HABITUAL PHYSICAL ACTIVITY AND THE ASSOCIATION
WITH DISEASE SEVERITY AND EXERCISE CAPACITY IN
CYSTIC FIBROSIS: A PILOT STUDY

by

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A thesis submitted in conformity with the requirements
for the degree of Master of Science
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Habitual physical activity and the association with disease severity and exercise capacity in cystic fibrosis: a pilot study

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Abstract

Objectives: To determine recruitment and compliance rates for the collection of habitual physical activity data, to profile trends in habitual physical activity patterns, and to determine if a positive relationship exists between lung function, habitual physical activity, nutritional status and exercise capacity in cystic fibrosis (CF) patients.

Methods: For this cross-sectional pilot study, 40 CF patients were recruited from the CF clinic at the Hospital for Sick Children over a three month period. Patients provided a self-report of their habitual physical activity patterns using two survey instruments: the Habitual Activity Estimation Scale (HAES), and the 7-Day Activity Diary. Pulmonary function and nutritional status data were collected from clinic records. Data on exercise capacity were available for a subset of patients who completed their annual exercise test on or near to (± 3 months) the study recruitment date.

Results: High recruitment (89%) and compliance (HAES, 100%; Activity Diary, 82%) rates indicated the feasibility of collecting habitual physical activity data in this study population. Positive and significant correlation coefficients were demonstrated between habitual physical activity (HAES), lung function, nutritional status and exercise capacity. Patients reported significantly higher Total Activity scores (mild to vigorous physical activity) for a typical weekend day (HAES, 8.0 ± 3.0 hours/day; Activity Diary, 4.8 ± 2.3) than weekday (HAES, 5.7 ± 2.8; Activity Diary, 3.9 ± 1.2). The Total Activity score for a typical weekday, derived from the HAES, was demonstrated to be a significant predictor of forced expiratory volume in one second (FEV1), the most important variable in describing CF lung disease.

Conclusions: These pilot study results will serve as the precursor for a longitudinal follow-up study that will begin to address the direction of the causal relationship between habitual physical activity and FEV1 in CF.
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CHAPTER 1

INTRODUCTION

1.1 Significance

Cystic fibrosis (CF) is a chronic, inherited disorder characterized by progressive lung disease in the majority of patients. Physiotherapy is prescribed as a conventional treatment of pulmonary impairment caused by lung infection and mucus obstruction. The goal of chest physiotherapy is to improve or maintain lung function. Exercise may also benefit pulmonary function, and has been proposed as a supplementary therapy in CF. An exercise training program of an appropriate frequency, intensity, type and duration may positively affect the pulmonary status of CF patients through the facilitation of sputum expectoration, and an increase in respiratory muscle endurance. Patient compliance with a long-term exercise training program, however, is difficult to maintain. Promoting healthy lifestyle changes in CF patients may be a more practical means of increasing physical activity levels. A longitudinal study is needed to determine whether the habitual physical activity level of CF patients is a significant predictor of the rate of change in pulmonary function.

Prior to the onset of a long-term investigation, an appropriate measurement of habitual physical activity is necessary for the CF population. The current pilot study was conducted to measure habitual physical activity in a sample of CF patients at The Hospital for Sick Children (HSC). Two instruments were used to capture this information: the Habitual Activity Estimation Scale (HAES) and the 7-Day Activity Diary. Both instruments provide data on the frequency, intensity and duration of activity. The Activity Diary, however, provides additional information on the type of activity being performed.
CF patients at HSC are frequently overwhelmed by requests for their participation in research studies. One important goal of this pilot study was therefore to calculate the recruitment and compliance rates for the collection of habitual physical activity data in order to predict the likelihood of success in patient recruitment and compliance for a long-term study. Trends in the relationship of pulmonary function with habitual physical activity level, nutritional status, and exercise capacity were also examined. These results were intended to encourage integration of the regular collection of habitual physical data into clinic management, generate further hypotheses, and guide the design of future clinical trials of exercise as therapy.

For this pilot project, we hypothesized that a positive relationship would be demonstrated between pulmonary function (forced expiratory volume in one second, FEV1), habitual physical activity (Activity score), nutritional status (percent of ideal weight) and exercise capacity (maximal work capacity or oxygen consumption). We proposed that CF patients with high values for FEV1 would have high activity scores, in addition to high percent of ideal weight and maximal work capacity or oxygen consumption values. Although it is plausible that a causal relationship between lung function and habitual physical activity could work in either direction, the issue of causality could not be addressed in this cross-sectional pilot study.

1.2 Objectives

The objectives of the current study were:

Primary

1. To determine recruitment and compliance rates for the collection of habitual physical activity data from the CF population.

2. To quantify the frequency, intensity, type and duration of habitual physical activity in CF children.
3. To compare the data from two different measurements of habitual physical activity: the 7-Day Activity Diary and the Habitual Activity Estimation Scale (HAES).

4. To determine if a positive relationship exists between pulmonary function, habitual physical activity, nutritional status and exercise capacity.

Secondary

5. To examine potential correlates of physical activity participation in CF children.
CHAPTER 2

BACKGROUND

2.1 Cystic Fibrosis

Cystic fibrosis is a chronic disease which is usually manifested in early childhood, and is characterized by an abnormal transport of chloride ions across the epithelial lining of multiple surfaces including the nasal cavities, lower airways, exocrine pancreatic ducts, and sweat ducts.\(^4\) Clinical manifestations of CF include chronic obstructive pulmonary disease, pancreatic insufficiency, and elevated sweat electrolyte levels.\(^5\) Although CF is the most common life-shortening, autosomal recessive genetic disease in Caucasian populations,\(^5\) this incurable disease is much less common in African and Oriental races.\(^4\) In Caucasian populations, the carrier rate is approximately 1 in 20,\(^4\) and the incidence is estimated at 1 in 2500 live births.\(^6\)

CF was first recognized as a disease in the 1930’s, at which time many patients died in their first year of life.\(^4\) Subsequent developments in CF research and treatment have dramatically improved the life expectancy of these patients from 11 years in 1960 to 31 years in 1997.\(^7\) Improved prognosis can be attributed to extensive international research efforts. At HSC in Toronto, the gene responsible for CF was located in 1989.\(^8\) This discovery has enabled scientists to consider gene therapy as an eventual treatment for CF. Refinements in therapy, the advent of anti-bacterial antibiotics, and more frequent recognition of mild cases have also contributed to improvements in prognosis.\(^4\) Despite this progress, some patients still do not survive past childhood. Research has demonstrated that factors associated with good prognosis include care in a CF clinic, male gender,\(^9\) good nutrition, normal intestinal fat absorption,\(^6\) and high cardiopulmonary fitness.\(^10\)
Lung function decline is a primary feature of CF patients. An estimated 75% of patients suffer from recurrent pulmonary infections, and 90% of all deaths from CF can be attributed to irreversible lung damage. Pulmonary dysfunction usually begins in infancy with an abnormally frequent cough, and eventually inhibits the child's ability to clear small airway secretions. Bacterial infections arise when mucus becomes trapped in the airways. As the cilia are unable to clear inhaled bacteria from the lungs, chronic irritation and inflammation of the airways result. The bacterial agents most likely to cause infection are Pseudomonas aeruginosa, Staphylococcus aureus, and Burkholderia cepacia. Viral agents also cause infection in CF patients. Originating in the upper respiratory tract, these infections can descend to cause bronchitis. In CF, complete obstruction of the bronchus by mucus will lead to a collapse of portions of the lung. As air cannot move into and out of the lungs properly, less oxygen will reach the bloodstream. During late childhood and early adulthood, many CF patients show a subsequent increased sensitivity of the bronchi to a variety of challenges, ranging from exercise to inhaled proteins.

Pancreatic insufficiency, an inability of the pancreas to secrete enough enzymes for food digestion, is another common clinical feature of CF. Approximately 85% of patients are unable to absorb adequate amounts of nutrients from their diets, and consequently require enzyme supplementation to help prevent growth delays and weight loss. Chest infections, in addition to pancreatic insufficiency, may also lead to weight loss through a reduction in appetite or increased energy expenditure.

Many factors influence the growth patterns of CF patients, including lung disease severity, respiratory infection frequency, the extent of nutrient malabsorption, and the degree to which treatment affects these conditions. The mean birth weight of CF infants is approximately 5% lower than that of healthy babies. In spite of delays in puberty and skeletal maturity, CF
children usually experience steady increases in height and weight during the first 10 years of life. These increases, however, are below the averages for normal children. Final height and weight values will be much greater for CF children who do not have significant pulmonary involvement than for children with severe lung impairment.4

Beginning with their diagnosis, CF patients at HSC integrate regular clinic visits into their lives. Approximately once every three months, patients and their families consult with a specialized team of health professionals, which includes doctors, nurses, physiotherapists, dieticians, and social workers. Measurements of height, weight, and temperature are taken in clinic, and sputum samples are collected. In children older than six years, partial pulmonary function testing (spirometry) is performed at every clinic visit. Exercise testing accompanies full pulmonary function testing once per year. Chest x-rays and blood tests are conducted on a biannual basis. X-rays show changes within the lungs, helping the doctor to assess the patient’s clinical status. Blood tests demonstrate liver functioning, nutritional status, hemoglobin levels, the presence or absence of infection, and the degree to which the patient can fight infection.12

Another component in the management of CF is in-hospital treatment. Periods of hospitalization usually range from 7-10 days, and are necessary if an acute chest infection does not respond to at-home treatment. This intensive treatment is comprised of intravenous antibiotics, physiotherapy, and adequate rest.12 Treatment regimens routinely conducted at home can resume once hospitalization is complete.

The aim of CF treatment is to alleviate symptoms and correct organ dysfunction. Patient contentment and compliance with treatment are important considerations in deciding on the best regimen to prescribe, and become even more important to consider in adolescent patients.
Pancreatic enzyme replacement, the prescription of antibiotics, and the clearance of lower airway secretions comprise the primary forms of treatment.

To combat weight loss, the clinic dietician prescribes a high-energy meal plan and caloric supplementation. CF patients need an energy intake of approximately 120-150% of normal requirements. Enzyme and vitamin supplements are recommended for pancreatic insufficient individuals.12 Treatments for pulmonary impairment include bronchodilator therapy, antibiotics, and chest physiotherapy. These therapeutic regimens have been very successful in modifying the natural history of lung disease to the extent that serious lung damage can now be delayed, in some patients, for many years.

