXA. In Study II and Study III, the values from children below 15 years were adjusted with the same age coefficient as that used for 15-year-olds.

3.2.2 Participation in physical activity

Study I

The obese children and adolescents took part in a semi-structured interview regarding e.g. mode of transport to school, participation in physical education classes (PEC), participation in organized physical activity in leisure time, number of hours spent watching television/using a computer/playing video games, prevalence of joint pain in association to physical activity, and motivation. One or both parents were present to confirm the information. Two questions were related to the child's participation in organized physical activities and adopted in the study: participation in PEC and participation in organized physical activity in leisure time. Three alternatives were given for participation in PEC: always, occasionally, and never. The criterion for answering "yes" to participation in organized physical activity was training at a sports club or other sports organization at least once a week. In the reference group, questionnaires were used to collect similar data on participation in physical activity (149).

In 2007 physical therapist students at Karolinska Institutet, tested the reproducibility of the questions used in the interviews with children at the National Childhood Obesity Centre (154). The aim of the project was to study the reproducibility of the following questions, a) mode of transport to school, b) participation in PEC, c) participation in organized physical activity in leisure time, d) number of hours spent watching television/using a computer/playing video games, and e) prevalence of joint pain in association to physical activity. Fifteen interviews, conducted by physical therapists at the clinic, were included in the project. The five questions were asked on two occasions within a week, and the answers were analyzed focusing on the reproducibility between interviews 1 and 2, explicitly to study whether the children gave the same answer on the two different occasions. Results showed that four of the five questions had high reproducibility. One of 15 children gave a different answer in interview 2 compared to interview 1 regarding mode of transport, prevalence of joint pain in association to physical activity, and participation in PEC. All the children gave a corresponding answer in both interviews regarding participation in organized physical activity. Only eight of 15 children gave answers about computer/TV time that corresponded in both interviews. Thus four of the five questions had high reproducibility. The question about time spent in front of computer/TV showed low reproducibility and should be modified in future interviews.

3.2.3 Insulin sensitivity

Study II

The FSIVGTT was used to determine SI, acute insulin response (AIR), and disposition index (DI) (113, 155, 156). To calculate SI, the minimal model computer program MINMOD, version 3.0, by Richard Bergman, 1994 was used. The test was performed in the morning after eight hours of fasting. An intravenous catheter was inserted in each arm. Four fasting baseline samples for glucose and insulin were drawn at the times -15, -10, -5 and 0 minutes. At time 1 minute, 0.3 g glucose per kilogram body weight was administered intravenously for 1 minute as 30% dextrose. At time 20 minutes, 0.02 U insulin (Actrapid, Novo Nordisk Scandinavia AB) per kilogram body weight was administered as an intravenous bolus dose. To determine glucose and insulin levels, blood samples were drawn repeatedly over the next three hours. AIR reflects the first phase of endogenous secretion in response to the glucose infusion and was calculated as area-under-the-curve during the first 10 minutes. DI is the product of SI multiplied by AIR.

3.2.4 Body composition

Study I-IV

The obese children and adolescents were dressed in light clothing (excluding sweaters, jackets, belts, and shoes). Height was measured to the nearest 0.1 cm using a stadiometer (Ulmer, Ulm, Germany). Weight was measured to the nearest 0.1 kg on an electronic scale (Vetek, Sweden, model Tl 1200). BMI was calculated as body weight in kilograms divided by height in meters squared ($kg \cdot m^{-2}$). In Study II, BMI SDS was calculated according to Karlberg et al. (5), and in Study III and Study IV according to Rolland-Cachera et al. (6). In the reference group in Study I regarding VO_2max, height and weight were recorded with children dressed in light clothing, without shoes, using a calibrated standard scale and stadiometer (82). In the reference group in Study III, height and weight were measured in light clothing without shoes at the different schools with available measurement instruments.

Study II

In Study II DEXA was used to measure body composition. The total body composition analysis was performed with DEXA (lunar DPX-L, version 1.5E; Lunar Corp, Madison, WI, USA, or Lunar Prodigy X-R, model 6830, Madison, WI, USA). The correlation between DPX-L and Prodigy in pediatric body composition (fat%) is excellent (0.97) (157). Body-fat content was expressed in absolute values, kilograms (fat mass kg) and as percent fat (fat mass %) in soft tissue. Fat-free mass was expressed in absolute values, kilograms (fat-free mass kg). Truncal fat was expressed as percent fat (truncal fat mass %) in soft tissue in the trunk.

3.2.5 Physical maturity

Study II

Pubertal stage was determined according to Tanner stage (158, 159) by a pediatrician. Gonadal development, breast development in girls and testicular volume in boys was used, pubic hair only as supplementary information.

3.2.6 Walking ability

Study III

Obese children

The obese children performed the 6MWT in a 70 m indoor corridor with marks every second meter on the side of the walkway. They were instructed to wear comfortable shoes. The instructions were to walk as many lengths as possible in six minutes, without running or jogging (128). To clarify the instructions, the children were also told to walk as fast as possible. Information was given during the test by telling the children how many minutes they had walked or minutes remaining. Directly after the test, HR was registered with a Polar watch (Polar, Polar Oy. Kempele, Finland), and the children were asked to rate exertion on the Borg RPE scale (6-20) (151). Finally the total 6MWD was measured.

Normal-weight children
The normal-weight children performed the 6MWT in a 30 m indoor corridor at their respective schools. HR was monitored with a Polar watch (Polar, Polar Oy. Kempele, Finland). The instructions and measurements were comparable to those given to the obese children.

3.2.7 Perceptions of obesity treatment

Study IV
Data collection
For the fourth study, semi-structured interviews and a phenomenographic research approach were chosen. The interviews were conducted by the first author from June to October 2007. The parents were not present. Care was taken to explain the study's objective and confidentiality. The interviewer strove for a spontaneous dialogue, allowing flexibility and interaction. The interviews were semi-structured and followed an interview guide developed by all the authors. The questions were tested in a pilot interview, which led to some minor changes and additions. The interviews lasted between 19 and 60 minutes. The questions focused on three areas; the participant's perceptions and understandings of obesity and weight loss, referral to the pediatric obesity clinic, and participation in obesity treatment.

Data analysis
To ascertain the qualitative variations in the individuals' perceptions the phenomenographic method (145, 160) was chosen. The interviews were transcribed verbatim and printed out. The tapes were listened to once more in order to guarantee agreement between them and the text. To familiarize themselves with the data, the authors (GM, GB, UEL) read the interviews several times and a summary of each interview was written. Responses from all participants to a certain question were compiled. The most significant elements in the descriptions from each participant were identified. The next step was to identify statements which corresponded to the aim of the study. The statements were grouped into preliminary categories of descriptions according to similarities and differences. These categories were discussed and cross-checked several times. After negotiated agreement, each category was described, assigned a metaphor, and illustrated with carefully selected quotations. The final result consisted of six categories of descriptions, which were interpreted and reflected upon by all the authors in order to find an internal structure. Two contrasting internal structures emerged, which constituted the outcome space.