Inhaled bronchodilator medications relax the bronchial tubes in the lungs. The subsequent increases in both the size of the air passages and in expiratory flow rates make it easier for patients to breathe. Bronchodilators are useful in combating occasional bouts of wheezing, shortness of breath, and persistent coughing. Antibiotic therapy is prescribed for chest exacerbations and for regular disease management. The patient’s response to antibiotic therapy may include a decrease in the frequency of chest exacerbations, improvements in lung function, a decrease in the bacterial density of sputum, and enhanced well-being.12

Chest physiotherapy mobilizes sputum from smaller to larger airways so that it can be removed by cough. In addition to increasing sputum expectoration, physiotherapy may also minimize lung tissue damage. Two common physiotherapy techniques require the assistance of a caregiver: manual percussion of the chest and postural drainage. Two independent techniques are forced expiration by the patient, and expiration against a positive pressure mask.12 Physiotherapy should be regularly administered so that infection can be delayed or prevented by the reduction
in obstructive mucus. Patients are recommended to perform two to three sessions of physiotherapy per day, with each session lasting 20 to 30 minutes.\textsuperscript{4}

Effective chest physiotherapy may require special equipment and a caregiver to assist in administration, and adequate compliance with treatment is essential. Compliance with physiotherapy is often difficult to encourage, however, especially if the physiotherapy sessions interfere with daily activities or set CF children apart from their peers. A supplemental treatment for CF patients is regular physical activity, which encourages patients to cough, and may lead to increased sputum expectoration\textsuperscript{4} and maintenance of pulmonary function.\textsuperscript{3}

2.2 Physical Activity in Children and Youth

2.2.1 Health Benefits

The health effects of physical activity participation in children and adolescents have not been well documented. Based on the available research, the potential health benefits of regular physical activity likely include: improved peak bone mass, immune status, cardiorespiratory fitness, and psychological well-being, reduced adiposity, and a decreased risk of musculoskeletal injury. As a result of these reported benefits, physical activity guidelines for adolescents have been developed. Experts recommend that healthy adolescents participate in a minimum of 3 weekly moderate to vigorous activity sessions, with each session lasting at least 20 to 30 minutes.\textsuperscript{14}

The health benefits of physical activity in children and youth are difficult to determine. Activity patterns in children and adolescents vary as a function of gender, age, and season. Males are generally more active than females, and overall participation in physical activity tends to decrease with age. Time spent in vigorous activity, however, may actually increase with age.
Children appear to be more active when outdoors, and seasonal variation in activity patterns has been reported.\textsuperscript{15,16}

2.2.2 Patterns in Chronically Ill Patients

In light of evidence supporting physical activity participation in healthy populations, researchers surmise that regular physical activity may also be beneficial for individuals with chronic disorders. Encouraging physical activity participation in childhood will help to establish lifestyle habits that may modify the course of some diseases, and research suggests that physical activity should become a regular component of CF management.\textsuperscript{17}

Studies indicate that chronically ill children are more sedentary than their healthy counterparts. Reduced physical activity in children with chronic disorders may be attributed to parental fear of harm, school worries about injury, physician concerns about disease exacerbation due to physical stress, time-consuming treatment regimens, or fewer opportunities to exercise. Exercise-related studies of children with asthma, Down's syndrome, cerebral palsy, juvenile rheumatoid arthritis, and CF suggest that exercise training programs are not detrimental. On the contrary, these programs may result in improved self-concept, enhanced medical treatment benefits, and increases in physical fitness.\textsuperscript{18} In CF patients, extensive research has been conducted to determine the effects of exercise training on general well-being, lung function and exercise capacity.

2.2.3 Exercise Considerations in CF Patients

The health benefits of recreational exercise for CF patients were first recognized in 1969. Exercise has since been proposed as an adjunct to chest physiotherapy,\textsuperscript{19} and is now widely accepted as a therapeutic intervention in CF.\textsuperscript{20} Studies have indicated that exercise training can increase sputum expectoration through heightened coughing, improve respiratory muscle
endurance, and contribute to the maintenance of pulmonary function status. In addition, exercise may improve clinical status, foster the child's participation in normal activities of childhood, and improve their morale. As a supplementary treatment, exercise is appealing because children can perform their therapy independently or with their peers in activities of their own choosing. While there is no evidence to suggest whether regular participation in physical activity can improve prognosis in CF patients or be as effective as chest physiotherapy, CF patients who do not exercise may experience reductions in muscle tone, strength, endurance, and aerobic capacity.

Although exercise in CF patients is considered to be generally safe, there may be additional risks for some individuals. Possible problems include a reduction in blood oxygen resulting in tissue death, dehydration, the inducement of violent coughing, and weight loss. As a result of these potential risks, extra precautions may be necessary. If oxygen desaturation occurs during exercise, it can be alleviated with oxygen supplementation. Training at a target heart rate of 10 beats per minute below the point where desaturation occurs should also be prescribed. A gradual increase in activity levels should precede the onset of any training program if the patient exhibits physical deconditioning.

Exercise testing is a useful tool in the assessment of disease progression. CF patients suffer progressively impaired exercise capacity as their lung disease worsens. Although heart rate and blood pressure responses to exercise are normal, exercise testing demonstrates that maximal values for work capacity, oxygen consumption and heart rate are less than expected when compared to the healthy population. In CF, exercise is limited by lung mechanics, whereas in healthy individuals, exercise is limited by the cardiovascular system. Exercise training programs of sufficient intensity in CF may result in benefits to exercise capacity, including
improvements in maximal work capacity, maximal oxygen consumption, maximal minute
ventilation, respiratory muscle endurance, and anaerobic threshold.\textsuperscript{19}

Guidelines have been suggested for exercise recommendations in CF patients. The
activity choice will depend partially on the patient’s access to appropriate equipment and
facilities. Aerobic activities that will promote sputum expectoration, such as swimming, running,
skating and dancing, should be encouraged from an early age.\textsuperscript{12} Participation should entail three
to five sessions per week at an intensity of 70 to 85\% of the maximal heart rate. CF patients are
generally not able to attain an age-predicted maximal heart rate due to ventilatory limitations.
Therefore, maximum heart rate should be individually determined. Patients should be allowed
significant input into the choice of activities in order to ensure good compliance with the
program.\textsuperscript{19}

Compliance with exercise programs can be difficult to foster in CF patients due to the
existence of time consuming treatment regimes, forgetfulness, or a negative attitude towards
exercise. Although many CF centers do not offer organized exercise programs, such programs
may encourage compliance. Summer camps, in-patient hospital programs, and home-based
programs are several possibilities. While summer camps offer brief periods of intense activity in
a positive social setting, in-patient hospital programs can teach patients how to incorporate
regular exercise into their lives. At-home exercise participation requires patients to partake
independently in unstructured programs. In North America, however, summer camp and group
exercise programs are no longer recommended due to the risk of cross-infection of Burkholderia
cepacia.\textsuperscript{22} Therefore, home-based exercise programs are the most viable option for CF patients.

As compliance with long-term exercise training programs is difficult to maintain, a more
feasible alternative for CF patients may be a change in habitual physical activity patterns.
Whereas exercise is characterized by an imposed and regimented training program, habitual physical activity refers to the level of activity one has incorporated into their daily life. Changes in habitual physical activity would represent a lifestyle modification, and may promote long-term health benefits more easily than exercise programs. Until now, the quantification of and follow-up of habitual physical activity in CF patients have not been adequately addressed. Research has, however, been conducted to examine the role of exercise training programs in positively affecting the health of CF patients. These studies are important to examine because they provide evidence of the benefits of physical activity in CF.

2.3 Exercise Training Programs in CF

2.3.1 Characteristics of Exercise Programs

Exercise-related studies in the CF population have been conducted to determine the effects of exercise training programs on pulmonary function, exercise capacity, sputum production, respiratory muscle endurance and psychological well-being. The various studies have implemented training programs of differing types, duration, frequency, and intensity.

The degree of supervision is an important consideration in exercise prescription. Supervised programs require regular intervention and program monitoring by an exercise specialist such that the safety of the individual can be periodically checked and individual tailoring of exercise programs can occur. These factors likely foster high patient compliance with the training program. On the contrary, the success of unsupervised training programs depends on the participant’s social support and self-motivation. Although compliance with the program may be less than optimal, unsupervised programs require minimal monitoring, and thus have the advantage of increased feasibility.
The desired duration of the exercise program should be decided on prior to the onset of training. Whereas long-term training programs have been shown to benefit lung function in CF, the effects of short-term exercise programs are still equivocal. Although positive results from shortened training periods have been demonstrated, these effects are often short lived. Training programs of varying intensities are also presented in the CF literature. High intensity, exhaustive programs have demonstrated positive results, but these programs may be difficult to incorporate into daily life. Exercise programs of lesser intensity have been considered as a more feasible alternative. Specific study examples of the various training programs are presented below.

2.3.2 Supervised Programs

Supervised training programs can occur in a formalized hospital setting, as demonstrated by Dutch and American based studies. The conflicting results from these investigations demonstrated either benefit to pulmonary function, or no harm to patients with training. In the American study, there was no reported difference in pulmonary function for subjects randomized to two groups: either two sessions of exercise plus one session of physiotherapy (n=9), or three sessions of physiotherapy (n=8). Patients (mean age=15.4 years) stayed on the program for an average of 13 days, and performed exercise on a cycle ergometer. Over this short study period, the investigators ensured high compliance with treatment, and concluded that substituting exercise sessions for regular physiotherapy was not harmful to patients.

The duration of hospitalization periods for CF patients are generally short, and are therefore not conducive to the implementation of an extended, supervised training program. Recreational settings are more suited to long-term programs. Eight supervised programs have been conducted in recreational settings under the supervision of a trained professional. The
activity types included swimming,\textsuperscript{24,27} running,\textsuperscript{28} trampoline exercise,\textsuperscript{29} intensive and multi-
activity training in a camp setting,\textsuperscript{23,30} and aerobic exercise directed by an instructor.\textsuperscript{31,32}

Two studies have evaluated the effects of a 12-week\textsuperscript{27} and a seven week swim program\textsuperscript{24} on the health of CF patients respectively. Research has suggested the value of swimming as a training mode in CF because the well-moisturized environment may increase sputum expectoration. Submersion-induced subtle changes in volume and pressure within the respiratory system may also contribute to benefits in CF patients with swimming programs.\textsuperscript{24} The seven week swim program was coupled with repeated evaluation of lung function and sputum production in 11 patients (median age=10 years).\textsuperscript{24} Children maintained their usual schedules of therapy throughout the study. Sputum volumes were found to be significantly higher on swimming days than on non-swimming days. In addition to enhanced mucus clearance, results also demonstrated significant improvements in pulmonary function following the training program. Although these patients were recommended to remain physically active after completion of the swim training, pulmonary function values eventually returned to baseline values. The positive changes in pulmonary function may have resulted from the swimming itself, or from the supervised nature of the program. Results from the 12-week swimming program,\textsuperscript{27} on the other hand, demonstrated no benefit to pulmonary function.

Trampoline jumping has been suggested as an appealing alternative to more typical and arduous forms of exercise, and may mimic the actions of chest physiotherapy. Eight children (mean age=11.5 years) participated in an eight-week exercise program on a trampoline, for a maximum of 109 minutes/week.\textsuperscript{29} The patients participated in a program that included rocking, jogging, and jumping on a mini-trampoline. This program resulted in significant improvement in forced vital capacity and maximal oxygen consumption.
Patients (age range=10-30 years) volunteered for a three-month running program in another supervised study. Twenty-one CF patients were allocated to the exercise group, while the remaining 10 patients formed the control group. The exercise group participated in an aerobic program three times per week that included warm-up, jogging, and cool-down components. The control group was asked not to change their usual activity. The exercise group demonstrated significant improvements in exercise capacity and in respiratory muscle endurance, but no change in pulmonary function. In the control group, forced expiratory volume in one second showed significant decline.

Supervised programs have also been implemented in a pediatric rehabilitation centre and at a summer camp. These types of settings provide optimal conditions for children to participate in physical activity for brief time periods. Seven CF patients (mean age=13.4 years) participated in four weeks of summer camp, undergoing 1.5 daily hours of intensive swimming and canoeing aimed at upper body endurance. Respiratory muscle endurance, which has been correlated with fatigue resistance, improved by 56.7% in these patients. No conclusions could be drawn from this study, however, about the potential benefits of lower body endurance exercise. At a pediatric rehabilitation centre, patients participated in a 17-day intensive training period, replacing usual physiotherapy with physical activity. Although pulmonary function did show significant improvement, less intensive exercise may not have demonstrated benefit to patients.

Results from these studies illustrate differential effects of supervised training on lung function, exercise capacity, and respiratory muscle endurance in CF. A multitude of factors must be considered prior to the onset of this type of program, including the type, duration, and setting of the program. A summary of the supervised programs are depicted in Appendix A as Table A.1.
2.3.3 Unsupervised Programs

Seven unsupervised training programs have been implemented in the CF population.33-38 Unsupervised programs are usually carried out in the home setting, and are generally longer in duration than supervised programs due to minimal monitoring requirements.

The two longest studies to date have been 30 months35 and three years3 in duration. The effects of physical training on work capacity, lung function and clinical condition were examined in seven patients (mean age=10.4 years) participating in daily exercise over 30-months.35 The exercise program was comprised of skipping, jumping, jogging and swimming. Chest physiotherapy was withdrawn after the initial 12 months. As pulmonary function parameters were unchanged over the course of the study, the investigators concluded that physical training could replace conventional chest physiotherapy except where strenuous exercise was not feasible.

In a three-year exercise intervention study in 65 CF patients (age range=7-19 years), the effects of long-term training on lung function were evaluated.3 Subjects were randomized to either an exercise or a control group. The exercise group was instructed to exercise a minimum of three times per week for 20-minute sessions, while the control group was asked to maintain their usual activity. Patients from both groups continued their usual schedules of chest physiotherapy. Subjects participated in aerobic activities of their own choosing, with a guideline target heart rate provided by the exercise physiologist. Results indicated a greater annual mean rate of decline in forced vital capacity for the control group compared with the exercise group. No differences in exercise capacity were demonstrated.

An Australian study37 investigated the effects of a 12-week home exercise program, comprised of sprints and jogging, on 41 exercise and 45 control patients (age range=8-14 years).
The exercise group demonstrated significant improvements in exercise capacity, but no change in pulmonary function. The investigators noted declining compliance in the latter half of the program which may have contributed to these non-significant results.

The literature indicates a need for further research in the area of unsupervised programs. Whereas one study suggested that exercise could have equivalent benefit to patients as conventional physiotherapy, another study reported no benefit to pulmonary function with unsupervised training. The unsupervised programs are presented in Appendix A as Table A.2.

Another possibility for exercise training is to combine supervised and unsupervised components into one exercise program. A study in the Netherlands showed improved pulmonary function (forced expiratory volume in one second) following a short period of hospitalization, and an increase in exercise capacity after one-year of at-home training. This type of program is useful if patients begin exercise training during a hospital stay, and want to maintain a similar level of physical activity once they return home. This study is presented in Appendix A as Table A.3.

2.3.4 Challenges of Training Programs

The effects of exercise training on CF patients are difficult to interpret due to small sample sizes and potential confounding variables. Investigators find it difficult to recruit enough patients for their studies because an extensive time commitment is required, and some individuals are not interested in pursuing exercise training. Loss to follow-up is also a problem in CF patient studies, further emphasizing the need for a large sample size. Chest exacerbations, for example, may interfere with the training protocol. Confounding variables must be adequately controlled for. Potential confounders to consider include: the heterogeneity of the disease and its diverse natural course, unpredictable occurrences of infection, complexity of the therapeutic
approach, and variable degrees of compliance with treatment. These factors must all be accounted for if conclusions are to be made on the relationship between exercise training and health in CF.

Compliance issues and the individual needs of the patient must also be given careful consideration. Programs that are too long or too intense may deter patients from participating. Individual tailoring of training programs, such that each program meets the training needs and interests of the patient, is essential if health effects are to be demonstrated. Finally, the benefits in lung function and exercise capacity seen with training may not last beyond the training program itself. Given the challenges involved in implementing successful exercise training programs in CF, further evaluation of habitual physical activity and its relationship to important health outcomes is necessary.

2.4 Relationship between Habitual Physical Activity, Lung Function, Nutritional Status, and Exercise Capacity in CF

Several studies have begun to explore the relationship between habitual physical activity and lung function in CF. In one investigation, the physical activity levels of 30 CF patients and 31 control subjects (ages 7-18 years) were compared. The investigators also evaluated whether habitual physical activity was related to exercise performance and pulmonary function in these CF patients. Kriska’s Modifiable Activity Questionnaire was used to assess habitual physical activity. Total hours of physical activity per week did not differ between the CF (7.3 hours/week) and the control (7.1 hours/week) groups. The total hours engaged in vigorous activity, however, were significantly lower in the CF patients (1.3 hours/week) compared with the healthy controls (3.2 hours/week). The results indicated that activity level was unrelated to both exercise tolerance and lung function.
A Quebec study used the Habitual Activity Estimation Scale (HAES) as an estimate of habitual physical activity in examining the relationship between activity levels, lung function and nutritional status in 36 CF patients (ages 6-16 years). Consistent with previous usage of the HAES, patients classified their activity into 4 different categories, and their activity level was represented by the total percentage of time spent in the somewhat active (i.e., walking) and active (i.e., biking) categories. Boys and girls spent 8.1 and 7.5 hours respectively being at least somewhat active. In children with significant lung disease, activity level was positively associated with nutritional status, but unrelated to lung function. From these results, the study investigators concluded that activity levels may be restricted by nutritional status in more severely affected patients.

Disease progression in CF is characterized by malnutrition and lung function decline. As the disease advances, exercise capacity is also limited. Researchers have hypothesized that pulmonary function may affect exercise capacity by limiting ventilatory capacity, or through skeletal muscle deconditioning. Nutritional status may be influential through reductions in muscle mass or changes to muscle quality. The inter-relationship of nutritional status, pulmonary function and exercise capacity has been previously investigated.

In 50 CF patients, exercise testing was performed to determine limiting factors of exercise capacity. In this sample of patients, exercise capacity was demonstrated to be correlated with both lung function and nutritional status. Another study was conducted in 22 CF patients with advanced lung disease to evaluate the effects of nutritional status on exercise capacity. Results indicated that exercise capacity was related to the degree of respiratory impairment, and independently influenced by nutritional status. In an investigation of 14 CF patients, lung disease severity and peripheral muscle function were both determined to be
limiting factors of exercise capacity. At HSC, long-term follow-up of CF patients demonstrated that the institution of a high fat diet resulted in improved nutritional status, and a subsequent increase in survival. These studies have demonstrated an association between nutritional status, exercise capacity and lung function in the CF population. The potential contribution of habitual physical activity to this relationship needs further investigation, as does the quantification of habitual physical activity in CF.

2.5 Measurement of Physical Activity

Pediatric chronic disease research has advocated the importance of incorporating a quantifiable measure of physical activity into regular disease management. A consensus has not been reached, however, on the best method of measuring physical activity. The difficulty lies in the many possible choices for physical activity quantification, ranging from isotope consumption to heart rate monitoring and self-report. Practicality, cost and measurement accuracy are important considerations in choosing the most appropriate method.

2.5.1 Doubly Labeled Water

Doubly-labeled water (DLW) is a relatively new technique that is being considered as the gold standard of energy expenditure estimation. Although the expense of this procedure deems it impractical in large-scale epidemiological studies, the accuracy of DLW makes it an appealing choice for field and laboratory studies. One limitation of this procedure, however, is that it cannot be used to determine the proportion of energy expenditure associated specifically with physical activity.

For this procedure, patients ingest a quantity of water with a known concentration of hydrogen and oxygen isotopes. Once the isotopes have distributed themselves in equilibrium with body water, labeled hydrogen exits the body as water, and labeled oxygen leaves the body
as water and carbon dioxide. By knowing the difference in the elimination rates of the 2 isotopes, the production of carbon dioxide can be calculated. Total energy expenditure is calculated from standard respiratory gas exchange equations.

2.5.2 Observation

In contrast to DLW, the observation method is a relatively simple means of assessing physical activity. Observation is useful in studying preschool and school-aged children, where alternate methods may be neither feasible nor appropriate. An observer monitors the activities of a subject for a pre-determined amount of time, and records data on the type, frequency, duration and intensity of each activity. To calculate total energy expenditure, the estimated energy cost of each activity is multiplied by the time spent in that activity.

The observation method has not been previously validated, although it has been used as a standard by which other techniques are compared. Due to restrictions on time and cost, this method is best suited for small studies. There are several other disadvantages to this technique. Observations can only be made over short time periods, and are not reflective of habitual physical activity. Additionally, subjects may alter their usual activity if they know that they are being observed.