3.2.8 Statistical methods

The statistical methods used in this thesis are presented in Table II.

Table II. Statistical methods used in Studies I-III.

	Study I	Study II	Study III
Descriptive statistics	x	x	x
Unpaired *t* test	x	x	x
Paired *t* test			x
Two-way analysis of variance ANOVA	x		x
Chi square test	x		
Fishers exact test	x		
Multiple regression	x	x	
Bonferroni's test	x		
Mann-Whitney *U* test		x	x
Pearson's correlation coefficient		x	x
Spearman's rank order correlation coefficient		x	x
Missing data analysis		x	
Sign test			x
Bland Altman method			x
Measurement error (Sw)			x
Coefficient of variation (CV)			x
Intra-class correlation (ICC) 1.1			x
Repeatability (R)			x

In Studies I-III the level of statistical significance was set at p value < 0.05. Microsoft® Office Excel 2003 and STATISTICA (7.1 Statsoft Inc., Tulsa, OK, USA) were used for all calculations.

The strength of the correlations was interpreted according to Domholdt (161), r < 0.25 = little, if any correlation, 0.26 – 0.49 = low correlation, 0.50 – 0.69 = moderate correlation, 0.70 – 0.89 = high correlation, and 0.90 – 1.00 = very high correlation.

3.2.9 Ethical approval

All four studies were approved by the Ethical Committee of Karolinska University Hospital, or by the Regional Ethical Review Board in Stockholm.

4 RESULTS

4.1 STUDY I

Cardiorespiratory fitness

The obese children had lower mean value for relative (BM) VO_2max than the reference group ($p< 0.001$) in all age groups (Figure 2). The subgroups boys 8-10 years ($p< 0.05$), girls 11-13 years ($p< 0.05$) and girls 14-16 years ($p< 0.001$) had higher mean values for absolute VO_2max than the reference group did (Figure 3).

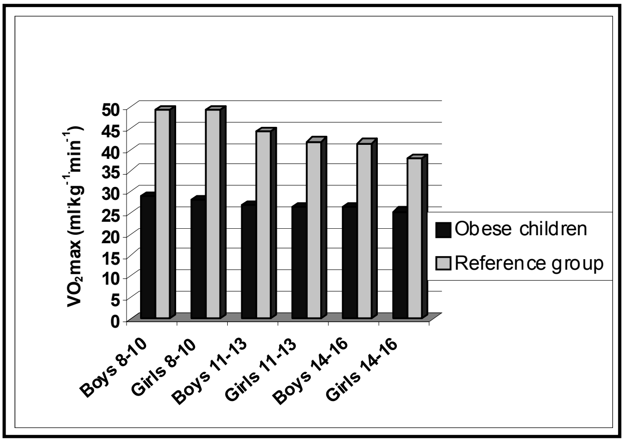

Figure 2. Relative (BM) VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) in the obese children (N=211) and the reference group (N=1351).

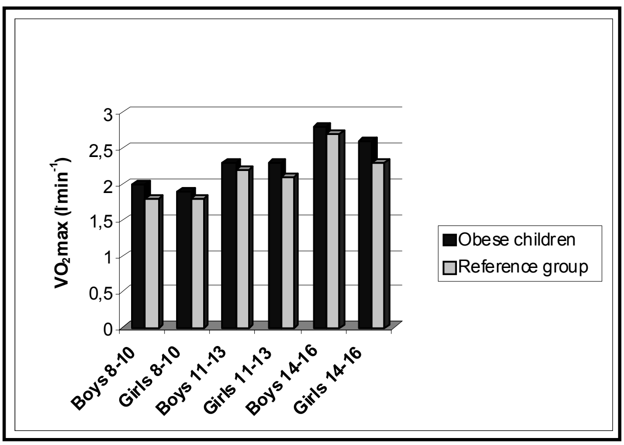

Figure 3. Absolute VO_2max in ($l \cdot min^{-1}$) in the obese children (N=211) and the reference group (N=1351).

ANOVA revealed that in the obese children absolute VO_2max differed between all age groups (p< 0.02 - p< 0.001), but in relative (BM) VO_2max no age differences were found. Among the obese children no gender differences were detected in absolute VO_2max or relative (BM) VO_2max, in contrast to the reference group (14) where gender differences existed in relative (BM) VO_2max, in the age groups 11-13 years and 14-16 years.

In multiple regression analysis with relative (BM) VO_2max as the dependent variable, BMI explained 45% (p<0.001), and participation in organized physical activity in leisure time 7% (p<0.001) of the variance in the age group 14-16 years. Seventeen percent of absolute VO_2max was explained by the variables BMI, gender PEC, and organized physical activity in leisure time. Of these, participation in organized physical activity in leisure time alone explained 8% (p<0.002).

Participation in physical activity

Altogether, the obese children participated less in PEC and in organized leisure-time physical activity than did the reference group (p< 0.001). No differences regarding non-participation in PEC between the obese and the reference group were found in the age groups 8-10 years and 11-13 years. In the age group 14-16 years, 19% of the obese boys and 12% of the obese girls did not attend PEC, compared to 2% in the reference group, Table III.

Table III. Non-participation in physical education classes (PEC) in the obese children (N=103) and the reference group (N=681).

	Obese children (%)	Reference group (%)	p-value
Girls 14-16 years	12	2	*<0.001*
Boys 14-16 years	19	2	*<0.001*

No difference in participation in organized leisure-time physical activity was found between the obese children and the reference group in the age group 8-10 years. In the age group 14-16 years differences regarding participation were found among boys, but not among girls, Table IV.

Table IV. Participation in leisure-time organized physical activity in the obese children (N= 103) and the reference group (N=681).

	Obese children (%)	Reference group (%)	p-value
Girls 14-16 years	34	45	*ns*
Boys 14-16 years	24	57	*<0.001*

4.2 STUDY II

Mean SI (SD) in the obese children and adolescents was 0.38 (0.32) ($x10^{-5}·min^{-1}·pM^{-1}$). Mean SI (SD) in prepubertal children (n=44) was 0.53 (0.5) ($x10^{-5}·min^{-1}·pM^{-1}$) and in pubertal adolescents (n=166) 0.34 (0.2) ($x10^{-5}·min^{-1}·pM^{-1}$).

Univariate correlations showed that log SI correlated positively with relative body mass (BM) VO_2max (Figure 4), and relative fat-free mass (FFM) VO_2max. It correlated negatively with BMI SDS, and fat mass (kg), but not with percent body fat (Figure 5), truncal fat or absolute log VO_2max, Table V.

Table V. Univariate correlations between log SI ($x10^{-5}·min^{-1}·pM^{-1}$) and BMI SDS, fat mass, truncal fat, absolute log VO_2max, relative body mass (BM) VO_2max, and relative fat-free mass (FFM) VO_2max in obese children.

	n	r	*p*
BMI SDS	228	-0.22	0.001
Fat mass (%)	200	-0.01	0.926
Fat mass (kg)	200	-0.31	<0.001
Truncal fat (%)	200	0.11	0.124
Absolute log VO_2max ($l·min^{-1}$)	210	0.01	0.877
Relative (BM) VO_2max ($ml·kg^{-1}·min^{-1}$)	210	0.42	<0.001
Relative (FFM) VO_2max ($ml·kg^{-1}·min^{-1}$)	187	0.36	<0.001

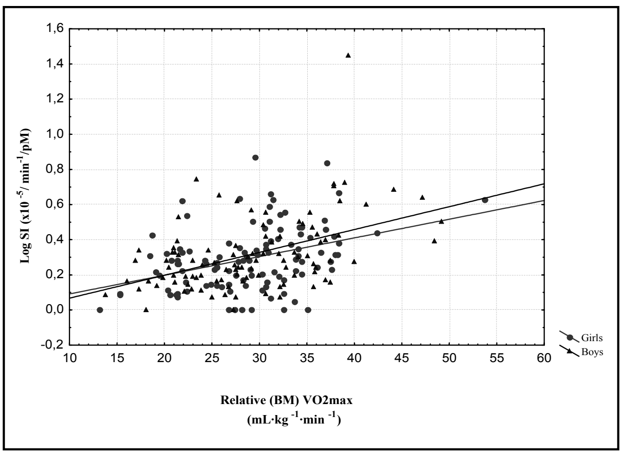

Figure 4. Univariate correlation between log SI ($x10^{-5}·min^{-1}·pM^{-1}$) and relative (BM) VO_2max ($ml·kg^{-1}·min^{-1}$) (N=210). The outlier was a physically active nine-year-old boy.

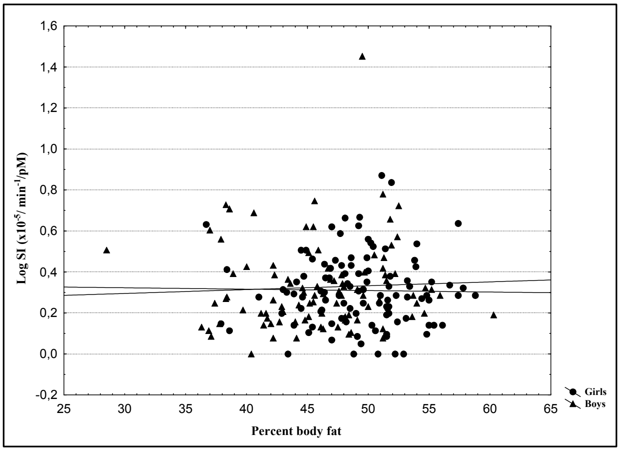

Figure 5. Univariate correlation between log SI ($x10^{-5}\cdot min^{-1}\cdot pM^{-1}$) and percent body fat (%) (N=200). The outlier was a physically active nine-year-old boy.

In a multiple regression analysis with log SI as the dependent variable, the independent variables gender, BMI SDS, age, relative (BM) VO_2max, Tanner stage, and percent body fat explained 26% of the variance in log SI, Table VI. The model was also performed with relative (BM) VO_2max replaced by absolute log VO_2max, and relative (FFM) VO_2max, both with less explained variance, 20% and 24%.

Table VI. Multiple linear regression analysis between the dependent variable log SI and the independent variables gender, BMI SDS, age, relative (BM) VO_2max ($ml\cdot kg^{-1}\cdot min^{-1}$), Tanner stage, and percent body fat in obese children.

	R^2=0.26		
***n* = 228**	***b***	***p***	**ΔR^2***
Gender	0.038	0.155	0.01
BMI SDS	-0.087	0.005	0.03
Age	-0.006	0.412	0.00
Relative (BM) VO_2max	0.010	<0.001	0.08
Tanner stage	0.103	0.009	0.02
Fat mass (%)	0.009	0.003	0.04

* loss in explained fraction when variable was removed

Mean SI was higher among the children who participated in organised physical activity than in non- or occasional participants (Figure 6). Participation refers to participation in organised physical activity and always in PEC, mean SI 0.51 (0.42) ($x10^{-5}\cdot min^{-1}\cdot pM^{-1}$). No participation refers to no participation in organised physical activity and never in PEC, mean SI 0.25 (0.21) ($x10^{-5}\cdot min^{-1}\cdot pM^{-1}$). Occasional participation: all other combinations, mean SI 0.32 (0.24) ($x10^{-5}\cdot min^{-1}\cdot pM^{-1}$).

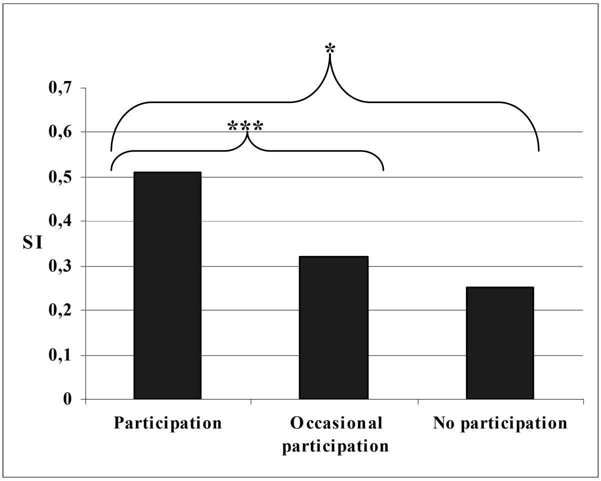

Figure 6. Insulin sensitivity (SI) and participation in physical activity in obese children and adolescents. Participation (N=77), occasional participation (N=134), no participation (N=14).

4.3 STUDY III

Test-retest in obese children

The obese children walked 571 m the first test and 574 m the second (p=0.578). The correlation between test 1 and test 2 (r=0.83) was high (161). The 6MWD, HR, and perceived exertion did not differ between the two tests. The agreement between the two tests is illustrated with a Bland Altman plot (162) (Figure 7). Analyses of reproducibility showed that the measurement error (S_{w}) was 24 m, coefficient of variation (CV) 4.3%, and repeatability (R) 68 m. The intra-class correlation (ICC1.1) (0.84) indicated good reliability (163).