2.5.3 Movement Assessment Devices

Movement assessment devices are worn on the trunk or extremities, and are designed to directly monitor movement and store this data for subsequent analysis. Two examples of these motion sensors are the pedometer and the accelerometer. Although the pedometer depends on acceleration and deceleration, it is not an accelerometer. An accelerometer measures acceleration of the body.
The pedometer counts the number of steps taken or estimates the distance walked. It is useful in estimating physical activity associated with walking or running, providing a quick assessment of activity levels. Individuals tend to walk with a greater impact on one foot than the other, and pedometer readings will vary depending on which side of the body the pedometer is worn. The pedometer will also underestimate activity levels for sports such as cycling, skating, and rowing, where activity is not based on vertical displacement.

The most common single-plane accelerometer is the Caltrac. This device clips close to the body at the non-dominant hip to ensure an accurate estimation of acceleration and deceleration. The Caltrac is designed to provide an activity score that reflects the intensity and quantity of the movement, and allows for an estimation of energy expenditure for activities within the vertical plane. Three-dimensional accelerometers reflect movement outside the vertical plane, and can estimate energy expenditure for many different types of activities. These triaxial accelerometers measure motion in the vertical, horizontal and diagonal planes. There are, however, disadvantages to use of the accelerometer. Energy expended as a result of lifting heavy objects cannot be reflected in the data. For water sports such as swimming, waterproofing of the accelerometer is necessary. For cycling, the device must be worn on the leg instead of the trunk.

2.5.4 Heart Rate Monitoring

A demonstrated positive relationship between heart rate monitoring and energy expenditure has led to the use of heart rate monitoring to estimate energy expenditure. This technique is appealing in populations where it is difficult to assess physical activity levels by other means, such as in young children. Relatively inexpensive heart rate monitors are available to assess daily activity, complete with full-day storage capacity for minute by minute data.
collection of heart rate. To obtain an individual’s heart rate profile, a minimum of four to five recording days is necessary in order to account for the variability seen in heart rate measurements. Many factors affect heart rate and could influence the relationship between heart rate and energy expenditure, including the active muscle group, anxiety, training, ambient temperature, and the type of muscle contraction. Using the heart rate monitor in conjunction with a self-report instrument could better reflect physical activity than if the monitor is used alone.

2.5.5 Self-Report Instruments

In epidemiological studies, activity diaries and questionnaires are the most common techniques used for assessing habitual physical activity. These instruments can either be self-administered or completed with the help of an interviewer. Parents or teachers may serve as proxy respondents in estimating the physical activity levels of young children. Habitual physical activity patterns or physical activity levels in the recent past may be of most interest to a researcher. Activity type, intensity, duration and frequency are the most common variables that are measured, and in some cases, an estimation of energy expenditure can be computed.

Advantages of using diaries and questionnaires to assess physical activity include low cost, quick administration time, the ability to gather information over an extended time period, and minimal staff. However, the validity and reliability of these instruments must be continually evaluated. Disadvantages include potential recall bias, and subjective responses to the questions. In addition, studies indicate that self-report instruments are not useful in children under 10 years old. Proxy response is, however, an acceptable alternative for completion of these instruments.
2.5.5.1 The Activity Diary

Activity diaries require subjects to detail their daily activity at intervals ranging from 1 minute to 4 hours. Individuals may broadly classify their activities, or express their activity patterns in more specific terms using prepared forms. Although this type of extensive reporting may be tedious, subjects can employ shorthand methods to efficiently report their activity levels, and may discover patterns in their weekly activity, making recording easier.

A 3-day activity diary was developed by Bouchard et al to estimate the amount and pattern of daily energy expenditure. Every 15 minutes over a 3-day period, 150 adults and children (ages 10-50 years) categorized their activities on an energy cost scale from 1 to 9. Mean energy expenditure was positively correlated with physical working capacity and negatively correlated with body fat. Reliability testing indicated high reproducibility for this measurement.

This 3-day diary was modified as a 7-day activity diary in a Swedish investigation. In two groups of randomly selected adolescents (aged 15 years) from two regions of Sweden (n=374), activity patterns were recorded over a 7 day period. Each subject was provided with a detailed explanation and demonstration of the diary. Total energy expenditure and physical activity level were computed from the diary entries. Results demonstrated high and concordant physical activity levels and energy expenditure in the two subject groups.

Validation of this activity diary was performed in a sub-sample (n=50) of these Swedish adolescents. The 7-day activity diary was compared to the doubly labeled water method, and was found to provide close estimates of physical activity level and total energy expenditure. These results suggested the suitability of the diary for estimating energy expenditure in groups of adolescents.
Although not previously used in a CF population, a similar version of this activity diary has been used in children with chronic disease.52 A sample of 23 children (ages 5-11 years) with juvenile rheumatoid arthritis (JRA) were compared to an equal sample of healthy children on daily physical activity levels using a 3-day activity record. The investigators hypothesized that children with JRA would be less active than their healthy counterparts. The 3-day activity record was completed by parents, and provided data on the type and intensity of the activities at 15-minute intervals. Mean physical activity values were significantly lower in JRA patients than for controls.

In a study of Quebec children and youth,53 the 3-day activity diary was used to examine the relationship between pulmonary function and habitual physical activity in 424 boys and 366 girls (ages 9-18 years). Estimates of daily energy expenditure and time spent in moderate to vigorous physical activity were computed from the diary. Results demonstrated that habitual physical activity was not associated with pulmonary function in this sample of children and adolescents. The investigators speculated that this lack of association could have been due to inadequate stimulus, age, growth status, and type of activity.

The diary offers several advantages. Data can be collected for many subjects simultaneously, and the type, duration and frequency of the activities can be recorded. This technique incurs a low cost to the investigator, and an estimation of energy expenditure is possible. Due to a possible reduction in accuracy over long periods of data collection,47 however, phone calls and careful description of the instrument may be necessary to encourage accuracy and completeness.
2.5.5.2 Questionnaires

Many questionnaires have been designed to quantify physical activity for various periods, including: the previous 24 hours, one week, three months, and one year. Attempts have also been made to quantify lifetime and occupational physical activity, and to estimate usual or habitual physical activity. These questionnaires are either self-administered, or administered in-person or over the phone by an interviewer. Several of the more commonly cited questionnaires are described below.

The Previous Day Physical Activity Recall (PDPAR) requires subjects to recall after-school activities from the previous day. Activity is recorded in 30-minute intervals with a rating of relative intensity provided by the subject. A listing of common youth activities is intended to aid in subject recall. One study concluded that PDPAR provided an acceptable estimate of relative energy expenditure over an 8-hour recording period, and accurately identified bouts of moderate to vigorous physical activity. Although this instrument provides a summary of type, frequency, intensity, and duration of the activities, there are limitations. Results depend on the accuracy of a one-day recall over an 8-hour period, which may not be representative of usual physical activity participation. A validity study was performed in older children only, and the appropriateness of PDPAR for younger children is unascertained.

The Physical Activity Questionnaire for Older Children (PAQ-C) is a self-administered 7-day recall measure designed to evaluate moderate to vigorous habitual physical activity during a specific season. Physical activity is described as sports or games that make you breathe or sweat hard, or make your legs tired. An activity score is calculated from a compilation of 9 questions. Although the PAQ-C was shown to be a cost-efficient method of assessing children’s physical activity during the school year, it cannot be used to estimate caloric expenditure, is not
designed to assess summer or holiday levels of physical activity, and does not discriminate between moderate and vigorous physical activity levels.

The Godin-Shephard Physical Activity Survey is a simple, quantitative physical activity self-report measure in which subjects report the number of times in an average week that they spent more than 15 minutes in activities classified as mild, moderate or strenuous. Examples of activities in each of the three categories is provided to subjects.\textsuperscript{56} This instrument was found to be reliable and positively correlated with PAR in one study, and investigators concluded that it could be a useful self-report measure in young children.\textsuperscript{57} However, this instrument may be subject to recall bias as individuals must recall their participation in physical activity over seven days.

The Habitual Activity Estimation Scale (HAES) is a self-report instrument designed to estimate habitual physical activity. Completion of the HAES entails estimating the proportion of time spent at each of four different activity categories for a typical day.\textsuperscript{58} The HAES has been used in both healthy and chronically ill pediatric populations. In 36 children with acute lymphoblastic leukemia, bone mass, mineral metabolism and physical activity were assessed. The HAES was completed for the most recent weekday and weekend day at 6-month intervals over the course of the therapy.\textsuperscript{59} In a group of 156 grade nine students in Southern Ontario, the relationship between habitual physical activity, as estimated through the HAES, and self-perceptions of physical activity among Native and non-Native adolescents was evaluated.\textsuperscript{60} In an investigation which examined normative values for lumbar spine bone mass in children in relation to age, gender, dietary intake, and physical activity, the HAES was also employed to assess physical activity.\textsuperscript{61} Although this instrument has not been used to estimate energy
expenditure, these studies have demonstrated successful use of the HAES as a self-report instrument in different populations.

Investigators have attempted to determine the accuracy of the HAES in the following three studies. The sensitivity of the HAES to detect change in activity patterns was evaluated in 24 hypoactive children (ages 5-16 years) with chronic conditions. Parents completed the HAES for their children prior to and following an 8-week outpatient program designed to increase physical activity. Significant increases in physical activity were demonstrated in comparing the two parental reports of activity. In a study of 52 girls (6-12 years), the relationship between percent body fat, body mass index, and inactivity was evaluated. Parents reported the activity levels of their children using the HAES for a typical weekday and typical weekend day. Significant, positive correlations were demonstrated for inactivity with both percent body fat and body mass index. In a sample of 17 school children, a positive and significant correlation was found between activity measured by a Caltrac accelerometer and the active category of the HAES. Although further validation of the HAES is desirable, results from these investigations demonstrate that the HAES is a practical and convenient tool that provides an acceptable level of accuracy in measuring habitual physical activity.

2.5.5.3 Summary of Self-Report Instruments

Questionnaires and diaries are practical and inexpensive tools used to quantify physical activity in epidemiological studies. Research is still needed, however, to determine the validity and reliability of these measures. Validation is challenging due to inadequate criteria by which to judge these self-report measures. An instrument such as the HAES gives subjects a full range of activity options, from inactivity to high activity, lessening the likelihood of biased estimations which might occur if only high activity levels were reported. The best techniques will capture
all types of physical activity, including occupational, leisure, and household. In addition, the instrument should be able to quantify the type, duration, frequency and intensity of the activity. It may be necessary to integrate the use of two different activity measures into one study in order to capture all dimensions of activity.

2.5.6 Summary of Physical Activity Measurement

Many methods are available to measure habitual physical activity. The quantification and profiling of habitual physical activity is necessary in order to follow these patterns over time, and to examine the association of physical activity with other important variables, such as lung function in cystic fibrosis. An additional importance of the quantification of physical activity is to explore potential correlates of physical activity participation. This knowledge could further explain differences in activity patterns between groups, and promote the adoption and maintenance of regular physical activity participation.

2.6 Potential Correlates of Physical Activity Participation

As the health benefits of regular physical activity are well established in adults, the habitual physical activity patterns of children and youth are also beginning to be investigated more closely. Studies have suggested that an active childhood may predispose individuals to similar activity patterns in adulthood, and may subsequently reduce the risk of chronic disease. The quantification of habitual physical activity in childhood is an important, preliminary step in understanding this association.

There is also a need to study the potential correlates of exercise behavior in childhood and adolescence. These factors may help to explain the differences in self-motivation between active and inactive individuals, and allow for the establishment of guidelines to promote regular participation in physical activity. Age and gender have already been recognized as important
determinants of exercise behavior, but modifiable factors such as psychosocial and environmental variables are of special interest, and require further study.64

The potential correlates of physical activity behavior can be summarized into three categories. *Personal characteristics* include age, self-motivation, weight, and personal attitudes. *Environmental characteristics* comprise access to facilities, family or peer influence, and climate. *Activity characteristics* encompass activity intensity and type.64 In the CF population, understanding the potential determinants of physical activity could have invaluable implications for health care professionals who make recommendations on exercise participation to patients. Studies in the healthy population have already proposed potential correlates of physical activity participation.

Modifying physical activity patterns through changes in the environment appears to be more practical than implementing expensive public intervention programs. A study was conducted in 110 college students to examine variables that may influence physical activity behavior. The *physical environment* was the primary variable of interest. In this investigation, self-report items were used to assess environmental variables at home, in the neighborhood, and on frequently traveled routes. Home exercise equipment and accessibility of exercise facilities were significant correlates of physical activity participation. After adjustment for neighborhood socioeconomic status, however, home exercise equipment was the only significant correlate.65

In a group of 528 children (median age=11 years), demographic, psychosocial, and environmental determinants of physical activity were assessed. Age, gender, television watching, and lack of exercise equipment in the home were found to be significant correlates of low activity status after elimination of non-significant variables. Results suggested that parents can
produce a *home environment* conducive to physical activity involvement by monitoring the time that their children spend watching television, and by providing access to exercise equipment.\textsuperscript{66}

Robinson et al sought to evaluate the relationship between hours of television viewing, adiposity, and physical activity in 671 female adolescents (mean age=12.4 years). Hours of after-school television viewing, physical activity level, and stage of sexual maturation were assessed with self-report instruments. In this sample, results suggested a weak association of television viewing time with adiposity, physical activity, or change in either over time.\textsuperscript{67} More research is needed to further assess the relationship between physical activity and television viewing.

For 30 young children (ages 5-9 years) and their parents, investigators sought to determine the relationship between parent and child activity levels. The children exhibited physical activity patterns that were similar to their parents. These results suggested that children’s physical activity participation may be increased through the promotion of regular physical activity in their parents.\textsuperscript{68}

Physical activity patterns are determined by the complex interaction of biological, psychological, social, cultural and environmental factors. No single variable can account for the variance in children’s physical activity participation. Further studies in both healthy and diseased populations are needed to stimulate hypotheses and provide information for designing and testing longitudinal intervention programs.\textsuperscript{69} Effective activity promotion interventions hold promise for improving the health of both children and adults through the encouragement of exercise involvement.\textsuperscript{64}
CHAPTER 3

METHODS

3.1 Overview of the Study Design

This was a cross-sectional pilot study. The first component of the study was descriptive: subject characteristics, nutritional status, pulmonary function measurements, and habitual physical activity levels of CF patients were described. The second component was analytical: the relationship of pulmonary function with habitual physical activity, nutritional status, and exercise capacity was explored.

3.2 Practical Planning and Implementation

The study coordinator (graduate student) conceptualized this project in September of 1998. The six-month planning period that followed was necessary for the development of an appropriate study protocol, and for securing project and ethics approval from HSC.

A thorough literature search, conducted by the study coordinator, confirmed that research in the proposed area was insufficient. This search entailed exploration of the PUBMED database using the following key words: cystic fibrosis, habitual physical activity, pulmonary function, and exercise capacity. While the quantification and evaluation of habitual physical activity in CF patients had not been adequately addressed, numerous studies had previously examined the relationship between exercise training programs and lung function. Therefore, the study coordinator concluded that the association between habitual physical activity and pulmonary function needed further investigation in CF.

A second literature search was conducted to assess the feasibility and appropriateness of different techniques used to quantify physical activity. Of particular interest were self-report
instruments that could be self-administered by CF patients. Two instruments, which together provided a comprehensive profile of habitual physical activity, were chosen for this study.

Patients in the CF clinic at HSC experience frequent requests to participate in both invasive and time-consuming research studies. A study coordinator must therefore inform the CF clinic staff of a new project, and gain their approval prior to patient contact. For the current project, support from clinic staff was also intended to encourage maximal participation from patients. In December of 1998, the study coordinator presented her thesis proposal at a weekly meeting attended by the CF clinic team, which included: one social worker, physiotherapist, dietician, exercise physiologist, biostatistician, five physicians, two nurses, and three study coordinators. The study coordinator invited the clinic team to critique the proposal, offer feedback and ask questions. The project received unconditional support, and the CF clinic team acknowledged its clinical relevance.

The study coordinator also arranged to meet individually with members of the clinic team. The physiotherapist offered a summary of her exercise recommendations for patients, and discussed common problems in encouraging compliance with therapy regimens. The exercise physiologist contributed her observations on the wide spectrum of physical fitness levels in CF patients. Informal discussions with the pulmonary function laboratory technicians proved to be invaluable during subject recruitment. The technicians helped the study coordinator to identify both potential participants and those patients who were ineligible due to chest exacerbations.

At HSC, all newly proposed research projects must undergo a comprehensive review process with the Research Ethics Board of the Research Institute. The study coordinator prepared the project proposal according to established guidelines, which included designing the appropriate consent and assent forms. The 10-page proposal and appendices were submitted for
internal review to clinicians within the Division of Respiratory Medicine. Two internal reviewers carefully scrutinized the project, and provided written and oral suggestions for improvement. The study coordinator discussed the necessity for revisions with the reviewers and her supervisor prior to making changes. The revised proposal was resubmitted to the Research Ethics Board, and due to the non-invasive nature of this project, it received expedited approval. The study coordinator initiated subject recruitment and data collection procedures in March of 1999.

3.3 Subject Selection

3.3.1 Eligibility Criteria

Study participants were selected from patients (7-18 years) under the regular care of the CF clinic at HSC (n=188). The number of eligible patients was determined by extracting data from the Toronto CF database to determine how many patients had visited the HSC clinic over a one-year period (January of 1998 to January of 1999). Patients younger than seven years cannot accurately perform the pulmonary function and exercise tests necessary for inclusion in this study, and were therefore not approached to participate. All other patients within the specified age range who attended their three-month routine clinic visit within the designated study period (March 4-June 6, 1999) were deemed eligible for participation (n=138). Patients were excluded if they presented at their clinic visit with a chest exacerbation or were hospitalized at this time. Under these circumstances, the study coordinator decided that their self-report of habitual physical activity would not be representative of their usual physical activity patterns.

3.3.2 Subject Recruitment

In order to facilitate efficient subject recruitment, the study coordinator reviewed clinic lists of scheduled patients prior to each of three weekly CF clinics. Eligible patients were identified based on their age. Communication with clinic staff allowed the study coordinator to
determine the most appropriate time to approach patients. The three other CF clinic study coordinators were consulted to ensure no overlap in subject recruitment.

Eligible patients were identified and approached by the study coordinator while they waited in clinic. These patients and their families were provided with both a written and an oral description of the study protocol, and were given an opportunity to ask questions and to assess the time requirements of their involvement. Benefits and risks of the study were outlined. Patients gave their informed consent in writing upon their agreement to participate. For children younger than 16 years, a parent provided informed consent, and the child gave their own informed assent. The consent and assent forms are shown in Appendix B.

During each three-hour clinic, the study coordinator made contact with as many patients as possible. In an average clinic, a maximum of two patients could be successfully recruited. Generally, there was not enough time to recruit more than two patients. Depending partially on the patient’s understanding of the study requirements, the study coordinator spent between 20 minutes and one hour with patients. In addition, patients were often called away for routine testing and consultation with clinic staff. In these cases, data collection was delayed. The study coordinator had to wait for the patient to return to the waiting room, preventing the recruitment of other patients.

3.4 Data Collection

3.4.1 Subject Data

For each patient recruited, the study coordinator reviewed updated clinic records to obtain necessary subject data. The patient’s age was calculated from their recruitment and birth dates. The clinic nurse routinely collects measures for height and weight and documents them in
the patient’s file. These values were recorded by the study coordinator, and used to compute a measure of nutritional status, percent of ideal weight.

Patients who refused to participate in the study were documented. In order to compare these non-participants to the study sample, relevant data was also collected from their clinic records. Subsequently, a comparison of these two groups could be made.

3.4.2 Pulmonary Function

Pulmonary function tests are routinely conducted in CF patients in the pulmonary function laboratory at HSC. These tests are designed to identify and quantify the degree of lung impairment.\(^7\) For the current investigation, all study patients performed pulmonary function tests either through full pulmonary function testing or spirometry.

Spirometry is the procedure used to measure the rate at which the lung changes volume during forced breathing maneuvers. The most commonly performed test procedure uses the forced expiratory vital capacity maneuver. This procedure, in which the subject inhales maximally and then exhales as rapidly and completely as possible, provided the pulmonary function measures needed for the current study.\(^7\)

At HSC, spirometry data is collected on the Vmax system (Sensor Medics Corp. Yoba Linda, California) according to accepted standards.\(^7\) Pulmonary function variables are expressed as percent of predicted value for height and sex.\(^7\) The four most common measurements are: forced vital capacity (FVC), forced expiratory volume in one second (FEV\(_1\)), peak expiratory flow (PEF), and average forced expiratory flow over the middle 50% of FVC (FEF\(_{25-75}\)). Complete data was available for all study patients on these four measures. These terms are further defined in Appendix C.
FEV₁ is the most reproducible⁷⁰ and sensitive indicator of disease severity.⁹ It has previously been established as the best predictor of survival in CF⁹,⁷³ For these reasons, FEV₁ was the variable used to represent pulmonary function for all data analyses.

3.4.3 Measurement of Habitual Physical Activity

Two instruments were used in the current study to quantify habitual physical activity: the Habitual Activity Estimation Scale and the 7-Day Activity Diary. These instruments were chosen because together they provided a comprehensive profile of habitual physical activity (frequency, intensity, type and duration), and could be self-administered by the study patients. These instruments are summarized in Table 3.1.