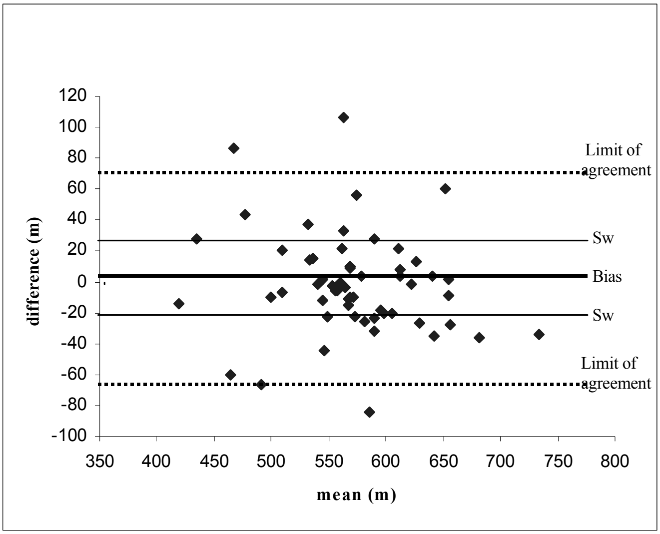

Figure 7. Bland Altman plot of agreement between two tests of six-minute walk distance (6MWD). The bias (mean difference between the two paired means) was 2.8 m, and the limits of agreement were 71 and – 65 m. Measurement error (S_{w}). N=49.

6MWD in obese and normal-weight children

The 6MWT proved valid in obese children and adolescents, since the difference in 6MWD between the obese and the normal-weight children, 92 m, was larger than the measurement error, 24 m. The 6MWD performed by the obese children averaged 86% of the distance the normal-weight children walked. Mean 6MWD (SD) in obese children was 571 (65.5) m and in normal-weight children 663 (61.1) m (p<0.001) (Figure 8). 6MWD did not differ between genders (p=0.267), except for obese adolescents 14-16 years (p=0.045). Mean HR in obese children was 147 (18.7) bpm and in normal-weight children 155 (21.4) bpm (p<0.001). Among the obese children, girls had higher HR than boys (p=0.018). Perceived exertion did not differ between obese children 12.5 (6-19) and normal-weight children 13 (6-18) (151).

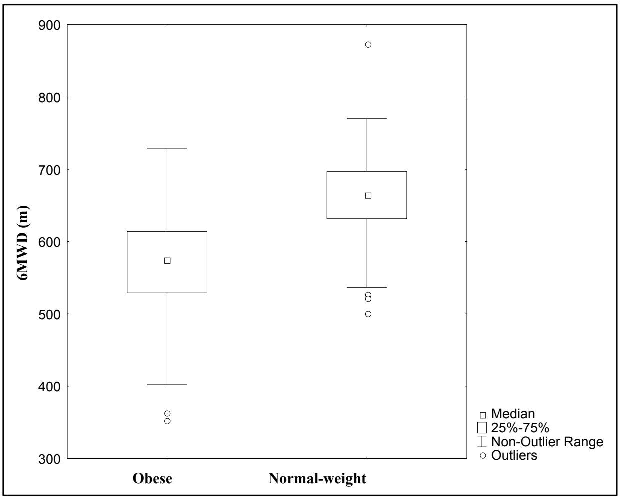

Figure 8. Six-minute walk distance (6MWD) in obese children (N=250) and normal-weight children (N=97).

Correlation between 6MWD and VO_2max in obese children
The correlation between 6MWD and absolute VO_2max ($r = 0.34$) and relative VO_2max ($r = 0.34$) was low (161).

4.4 STUDY IV

Qualitatively different ways of perceiving and responding to obesity treatment were discovered and were described in six categories of descriptions; a) personal empowerment, b) despair and disappointment, c) safety and relief, d) ambivalence and uncertainty, e) acceptance and realization, and f) shame and guilt. The categories had two contrasting internal structures regarding main focus and treatment objective. The two identified structures were; main focus on the individual and main focus on body weight, Figure 9.

The differences in the two structures and the categories of descriptions reflected the participants' understanding and perceptions of the overall aim of the treatment program, as well as their involvement in and compliance with the treatment process, their working alliance and relationship with the staff at the clinic, and their emotional reactions and behavioral strategies. The first structure reflects that main focus in obesity treatment aims primarily at emphasizing individuals' needs and personal goals, not body weight per se. In the second structure the main focus is primarily on body weight and not the individual's unique needs and personal goals.

Each category of descriptions is described in detail below and illustrated with translated excerpts from the interviews, IP (interviewed person).

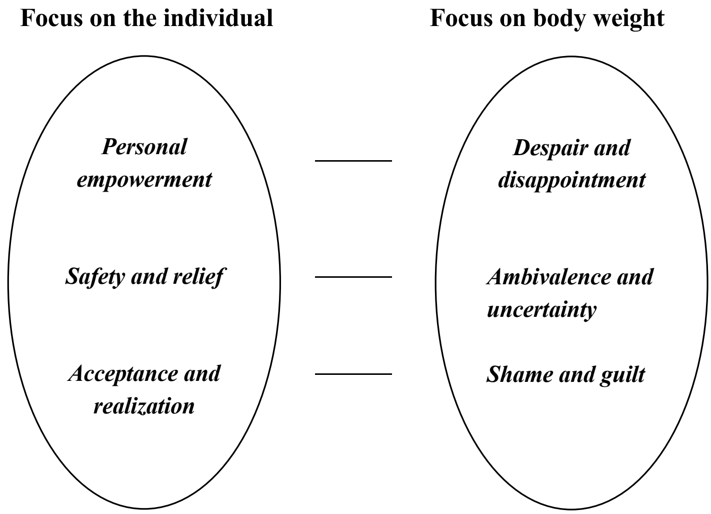

Figure 9. The outcome space: ways of perceiving obesity treatment in a group of adolescents.

a) ***Personal empowerment***

In the category personal empowerment the obesity treatment is characterized by personal empowerment. The obesity program is understood as being flexible, adaptable and adjusted to personal needs of the individual. Recommendations and treatment goals are looked upon as realistic and viable, and prepared in negotiated agreement. One's own responsibility, determination, and involvement to achieve successful weight loss are emphasized as important as well as behavioral changes made by oneself. Information about treatment strategies and results is valued as important, as well as the possibility to have different opinions and ideas.

> *" They help you and give support..you get better help...to think* ***yourself****..."* (IP 6)

> *"If I know I can't make it...I can say that and we can find another solution."* (IP 4)

b) Despair and disappointment

In the category despair and disappointment the obesity treatment is characterized by feelings of despair and disappointment. The obesity program is understood as following an instruction manual and not being innovative, flexible or adjusted for individual needs and requests. Feelings of not being seen as unique persons are expressed. In general, the recommendations are perceived as unrealistic and difficult to implement in everyday life outside the hospital. When recommendations regarding behavioral changes such as reduction in food intake and increased physical activity fail, other options, for example weight-loss drugs and surgery, are not discussed. Dialogue and a working alliance with the staff have not been established, and commitment and involvement have failed to come. Absence of personal bonds with the staff contributes to feelings of neglect and desertion. Instead of competence and hope for the future there is escape and defiance. Reactions such as obstinacy and the desire to do just the opposite of recommendations given can occur.