3.4.3.1 The Habitual Activity Estimation Scale (HAES)

The HAES was initially designed as a clinically feasible tool to assess habitual physical activity levels in children with chronic disorders.⁵⁸ In the HAES, as outlined in Appendix D, a typical waking day is delineated by five periods: wake-up time, the three main meals, and bedtime. Activity intensity is partitioned into four categories: inactive (i.e., sleeping), somewhat inactive (i.e., sitting), somewhat active (i.e., walking) and active (i.e., running). The HAES captures data on the intensity, frequency and duration of activity. The somewhat active and active categories were used to compile the Activity scores. Patients were asked to recall one usual weekday and one usual weekend day from the past two weeks. They were then able to complete the HAES, by estimating the proportion of time spent in each of the four activity categories for the specified weekday and weekend day respectively. Data were collected for a weekday and weekend day separately to account for any differences in habitual activity patterns for these two periods.
3.4.3.2 The 7-Day Activity Diary

In addition to the intensity, frequency and duration of activity measured with the HAES, the 7-Day Activity Diary,\textsuperscript{49,50} as illustrated in Appendix E, also captures data on the type of activity being performed. For seven consecutive days, study patients used the Activity Diary to classify the intensity and type of their activity in 15-minute increments according to nine predetermined categories. Study patients listed the entire range of their activities, regardless of intensity level. Category 1 represented inactivity (sleeping), Categories 2 and 3 represented sitting and standing respectively, Categories 4 and 5 represented walking, Categories 6,7, and 8 represented physical activities of mild, moderate and hard intensity respectively, and Category 9 represented competitive sport.

The Activity Diary Activity scores were compiled from categories 4-9. For each diary entry, the patients were also asked to record specific details on the types of activities they were involved in. These entries allowed the study coordinator to construct a profile of physical activity, and served as confirmation that the appropriate intensity level had been documented. As categories 1-3 represented varying levels of inactivity, they were not incorporated into the Activity score. These categories were important, however, as they encouraged patients to report on the entire range of activity, decreasing the chances for over-estimation of physical activity.

3.4.4 Administration of the HAES and the Activity Diary

The HAES was self-administered by all study patients in the clinic waiting area. Completion of the two scales (weekday and weekend) typically required less than 15 minutes, although a few patients required as long as 25 minutes to complete it. Even though written instructions and a sample entry were provided to each patient, the study coordinator offered additional instruction and assistance as needed. The completed HAES was returned to the study
coordinator in clinic, who immediately examined it for completeness and accuracy. Missing values or apparent errors were discussed with the patient and corrected if necessary.

In clinic, patients were also introduced to the Activity Diary and given extensive instruction on its proper completion. The study coordinator showed patients excerpts from a sample diary and reviewed the different category definitions with them. Patients were sent home with the diaries, and asked to prospectively record their activity for the following seven days. During the completion period, the study coordinator telephoned each patient at least once to encourage compliance and respond to any concerns. The completed diaries were mailed to the study coordinator for scoring and analysis.

The literature suggests that younger children are unable to provide an accurate description of their own physical activity. Therefore, parents of children younger than 13 years in the current study were carefully briefed on completion of the HAES and the Activity Diary, and asked to serve as proxy respondents. The study coordinator recommended that parents probe their children about their school-related activities, and where necessary, consult with teachers and school staff. The children provided their parents with valuable input on their activities, enabling them to complete these measures.

3.4.5 Nutritional Status

Measures of height and weight were used to calculate both height and weight percentiles and percent of ideal weight, according to standards of Tanner et al. Although these standards were published in 1965, the methods of measurement are considered superior, and are routinely used in clinical research at HSC. The height and weight percentiles illustrated whether the study patients differed from their healthy peers in the same age-sex group. Percent of ideal weight was calculated as an indicator of nutritional status.
To compute percent of ideal weight, the patient’s height is first plotted on a growth chart and the height centile is determined. The ideal weight for height is determined by finding the weight on the same centile as that for height, age and sex. Percent of ideal weight is a measure of actual weight divided by ideal weight for height, multiplied by 100. Percent of ideal weight was previously found to be a reliable indicator of nutritional status in both healthy subjects, and in children and adults with CF.

3.4.6 Exercise Capacity

Exercise testing was performed in those study patients who were scheduled for their annual exercise test on or near to their study recruitment date. The annual scheduling of the exercise test and the three-month recruitment period meant that only a sample of the total study patients underwent exercise testing on the same day as study recruitment. Exercise data was accepted from the previous or subsequent clinic visit (± 3 months) if the patient’s clinical status had not changed significantly between visits, based on the stability of their pulmonary function test results between clinic visits. It has been previously established that a change of less than 12% predicted in FEV₁ is within the normal range of variability.

Patients performed a maximal, incremental cycling test on an electrically braked cycle ergometer (Rodby Electronik AB, Enhörna, Sweden). Similar to previous HSC investigations, increments were chosen based on the patient’s sex and height, so that the patient typically terminated the test in 8 to 10 minutes due to exhaustion. The last completed minute of the exercise test was documented as the patient’s maximal workload. Throughout the test, patients breathed through a mouthpiece connected to a two-way Y-valve of low resistance and dead space. Heart rate (Lead II, ECG), oxygen saturation (Ohmeda, Biox 3700 pulse oximeter, Louisville, KY), inspired minute ventilation (Parkinson-Cowan dry gas meter,
Manchester, England), mixed expired oxygen (Applied Electrochemistry oxygen analyzer, Sunnyvale CA), carbon dioxide (CO2-44A, rapid response carbon dioxide analyzer, Fitness Instrument Technologies Corp., Quogue, NY) and respiratory rate (thermister) were monitored continuously on an eight-channel recorder. Oxygen consumption, carbon dioxide production, tidal volume and respiratory exchange ratio were measured continuously on-line through an automated exercise testing program developed in the exercise lab at HSC. Blood pressure was measured at rest and immediately after peak exercise by a mercury sphygmomanometer.

The exercise test was conducted by an experienced exercise physiologist who evaluated the validity of the data. In several study patients, a maximal effort was not achieved on the cycle ergometer due to maturity level and uncontrollable coughing, and these data were not used. The exercise test provided data on the following maximal exercise parameters: heart rate, minute ventilation, oxygen saturation, oxygen consumption, work capacity, and ventilatory reserve. These terms are defined in Appendix C. Values for percent body fat and lean body mass were calculated by the exercise physiologist prior to the exercise test. Percent body fat was computed from the sum of four skinfolds (biceps, triceps, subscapularis, and suprailliac).\textsuperscript{81} Lean body mass was calculated by subtracting the patient’s fat mass (calculated from percent body fat) from their total weight.

For the purposes of the current study, maximal oxygen consumption and maximal work capacity were the two most relevant exercise parameters. In the CF population, maximal oxygen consumption has been suggested as a predictor of survival,\textsuperscript{10} while maximal work capacity has been documented as an indicator of overall clinical status.\textsuperscript{82}
3.4.7 Compliance with Physiotherapy

Compliance with physiotherapy was an important variable to evaluate in the current study. Most CF patients are prescribed daily chest physiotherapy to maintain or improve their pulmonary function, yet compliance is difficult to encourage. Some patients deliberately replace their physiotherapy with regular physical activity under their own assumption that the benefits will be equivalent. Patients who do comply with physiotherapy, on the other hand, may have less time for participation in regular physical activity. A measure of compliance with physiotherapy was essential considering its potential to confound the relationship between habitual physical activity and pulmonary function.

Patients were asked to rank their compliance with physiotherapy from three possible responses. This scoring system was previously developed for use in the CF population. The choices, zero, one and two represented poor, partial and full compliance respectively. The clinic physiotherapist was able to verify or dispute the patient's response, if necessary.

3.4.8 Potential Correlates of Physical Activity Participation

Potential correlates of physical activity participation were evaluated through a series of questions answered by parents. The Parent Questionnaire (PQ), as shown in Appendix F, was intended to provide data on environmental factors that could be related to the study patient's participation in physical activity. The factors of interest included: parental activity level, the # of organized activities that the child was involved in, proximity of the household to sporting facilities, safety of the family's neighborhood, and the number of exercise-related items in the home. The study coordinator compiled the PQ from relevant questions published in other surveys. A description of the PQ is provided in Table 3.1.
Table 3.1: Summary of the survey instruments

<table>
<thead>
<tr>
<th>Survey Instrument</th>
<th>Purpose</th>
<th>Type of Administration</th>
<th>Approximate Time to Administer</th>
<th>Recording Period</th>
<th>Variables Assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitual Activity Estimation Scale (HAES)</td>
<td>To assess habitual physical activity levels by patient recall</td>
<td>Self-administered in clinic, patient and parent†</td>
<td>15-25 minutes</td>
<td>Usual weekday and weekend day activity</td>
<td># of hrs spent at each of 4 activity levels</td>
</tr>
<tr>
<td>7-Day Activity Diary</td>
<td>To prospectively assess habitual physical activity levels</td>
<td>Self-administered at home, patient and parent†</td>
<td>15-20 minutes / day</td>
<td>1-week</td>
<td># of hrs spent at each of 9 activity levels, type of activity</td>
</tr>
<tr>
<td>Parent Questionnaire (PQ)</td>
<td>To examine potential correlates of physical activity participation</td>
<td>Self-administered in clinic, parent</td>
<td>10-15 minutes</td>
<td>Once</td>
<td>parent's activity level, # of organized activities, proximity to facilities, safety of neighborhood, home exercise equipment</td>
</tr>
</tbody>
</table>

† if child younger than 13 years
3.5 Sample Size

As determined from the CF database, 188 patients (7-18 years) made at least one routine visit to the CF clinic between January of 1998 and January of 1999. This estimated number of patients served as the sampling frame for the current pilot study. For the purpose of sample size estimation, the study coordinator approximated that 50% of the eligible number of patients would be scheduled to visit the CF clinic during the three-month recruitment period. From these 94 potential participants, a sample size of 40-50 patients was predicted. The final sample size for this study was 40 patients.

Logistics and estimates of feasibility were used to generate the estimated sample size prior to the onset of subject recruitment. Time constraints of CF patients in clinic, personnel limitations, and refusals were the main limitations of sample size for this pilot study.

In order to conduct a longitudinal study based on the demonstrated trends of this pilot study, a power calculation will be needed. This power calculation is depicted in Appendix G, and will be the basis for a longitudinal study examining the relationship of FEV₁ with habitual physical activity, nutritional status and exercise capacity.

3.6 Data Analysis

The Statistical Analysis System (SAS), version 6.12, was the software package used for statistical analysis. A permanent SAS dataset was created for storage of the study data.

3.6.1 Data Scoring

To compare the habitual physical activity data captured by the HAES and the Activity Diary, comparable activity scores were needed. Based on the activity category definitions for the HAES and the Activity Diary, categories 4-5 of the Activity Diary represented the somewhat active category of the HAES, and categories 6-9 represented the active category of the HAES.
3.6.1.1 The HAES

The complete HAES data was entered into a Microsoft Excel '97 program that was previously developed to compile activity data from the HAES. The program computed the total proportion of time (%) that the subject spent in each of the four activity categories (inactive, somewhat inactive, somewhat active, and active) for the reported weekday and weekend day respectively. These percentage values were subsequently converted into hours/day using a SAS program.

The final HAES Activity scores, as depicted in Table 3.2, were compiled from the two categories representing the highest levels of physical activity: somewhat active and active. Based on a previous study, habitual physical activity can be represented by a combination of the somewhat active and active categories (Total Activity), or by the active category (High Activity) only.42

For the current study, separate scores were calculated for the HAES data to reflect differences between both weekday and weekend day activity, and total and high activity levels. A Weighted Activity score was also compiled for each of the Total and High Activity levels to represent a combination of weekday and weekend day activity. The Weighted Activity score was created by assigning a weight of five to the weekday activity and a weight of two to the weekend activity, and then divided by seven.

3.6.1.2 The Activity Diary

The study coordinator developed score sheets for this study to compile activity data from the Activity Diary. As the subjects reported their activity in 15-minute increments, each 15-minute time period was designated as one unit. For each of the nine activity categories (1-9), a summary number was computed based on the total number of units in that category. The total
number of hours spent in each category was subsequently calculated (total number of units / 4).

The Activity Diary Activity scores, as depicted in Table 3.2, were based on activity categories 4-9. In a previous study, a compilation of categories 6-9 represented moderate to vigorous physical activity,\textsuperscript{26} which was termed High Activity for this investigation. Subsequently, a summation of categories 4-9 represented mild to vigorous physical activity, which was termed Total Activity. Similar to scoring for the HAES, separate Activity Diary Activity scores were also computed to represent weekday and weekend activity, and Weighted Activity scores were calculated to combine weekday and weekend day activity.

3.6.1.3 Activity Type

The activities listed in the Activity Diary were classified individually by their type. A listing of the different types of activities (categories 4-9 only) was first compiled from all the Activity Diaries. The activity types and the time spent performing each type were then allocated to an activity classification within their specific activity category. For each activity category (categories 4-9), the eight possible activity classifications were: personal care, domestic work, school-related, employment, unstructured play, walking, sport and undefined. Histograms were created to compare the amount of time spent in each activity classification.

3.6.2 Data Quality Control

The raw data was entered into the SAS dataset by the study coordinator, and data checks were conducted to ensure the accuracy of the data. Maximal and minimal values for all variables were examined, and any discrepant values were checked against the raw data. In addition, a research assistant unfamiliar with the study entered the data a second time into a temporary dataset. A comparison program written in SAS confirmed the accuracy of the data entry.
Table 3.2: Activity scores compiled from the HAES and the Activity Diary

<table>
<thead>
<tr>
<th>Activity Score</th>
<th>HAES (hours spent)</th>
<th>Activity Diary (hours spent)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Activity†</strong></td>
<td>Categories:</td>
<td>Categories:</td>
</tr>
<tr>
<td></td>
<td>Somewhat active‡‡</td>
<td>4+5+6+7+8+9</td>
</tr>
<tr>
<td></td>
<td>+ active§</td>
<td></td>
</tr>
<tr>
<td><strong>High Activity†</strong></td>
<td>Categories:</td>
<td>Categories:</td>
</tr>
<tr>
<td></td>
<td>Active only</td>
<td>6+7+8+9</td>
</tr>
<tr>
<td><strong>Weighted Total Activity</strong></td>
<td>[(5 * Weekday Total Activity) + (2 * Weekend Total Activity)]/7</td>
<td>[(Weekday Total Activity) + (Weekend Total Activity)]/7</td>
</tr>
<tr>
<td><strong>Weighted High Activity</strong></td>
<td>[(5 * Weekday High Activity) + (2 * Weekend High Activity)]/7</td>
<td>[(Weekday High Activity) + (Weekend High Activity)]/7</td>
</tr>
</tbody>
</table>

† scores for both weekday and weekend day respectively
‡‡ somewhat active: e.g., walking
§ active: e.g., biking
3.6.3 Descriptive Statistics

Univariate analysis was conducted to compute the range, frequency, mean and standard deviation (SD) of each study variable. SAS macro programs were used to compute weight and height percentiles, percent of ideal weight, and percent predicted values for pulmonary function. The study dataset was merged with data files in the Toronto CF database to obtain additional subject data, including birth date and gender. A dummy variable was created for gender, a categorical variable.

PROC UNIVARIATE was used to compare weekday and weekend Activity scores by means of a paired t-test. PROC TTEST was used to evaluate whether any statistically significant differences were present between males and females.

3.6.4 Pearson’s Correlation

Pearson’s correlation was used to assess the strength of the association between pairs of variables through the creation of correlation matrices. The significance of a correlation coefficient is a function of both the magnitude of the correlation coefficient (R), and the sample size. Therefore, the importance and strength of each relationship was assessed in addition to the significance of the correlation coefficient. R-square values were assessed as an approximation of the amount of variability in one variable that was explained by association with another variable. Scatter plots were also created for each of the pairs of interest to evaluate whether outlying data points were causing the correlation coefficient to be larger or smaller than the overall trend.86

The correlations of the different HAES and Activity Diary Activity scores with FEV₁ were the primary focus. As part of model building, the correlation coefficients and probability values (p-values) were examined to determine which of the different activity scores demonstrated the strongest relationship with FEV₁. The HAES and Activity Diary Activity scores that demonstrated
both significant p-values and the highest correlation coefficients when analyzed with \( \text{FEV}_1 \) were of most interest for regression analysis.

The correlation coefficients for the association of the *Activity scores* and \( \text{FEV}_1 \) with age, gender, percent of ideal weight, maximal oxygen consumption, maximal work capacity, and compliance with physiotherapy were of secondary interest. The strength of these correlation coefficients were important in estimating which variables might be important in the relationship between \( \text{FEV}_1 \) and the *Activity scores*, and thus practical for multiple regression analysis. In addition, the correlation of the *HAES Activity scores* with the *Activity Diary Activity scores* were examined to estimate the degree of consistency between these two measurements.

### 3.6.5 Regression Analyses

In separate multiple correlation analyses, either \( \text{FEV}_1 \) or one of the *Activity scores* was considered as the outcome variable as the direction of causation between lung function and habitual physical activity could not be established from this pilot study. The *Activity scores* used in the final regression models were chosen based on the strength and significance of the association demonstrated in multiple correlation.

The *explanatory variables* were:

i) \( \text{FEV}_1 \) or an *Activity Diary/HAES Activity score* (whichever was not the outcome), ii) percent of ideal weight, iii) one of maximal oxygen consumption, or maximal work capacity, iv) compliance with physiotherapy, v) age, and vi) gender.

#### 3.6.5.1 Multiple Correlation

Multiple correlations between variables were examined by means of the all possible regression subsets technique. All possible regression analysis requires the fitting of every possible regression equation that involves the outcome variable plus the explanatory variables.
As further model building for the final multiple regression analysis, the technique of all possible regression analysis was used to find the best fitting model. It is preferable to step-wise regression, where important relationships among variables may be missed. This technique was well-suited for this study because the number of explanatory variables was relatively small. The adjusted R-square values and the Cp Mallow statistic were evaluated to determine the best models. PROC REG in SAS produces efficient output of these statistics.

The model that was most parsimonious (i.e., the fewest explanatory variables explaining the most variability in the outcome variable as determined by the adjusted R-square values), and for which the Cp Mallow statistic most closely matched the number of parameters in the model was considered the be the strongest candidate for final multiple regression analysis.

3.6.5.2 Modelling FEV$_1$ as the Outcome Variable

Multiple linear regression involves expressing the continuously distributed outcome variable as a linear function of a certain number of explanatory variables.$^7$ PROC REG in SAS was used to generate more detailed results of the best multiple regression models selected from the results of multiple correlation. The adjusted R-square values, parameter estimates and standard errors were examined to evaluate changes in the amount of variability explained with additional variables in the model. An interaction term was also included.
CHAPTER 4

RESULTS

4.1 Descriptive Statistics

The study variables are presented as mean ± standard deviation (SD) for males, females, and the total study population. It was important to look for any differences between males and females in this sample because of a reported poorer survival in female CF patients compared to males.  

4.1.1 Patient Characteristics

4.1.1.1 Study Participants

Twenty-three males (57.5%) and 17 females (42.5%) were recruited from the CF clinic at HSC over a three-month period (March 9-June 4, 1999). Subject characteristics for these 40 study patients are detailed in Table 4.1. Mean height and weight values below the 50th percentile in this group of patients indicated subnormal growth. Percent of ideal weight, however, did not reveal any degree of malnutrition.  