> *"It was almost just focus on weight...not how I felt...sort of..due to being overweight..it was more "lose weight that's that!"...no one asked how I felt about it."* (IP 12)

> *"Yes, I can feel that even today...I'm not good enough if I don't lose weight...that's how I feel..."* (IP 8)

c) Safety and relief

Here safety and relief are experienced, above all due to medical examinations and competence in the specialized clinic. Anxiety and fear of diseases, primarily type 2 diabetes mellitus, are expressed. Diabetes is often present in close relatives since many of them are obese as well. Regular medical examinations and laboratory tests provide a feeling of security, since someone is checking and controlling one's health condition. The chance to share anxiety and fear of diseases with a staff member one can rely upon and to obtain care without blame and guilt, despite weight gain, contributes to the feelings of relief and safety. Two ways of responding to results from medical tests are possible, an interest and involvement in results and consequences, or a reluctance to know unless something serious is exposed. Both reactions express the importance of tests.

> *"She said ..."just e-mail or call if you feel you're putting on weight and need help"...kind of...need to talk to somebody...it feels good to be able to call if I have something to say to them."* (IP 7)

d) Ambivalence and uncertainty

In this category obesity treatment is characterized by struggling with ambivalence and uncertainty regarding personal motives and motivation for treatment and weight reduction. These feelings are reinforced especially as the treatment program is perceived as focusing solely or mainly on weight reduction. This treatment focus does not always fit in with one's own ambitions and goals. Other things could be more important than, or just as important as, weight reduction, for example feeling good and accepting oneself, being healthy and in good physical shape, having more self-esteem, and not worrying about hospital visits and future diseases. More, finding a body weight that is pleasant and comfortable for oneself regardless of recommended BMI limits. Frustration and dissatisfaction can occur when personal needs and goals are not fully understood and confirmed by the staff.

> *I'm not doing this for myself (author's remark; attempts to lose weight)... it has been like that a lot, I'm doing it for my father and mother and the hospital sort of... to...don't want a lot of criticism and stuff..."* (IP 12)

e) Acceptance and realization

In this category obesity treatment is characterized by acceptance and increased awareness of the severity and the extent of one's obesity, as well as the necessity of one's own involvement if one is to lose weight successfully. Previous attempts have been made elsewhere. Referral to the specialized clinic is seen as the final place or step to get help. Summer camps and group treatments can be experienced as turning points for awareness of the importance of one's own responsibility, and that staff recommendations at the clinic actually work in practice.

> *" This is the final step so to say...this is were you realize...well I am* ***very*** *very overweight"* (IP 4)

> *"...my mother and others tried but it did not help until you really heard that this is life-threatening from doctors who really know...then it became motivating..."* (IP 7)

f) Shame and guilt

Where there are mainly feelings of shame and guilt, only close friends and relatives are informed about referral and clinic visits. Regular visits mean sacrifices for the parents regarding transport, taking time off from work etc., which can reinforce the guilt feelings. Shame and guilt are also mentioned if parents are held responsible for unsuccessful treatment results. Weight gain prompts feelings of embarrassment and shame. In this case one does not want to be confronted and it is common to "fail" to attend booked appointments. This response reinforces the feelings of failure and guilt**.**

> *"Coming to the clinic is not something you want to tell your friends...I don't know why but...you don't want anyone to mention it...because then it might seem that you've failed in some way..."* (IP 4)

> *"yes, I was very worried...I was kind of nervous...couldn't eat as much that day because I was thinking "what if I've put on weight?"* (IP 1)

5 DISCUSSION

To gain knowledge for clinical practice and further research, the main objective of this thesis was to explore, describe, and present data regarding obese children's and adolescents' cardiorespiratory fitness, participation in physical activity, insulin sensitivity, and walking ability. A further aim was to describe variations in obese adolescents' perceptions of obesity treatment.

5.1 FINDINGS

In Study I the obese children had higher absolute VO_2max than the reference group, significantly so in some age groups. Compared to the reference group, the obese children had lower VO_2max relative to BM in all age groups. Similar findings regarding VO_2max in obese and non-obese children and adolescents are reported by Zanconato et al. (164) and Marinov et al. (165). Diverse explanations exist as to why obese children have higher absolute VO_2max than non-obese. According to Rowland (166), it may be because increased fat levels are associated with increased cardiopulmonary work. On the other hand, according to Maffeis et al.(167), increased FFM (i.e.the metabolically active tissue) which accompanies excess fat could partly explain the higher absolute VO_2max in obese children and adolescents.

The functional consequences of normal or higher absolute VO_2max but lower relative (BM) VO_2max among obese children than among non-obese could be their poorer performance in weight-dependent activities. In running, walking, stair-climbing etc they have more body mass to transport, which requires and costs energy, while in non-weight-dependent activities e.g. swimming, rowing, and paddling, absolute VO_2max could be more important and their performance probably similar to that of non-obese. However, since most activities in daily life are weight-bearing, relative (BM) VO_2max seems more important than absolute VO_2max when comparing obese and non-obese children.

Adolescent boys generally have higher relative (BM) VO_2max values than girls (79, 82), and this was the case in the reference group in age groups 11–13 years and 14–16 years (Study I). In the obese adolescents we found no gender differences, indicating that the obese boys were relatively less fit than the obese girls. Overall, the obese children and adolescents participated less in physical activity than the reference group did. While there is consistent evidence that boys are more physically active than girls in the general population (61, 63, 64), we found no significant gender difference in participation in physical activity in obese adolescents. Similar findings have been reported by Stratton el al. (65), who found that overweight boys and girls were equally active, but that overweight boys were significantly less active than their normal-weight male counterparts. This difference did not hold true for girls (65). One possible explanation of the absence of gender differences in the obese adolescents could be that in typical sport activities for boys, for example soccer and ice hockey, heavy competition and focus on success are present from an early age. For obese boys, with low relative (BM) VO_2max, it could be hard to compete under the same conditions.

According to Pierce et al. (168) overweight children commonly report being "embarrassed doing physical activity and playing sports", and 72 % of those authors' respondents felt excluded from games and sports because of their body size. The present Study IV reports similar perceptions by the interviewed adolescents e.g.: inability to perform in the same physical activities as friends "*couldn't keep up with my mates' activities*", low physical fitness and difficulty in finding activities where they could fit in "*hard to find an activity where I could fit in*", feelings of insecurity and not having the courage to try new activities "*careful, don't dare to try new activities*", and feelings of being observed and commented on "*people look at you and make remarks*". These aspects came out when the adolescent answered the question on how their lives were influenced by obesity. Since physical activity is essential for all children and adolescents, efforts should be made to prevent non-participation. Adolescents who participate in organized physical activity are more likely to remain physically active as young adults (169). School physical education programs may improve health-related fitness in children and adolescents by increasing their participation in moderate-to-vigorous activities (170). The prevalence of obese children and adolescents is increasing, necessitating changes in the design of physical education programs. Further, sports organizations should give more attention to these children and adolescents, offering activities that are accepted and manageable by the obese and inactive child and adolescent.

Study I showed that participation in organized physical activity influenced relative VO_2max, but that the variance was explained primarily by BMI. These findings are not unexpected since we just looked into a small component of the participants' physical activity. Our questions on participation in physical activity, did not take into account intensity, frequency, or duration. The participation rate probably reflects a combination of the children's attitude towards physical activity and their physical ability to participate.

Only a limited number of studies are published on cardiorespiratory fitness and SI in obese children and adolescents, and the results vary (45, 98, 99). No studies have previously been performed in a large cohort of severely obese children and adolescents. In Study II, 228 severely obese children and adolescents participated, and SI was measured by a reliable method, the FSIVGTT (113).

In Study II we found that relative (BM) VO_2max and relative (FFM) VO_2max were stronger predictors of SI than percent body fat within a group of severely obese children and adolescents. The study confirms that cardiorespiratory fitness is of importance for SI in this population, and that efforts to improve SI should include physical activity targeting cardiorespiratory fitness. Allen et al.(45) found that in obese middle-school children relative (FFM) VO_2max was an independent predictor of fasting glucose. However, the correlation between insulin resistance ($HOMA_{IR}$) and relative (FFM) VO_2max was significant only in males, not in females. In the present study similar gender differences regarding SI and VO_2max were found, indicating that VO_2max had higher significance in obese males than in females. Further, Gutin at al.(171) found, in black and white youths, that both percent body fat and relative (BM) VO_2max explained a significant proportion of insulin variance for boys but only percent body fat did so for girls. The reason for these gender differences is unclear. However, boys generally have higher relative VO_2max values than girls. This was not the case in the present study, suggesting that the obese boys were relatively less fit than the obese girls. The disparity in physical maturity and body composition between the boys and the girls may also partly explain the gender differences regarding SI and VO_2max, but further research is required.

SI did not correlate with absolute VO_2max. Similar findings regarding SI and absolute VO_2max in overweight Hispanic youths were reported by Ball et al. (98). However, the true relationship between SI and VO_2max is complex, partly because of the strong relationship both variables have with body composition (172-174), and partly because genetic variability plays an important role (175). Cardiorespiratory fitness is to a certain extent genetically determined, but can also be influenced by environmental factors (66, 175). In intervention studies, positive effects on SI through physical exercise and increased cardiorespiratory fitness have been found in overweight and obese children, independently of changes in body composition (57, 58). On the other hand, Shaibi et al. (59) found that resistance training in overweight adolescent males improved SI. Alterations in body composition such as increased lean-tissue mass and decreased percent body fat were found, but no improvement in cardiorespiratory fitness.

SI did not correlate with percent body fat. In multiple regression analyses percent body fat was, with low explained variance, related to SI. Allen et al. (45) found a weak correlation between insulin resistance ($HOMA_{IR}$) and percent body fat in obese middle-school children. However, even though all children in those authors' study had BMI > 95th percentile, only mild elevations in fasting insulin levels were observed. In the present study it is possible that, compared to others (98, 176), body composition was of limited importance because we studied severely obese children within a relatively narrow BMI SDS and SI range. The majority of the children were insulin-resistant. Had lean subjects or more moderately-overweight subjects been included the results may have been different.

The association between adipose tissue mass and insulin resistance is complex, and the role of distribution of adiposity in children is unclear (176). Abdominal visceral fat is of major importance in adults (177, 178), contributing predominantly to hepatic insulin resistance. In the present study SI did not correlate with truncal fat. Previous results regarding the importance of abdominal obesity for insulin resistance in obese children are divergent (176, 179, 180). Druet et al. (176) found that insulin resistance ($HOMA_{IR}$) in overweight and obese children was related to total adiposity but not to its distribution, whereas Caprio et al. (179) found on the other hand, in obese girls, that visceral fat correlated highly with insulin resistance. However, methodologies and patient populations vary greatly. Factors such as ethnicity, degree of obesity, age, physical maturity, and family history of diabetes may explain some of the differences. In addition, the methods used to assess SI and body composition are of importance. SI estimations based on fasting insulin and glucose such as $HOMA_{IR}$ and the QUICKI have often been used. We have recently shown that these surrogate measures are not fully reliable in obese children and adolescents (116).

In Study III, the 6MWT showed known group validity in obese children since the difference between the obese and the normal-weight children in distance walked, 92 m, was greater than the measurement error, 24 m. Further, the 6MWT showed good reproducibility as the test-retest difference was insignificant, the CV was low and the ICC1.1 was high. These findings suggest that just one 6MWT should be sufficient to evaluate walking ability in clinical practice in obese children and adolescents. For individual evaluation over time or after intervention, statistical significance requires an improvement of at least 68 m. Such an improvement may seem large, but our results are similar to others in various populations, 65 m–133 m or 10%–23% (135, 136, 139, 181-183). A statistically significant mean increase in 6MWD in a group is often much less than a statistically significant increase in an individual (128). In the present study the statistically significant mean increase in 6MWD at group level was 24 m.

The 6MWD performed by the obese children averaged 86% of the distance the normal-weight children walked. The present mean 6MWD among the obese children (571 m) was shorter than results presented by Calders at al. (133), 611 m. A difference in the patient populations might explain the disparity in 6MWD, since those authors' children were older and had lower BMI. The 6MWD among the normal-weight children in the present study was comparable to results by Li et al. (135). One explanation for shorter 6MWD in obese children than in normal-weight could be lower relative VO_2max, as shown in Study I. The correlation between 6MWD and relative VO_2max among the obese children was low ($r = 0.34$), but multiple regression analyses showed that relative VO_2max explained 12 % of the variance in 6MWD and may well have contributed to shorter 6MWD. In the present study BMI ($r = -0.27$) and BMI SDS ($r = -0.42$) showed unexpectedly low correlation with 6MWD. The influence of BMI on 6MWD in obese children was shown by Calders et al.(133) who found BMI z-score ($r = -0.52$) to be the most dominant predictor of 6MWD. However, we studied severely obese children within a relatively narrow BMI range (32.0-37.7 $kg \cdot m^{-2}$) which may explain the low correlation. When we analyzed obese and normal-weight together, the correlation was moderate ($r = -0.56$): hence BMI affected 6MWD. Apart from relative VO_2max and BMI, factors such as motivation, attitude to physical activity, musculoskeletal pain, and movement pattern, might be important for the 6MWD in obese children and adolescents. However, most of these variables are difficult to assess and were not evaluated in the present study.

We found low correlation ($r=0.34$) between 6MWD and absolute and relative VO_2max. Consequently the 6MWT cannot replace a submaximal bicycle ergometry test. Comparable findings in obese children ($r = 0.23$-0.33) were reported by Calders et al. (133), and in healthy children ($r = 0.44$) by Li et al. (135). However, the latters' results are not fully comparable since VO_2max was estimated on a treadmill. In Calders' et al. (133) study, VO_2max was determined by a maximal bicycle test. Our interest was in the correlation between 6MWD and a submaximal bicycle test, since these tests are used in clinical practice in this population.

Adolescents at a pediatric obesity clinic (Study IV) varied broadly in how they perceived and understood the treatment program, how they related to the staff, and how they responded and reacted in the treatment process. Obesity in adolescents is one of the most frustrating and difficult diseases to treat in health care (184), and reviews of obesity treatment strategies often fail to discriminate between adolescents and children (185). Developmental considerations during adolescence often include striving for independence and individual identity (186). This must be considered when planning and implementing behavior-modification-oriented treatment of adolescents. The importance of sharing with the staff one's ideas and thoughts about treatment strategies emerged, as did that of being encouraged to think independently and express one's own ideas and opinions. Further, attempts to lose weight should be made for themselves, not for someone else, e.g. parents and staff. Where the individuals understood the program as flexible and adjusted to their own needs, they expressed that their ideas and opinions were important and sought. Consequently, they felt confirmed as unique individuals. This facilitated personal empowerment and self-efficacy, which is important for behavior changes (187).

Where the individuals perceived the program as just following an instruction manual rather than being adjusted to individual requirements, they saw the main focus on body weight and not on their own needs and goals. As a consequence, they assumed they were expected to conform. Their reaction to this could be obstinacy and a wish to do the opposite. As a consequence, no inventive dialogue or working alliance with the staff was established.

Some expressed ambivalence and uncertainty about their motives and motivation for treatment and weight reduction. Personal expectations and goals are important for accomplishing behavioral changes (187), and should be carefully discussed with adolescents in obesity treatment. Some individuals pointed out that the treatment program considered weight reduction as the only and primary goal, and this was not always in accordance with their own ambitions and goals. Further, some individuals expressed that recommendations were unrealistic and hard to implement in everyday life. When recommendations were successful the individuals perceived they were realistic, set in accordance with their requests and personal goals, and that one could be honest and open regarding compliance.

Living with obesity reportedly had a large impact on the individuals' lives. Apart from bullying, bad physical fitness, problems finding clothes, they brought up such aspects as poorer relationships with their parents, inability to focus and concentrate at school, furtive eating, and pronounced fear of disease. For some, the primary motive for weight reduction was fear of disease, mainly T2DM. It is important for health professionals dealing with obese adolescents to be aware of this anxiety and fear. Despite the widespread idea that young people act and feel as if they are immortal, research has suggested that threat appeals may be just as effective in youth as they are in adulthood (188). Further, knowledge of health risks and benefits creates the precondition for behavior change (187). The present study showed that if no information was given regarding test results, the individual's anxiety and worry was increased. The importance for the staff to inform and discuss obesity-related risk factors, medical examinations, and treatment to avoid obesity-related diseases should be emphasized so as to avoid fear and anxiety.

The transtheoretical model (TTM) (189) suggests that health-behavior change involves progress through six stages of change: pre-contemplation, contemplation, preparation, action, maintenance, and termination. Staff involved in childhood obesity treatment need to attempt to determine where in this process the patient and parents are. If the patient is pre-contemplating (no intention of changing behavior in the foreseeable future), or contemplating (intending to change within the next six months) and staff are persistent and over-eager, promptly suggesting numerous recommendations for diet and exercise, the outcome will presumably be failure, and no dialogue or alliance will be established. Further, some individuals expressed that they were not offered any alternative to recommendations for behavioral change regarding diet and exercise, nor were they informed about treatment alternatives, such as weight loss drugs and surgery. They thought one reason could be that they often met different doctors, and this was why their treatment did not proceed. However, the medication options for overweight children and adolescents are limited, and while surgery may be an option for some morbidly obese adolescents, there are still many unsolved ethical considerations. Bariatric surgery has not yet been convincingly tested in children and adolescents (49). Still it is important that those concerned are given the opportunity to share ideas on this topic.

The individuals' involvement in and compliance within the treatment process depended markedly on trust and confidence in the staff. Continuity and stability in the staff were called for, as well as a specific staff member to connect with and rely on. It was important that the individuals were met with empathy. Further, staff availability, e.g. that they could make contact with the staff easily by phone or email if they needed help, was expressed as an important aspect. The present study supports that confidence in, and encouragement from, staff with experience in childhood obesity, enhanced the opportunities for self-monitoring, goal setting, and problem-solving – all important for behavioral change (187).

5.2 METHODOLOGICAL CONSIDERATIONS

In the present thesis a submaximal bicycle ergometry test according to Åstrand and Ryhming (81) was used to estimate VO_2max. In our clinical experience, a submaximal test is preferable in this population since it is hard to motivate severely obese children and adolescents to perform to exhaustion. Regarding maximal tests in children, Wedderkopp et al. (104) excluded 6% of the children (population-based 9-year-olds) in their study for not meeting the criteria of exhaustion, and only 71% of the children (population-based 8-11 year-olds) in a study by Dencker et al. (190) reached the predicted max HR. Further, obese children's performance on treadmills is often interrupted due to insecurity and balance problems (191). The choice of a submaximal test to estimate VO_2max in children was evaluated by Mocellin et al.(192). Various methods originally developed for adults (e.g. Åstrand and Ryhming, 1954; Margaria, Aghemo and Rovelli, 1965) yield the same levels of reliability and validity (test-retest $r > 0.90$ and $r > 0.75$ as does direct VO_2max in 13-14-year old boys (193). However, tests originally designed for adults underestimate for children (12-25%) (193, 194). In Study I no correction factor for max HR or age was applied in the obese children so as to have comparable values to "Skolprojektet" (82). In Study II and III, the values from children younger than 15 years were adjusted with the same age coefficient as that used for 15-year-olds. The potential problem associated with this may possibly be that the present VO_2max values are somewhat underestimated.

In Study I we wanted to compare obese children's and adolescents' participation in organized physical activity at school and in leisure time with that of children representative of the general population. In the obese children semi-structured interviews were used, and in "Skolprojektet" (149) questionnaires. Discrepancy in data collection is a limitation, but since the questions were fairly uncomplicated, with few answer alternatives, we consider any discrepancy to be of minor importance. Further, the reproducibility of the questions used in the interviews with the obese children is good – see section 3.2.2.

During the period of data collection in Study II, the DEXA instrument was changed. Thus approximately one-third of the children were scanned on a Lunar DPX-L version 1.5 E and two-thirds on a Prodigy X-R model 6830. Cross-validation between the instruments has shown the correlation to be excellent (0.97) (157). Further, results regarding the correlation between SI and truncal fat must be interpreted with caution since we measured truncal fat only with DEXA, not with tomography or by magnetic resonance imaging. Although DEXA has been shown to provide accurate measurements of abdominal fat mass (195), subcutaneous and visceral fat cannot be distinguished with this method.

Corridor length affects the 6MWD (128). In Study III, the obese children performed the test in a 70 m corridor, and the normal-weight children in a 30 m corridor. According to ATS (128), a long corridor results in fewer turns, which might lead to longer 6MWD. This should have favored the obese children, since the normal-weight children had to turn more often. This might have influenced the 6MWD, but then the difference in 6MWD between the obese children and the normal-weight would have been even larger.

Several strategies were used to establish and maintain trustworthiness (196) (Study IV). Strategic sampling was performed, and great care was taken to recruit a wide variation of participants regarding important variables such as gender, age, degree of obesity, weight-loss achievement, ethnicity, time of registration, and socioeconomic status. The logic and value of this purposeful sampling was the richness of detailed information as well as the variation in perceptions of the phenomenon under study. More than half the nominated adolescents declined participation, which may have influenced the results. However, the decliners did not differ from the participants regarding the relevant variables. Although the majority of the participants were girls, the present data analysis did not indicate any major differences from a gender perspective.

It is possible that the participants were more positive towards referral and obesity treatment than the decliners: or the opposite, that they wanted to share their anger and dissatisfaction. However, our findings revealed both positive and negative experience regarding the treatment program, relations to the staff, and reactions in the treatment process. The reason for declining participation is unknown since no questions were asked about this. However, the most spontaneous reason given was lack of time.

Eighteen adolescents participated. Since no new information was obtained during the last interviews, the authors decided that data saturation had been achieved.
The trustworthiness of the study was strengthened by the fact that the same person, the first author with long experience of working with obese children and adolescents, conducted all the interviews. She was not involved in the participating adolescents' treatment. Further, the authors represent experience and knowledge from a variety of research areas such as childhood obesity, adult obesity, behavioral medicine, psychosomatics, and pedagogy. Consequently, data was approached from different perspectives. Frequent meetings were held to ensure agreement on the categories of descriptions and the final outcome space.

The study involved only adolescents registered at one pediatric obesity clinic. The results might thus not be transferable to obese adolescents in general. Nevertheless it is likely that the various perceptions of obesity treatment could be identified in other obese adolescents participating in other obesity treatment programs. To aid transferability of the present results, clear characteristics of the participants as well as of the obese treatment program at the pediatric obesity clinic are provided.

5.3 STATISTICAL CONSIDERATIONS

The results in age group 8-10 years (Study I) should be interpreted with caution since the number of obese children in this group was low.

In the multiple regression analyses in Study II, BMI SDS was used even though both age and gender were included. The variance, or results regarding the correlation between SI and VO_2max and body composition, was unaltered if age was removed from the model or BMI used instead of BMI SDS. However, when BMI was used instead of BMI SDS, the Tanner stage became non-significant (p= 0.058).

5.4 CLINICAL IMPLICATIONS

Obesity in childhood has been shown to be associated with morbidity and mortality in adulthood. Consequently, the prevention of chronic diseases should start early in life. The present obese children had lower relative VO_2max, and participated less in organized physical activity than children and adolescents representative of the general population. They achieved shorter 6MWD than normal-weight children did. We also found that relative VO_2max was a stronger predictor of SI than body composition was. These results confirm the need for increased physical activity in this population. School physical education programs and sports associations must offer activities that are accepted by and performable by obese and inactive children and adolescents. Further, childhood obesity treatment should include physical activity targeting cardiorespiratory fitness so as to improve SI and prevent T2DM.

The demand for clinical assessment tools to evaluate physical capacity and performance in obese children and adolescents is growing. The 6MWT showed good reproducibility and known group validity in obese children and adolescents, and can be recommended for use in clinical practice in this population. Apart from information about six-minute walked distance, heart rate, and perceived exertion, the test gives valuable information about the child's movement pattern, posture, joint position in ankle and knee, degree of pain, and endurance. This is important information here, since these aspects might influence the recommendations that will be given about physical activity. The 6MWT cannot replace a submaximal bicycle ergometry test in this population in clinical practice, since the correlation between 6MWD and VO_2max was low.

Numerous children and adolescents are today referred to medical and behavioral treatment for obesity. Very little is known about how they experience and perceive obesity, weight loss, medical guidance, and treatment. To accomplish changes in behavior and lifestyle we must engage the obese child or adolescent personally in the treatment. Knowledge of different perceptions has relevance for health-care professionals, since treatment and interventions have to take into account adolescents' individual thoughts about goals and motives for treatment and weight reduction. It is not enough merely to focus on body weight.

6 CONCLUSIONS

- The obese children had lower estimated relative maximal oxygen uptake (VO_2max), and participated less in organized physical activity than the reference group. Non-participation increased with age. Participation in organized physical activity influenced relative VO_2max but the variance was primarily explained by body mass index (BMI).

- Obese adolescents, especially boys, were at risk of physical inactivity. Among the 14-16-year-olds, every fifth obese boy and every eighth obese girl did not participate at all in physical education classes. This calls for changes in the design of physical education programs involving obese adolescents.

- Cardiorespiratory fitness was a stronger predictor of insulin sensitivity (SI) than body composition in obese children and adolescents. Efforts to improve SI and prevent type 2 diabetes (T2DM) should include physical activity targeting cardiorespiratory fitness also in severely obese children and adolescents.

- The six-minute walk test (6MWT) showed good reproducibility and known group validity in obese children and adolescents, and can be recommended for use in clinical practice in this population. To evaluate individual outcomes after intervention, the six-minute walk distance (6MWD) needs to have changed by > 68 meters to be statistically significant.

- The 6MWD performed by the obese children averaged 86% of the distance normal-weight children walked. In obese children the correlation between 6MWD and estimated VO_2max was low, hence the 6MWT cannot replace a submaximal bicycle ergometry test.

- Adolescents at a pediatric obesity clinic varied broadly in how they perceived and understood their treatment program, how they related to the staff, and how they responded and reacted in the treatment process. Knowledge of such perceptions has relevance for health-care professionals seeking to accomplish successful treatment and interventions.

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