4.1.1.2 CF Population Values

Table 4.2 displays the characteristics for 77 males (55.8%) and 61 females (44.2%) who met the study eligibility criterion (7-18 years) and also attended the CF clinic during the three-month study recruitment period. The study sample was similar to all eligible CF clinic patients.
Table 4.1: Study patient characteristics (mean ± SD)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n = 23)</th>
<th>Female (n = 17)</th>
<th>Total (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>12.6 ± 2.9</td>
<td>12.2 ± 3.9</td>
<td>12.4 ± 3.3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>146.9 ± 15.8</td>
<td>144.3 ± 16.7</td>
<td>145.8 ± 16.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>37.9 ± 12.1</td>
<td>39.1 ± 14.2</td>
<td>38.4 ± 12.9</td>
</tr>
<tr>
<td>Height percentile</td>
<td>34.6 ± 27.7</td>
<td>45.8 ± 26.2</td>
<td>39.4 ± 27.3</td>
</tr>
<tr>
<td>Weight percentile</td>
<td>32.2 ± 24.0</td>
<td>41.8 ± 23.7</td>
<td>36.3 ± 24.0</td>
</tr>
<tr>
<td>% of ideal weight</td>
<td>99.5 ± 9.9</td>
<td>96.4 ± 8.7</td>
<td>98.2 ± 9.5</td>
</tr>
</tbody>
</table>

Table 4.2: CF patient characteristics for all eligible patients attending clinic from March 9-June 4, 1999 (mean ± SD)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male (n=77)</th>
<th>Female (n = 61)</th>
<th>Total (n = 138)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>11.9 ± 2.9</td>
<td>12.6 ± 3.1</td>
<td>12.2 ± 3.0</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>144.6 ± 16.5</td>
<td>147.3 ± 13.5</td>
<td>145.8 ± 15.3</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>36.9 ± 12.8</td>
<td>39.4 ± 11.0</td>
<td>38.0 ± 12.0</td>
</tr>
<tr>
<td>Height percentile</td>
<td>38.7 ± 28.4</td>
<td>44.8 ± 26.3</td>
<td>41.4 ± 27.6</td>
</tr>
<tr>
<td>Weight percentile</td>
<td>35.3 ± 28.0</td>
<td>35.8 ± 26.5</td>
<td>35.6 ± 27.2</td>
</tr>
<tr>
<td>% of ideal weight</td>
<td>101.5 ± 17.9</td>
<td>95.2 ± 12.4</td>
<td>98.7 ± 16.0</td>
</tr>
</tbody>
</table>

4.1.1.3 Study Refusals

The study coordinator approached 45 patients, 40 of whom agreed to participate in the study. There was an 89% recruitment rate. Five patients refused to participate: one was moving from the province, one was involved in another research study, one was hospitalized at the time of recruitment, and two were uninterested in the study protocol. Relevant clinic data for these two boys and three girls were collected (mean ± SD: age, 13.3 ± 2.7 years; height, 146.8 ± 10.6
cm; weight, 36.7 ± 7.5 kg; height percentile, 29.2 ± 20.5; weight percentile, 26.3 ± 23.9; percent of ideal weight, 97.9 ± 17.8). This group of study refusals, who also had subnormal growth and normal nutritional status, did not differ from the study patients.

4.1.2 Measurement of Habitual Physical Activity

4.1.2.1 The HAES

All study patients completed the HAES either in clinic, 97.5% (39/40) or at home, 2.5% (1/40). Results from the HAES indicated significantly higher scores for the Total and High Activity categories of a weekend day than a weekday, suggesting that the study patients were more physically active on a weekend day than a weekday (see Table 3.2 for clarification of the Activity scores). Figure 4.1 depicts the average activity levels for each category of the HAES. The reported time spent in the Total Activity category for males and females was slightly lower than that reported in another CF population.42

Although not statistically significant, males consistently reported more time than females in the High Activity category, while females reported more time than males in the Total Activity category. These results are shown in Table 4.3.
Figure 4.1: Average Activity Levels for the HAES

<table>
<thead>
<tr>
<th>Activity Category</th>
<th>Average hours/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekday INACTIVE</td>
<td>9</td>
</tr>
<tr>
<td>Weekend INACTIVE</td>
<td>10</td>
</tr>
<tr>
<td>Weekday SOMEWHAT INACTIVE</td>
<td>8</td>
</tr>
<tr>
<td>Weekend SOMEWHAT INACTIVE</td>
<td>5</td>
</tr>
<tr>
<td>Weekday SOMEWHAT ACTIVE</td>
<td>4</td>
</tr>
<tr>
<td>Weekend SOMEWHAT ACTIVE</td>
<td>3</td>
</tr>
<tr>
<td>Weekday ACTIVE</td>
<td>2</td>
</tr>
<tr>
<td>Weekend ACTIVE</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 4.3: Activity hours (hours/day) compiled from the HAES (mean ± SD)

<table>
<thead>
<tr>
<th>Activity Category</th>
<th>Males (n = 23)</th>
<th>Females (n = 17)</th>
<th>Total (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weekday Score</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Activity†</td>
<td>5.5 ± 2.8</td>
<td>6.0 ± 2.9</td>
<td>5.7 ± 2.8</td>
</tr>
<tr>
<td>High Activity‡</td>
<td>3.1 ± 1.7</td>
<td>2.6 ± 1.3</td>
<td>2.9 ± 1.5</td>
</tr>
<tr>
<td><strong>Weekend Day Score</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Activity†</td>
<td>7.8 ± 3.5</td>
<td>8.2 ± 2.4</td>
<td>8.0 ± 3.0</td>
</tr>
<tr>
<td>High Activity‡</td>
<td>4.5 ± 3.3</td>
<td>3.1 ± 2.5</td>
<td>3.9 ± 3.1</td>
</tr>
<tr>
<td><strong>Weighted Score</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Activity†</td>
<td>6.2 ± 2.7</td>
<td>6.6 ± 2.5</td>
<td>6.4 ± 2.6</td>
</tr>
<tr>
<td>High Activity‡</td>
<td>3.5 ± 2.0</td>
<td>2.7 ± 1.3</td>
<td>3.2 ± 1.8</td>
</tr>
</tbody>
</table>

† somewhat active + active
‡‡ active

4.1.2.2 The 7-Day Activity Diary

Thirty-nine patients (97.5%) agreed to complete the 7-day Activity Diary at home. One patient did not agree because he was moving residences, and did not think that the diary would be representative of his usual activity. From the 39 patients who were sent home with the Activity Diary, 33 (84.6%) returned their diaries by mail or at a subsequent clinic visit to the study coordinator. Thirty-two of the 33 returned diaries (97%) were filled out according to instructions. One diary was too incomplete for any score to be estimated. The study patients who completed the Activity Diary did not differ from those who did not complete it.

The Activity scores reported in Table 4.4 were based on an average of the 5 reported weekdays or 2 reported weekend days such that a comparison with the HAES could be made (see Table 3.2 for clarification of the Activity scores). Average activity levels are illustrated in Figure 4.2. The Activity scores showed similar trends to those of the HAES. Although not
statistically significant, males consistently spent more time in the High Activity category, while females spent more time in the Total Activity category. Significantly more time was reported for the High and Total Activity categories of a weekend day than a weekday.

Table 4.4: Activity hours (hours/day) compiled from the 7-Day Activity Diary (mean ± SD)

<table>
<thead>
<tr>
<th>Activity Category</th>
<th>Males (n = 17)</th>
<th>Females (n = 15)</th>
<th>Total (n = 32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekday Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Activity†</td>
<td>3.5 ± 1.1</td>
<td>4.3 ± 1.2</td>
<td>3.9 ± 1.2</td>
</tr>
<tr>
<td>High Activity††</td>
<td>2.3 ± 1.0</td>
<td>1.9 ± 1.2</td>
<td>2.1 ± 1.1</td>
</tr>
<tr>
<td>Weekend Day Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Activity†</td>
<td>4.7 ± 1.9</td>
<td>5.1 ± 2.8</td>
<td>4.8 ± 2.3</td>
</tr>
<tr>
<td>High Activity††</td>
<td>3.1 ± 1.7</td>
<td>2.2 ± 2.0</td>
<td>2.7 ± 1.9</td>
</tr>
<tr>
<td>Weighted Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Activity†</td>
<td>3.8 ± 1.3</td>
<td>4.5 ± 1.4</td>
<td>4.1 ± 1.4</td>
</tr>
<tr>
<td>High Activity††</td>
<td>2.5 ± 1.1</td>
<td>2.0 ± 1.3</td>
<td>2.3 ± 1.2</td>
</tr>
</tbody>
</table>

† category 4+5+6+7+8+9
†† category 6+7+8+9
Figure 4.2: Average Activity Levels for the Activity Diary
4.1.2.3 A Comparison of Data from the HAES and the Activity Diary

In comparing self-report of activity from the HAES and the Activity Diary for patients who completed both instruments, significantly more time was reported in both the Total and High Activity categories (weekday and weekend) as reported with the HAES. This suggests that the HAES and the Diary may have been capturing different dimensions of activity.

4.1.3 Pulmonary Function

Pulmonary function data, illustrated in Table 4.5, were collected for all patients. Depending on the status of their lung disease (FEV1), patients were classified as severely (<50% predicted), moderately (50-80% predicted) or mildly (> 80% predicted) impaired. Twenty-six patients (65%) had mild pulmonary impairment, 11 patients (27.5%) had moderate impairment, and three patients (7.5%) had severe impairment, demonstrating that this sample was comprised mainly of patients with mild pulmonary disease. This high prevalence of mild lung impairment has been previously documented for pre-adolescent and adolescent CF patients.3

Table 4.5: Percent of predicted pulmonary function (mean ± SD)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Males (n = 23)</th>
<th>Females (n = 17)</th>
<th>Total (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1</td>
<td>86.7 ± 18.4</td>
<td>84.2 ± 24.5</td>
<td>85.7 ± 21.0</td>
</tr>
<tr>
<td>FVC</td>
<td>89.8 ± 16.0</td>
<td>90.9 ± 18.0</td>
<td>90.3 ± 16.7</td>
</tr>
<tr>
<td>FEF25-75</td>
<td>74.8 ± 28.8</td>
<td>66.8 ± 31.6</td>
<td>71.4 ± 29.9</td>
</tr>
<tr>
<td>PEF</td>
<td>83.5 ± 15.2</td>
<td>80.8 ± 21.8</td>
<td>82.3 ± 18.1</td>
</tr>
</tbody>
</table>

Definition of abbreviations, see Appendix C
4.1.4 Annual Exercise Testing

4.1.4.1 A sub-sample of study patients

Only patients scheduled for their annual exercise test on or near to (± 3 months) their recruitment date had data on exercise capacity. Although exercise data was available for 26 patients (65.0%), the exercise tests from 2 patients (1 M, 1 F) were considered invalid by the exercise physiologist. The female patient was too immature to perform the test, and was uncooperative with the testing protocol. The male patient was unable to complete the test due to uncontrollable coughing. These results were not included in the final analysis. Twenty-two of the 26 patients (85%) completed their exercise test on the same day as their study recruitment date. The remaining 4 patients (15%) completed their exercise test prior to, or following their recruitment date (± 3 months). As a result of the two invalid exercise tests, final exercise capacity data was available for 24 patients.

4.1.4.2 Assessment of exercise capacity

Values for exercise parameters are documented in Table 4.6. Study patients (n=24) had mean maximal values for workload and oxygen consumption slightly lower than those reported in a similarly aged group of healthy children,\textsuperscript{89} suggesting that these CF patients had reduced exercise capacity compared to normal, school age children.\textsuperscript{89,90} Females had a statistically significant higher percent body fat than males. These values are consistent with trends presented elsewhere,\textsuperscript{89} reflecting usual differences between healthy boys and girls.\textsuperscript{91}
Table 4.6: Exercise parameters (mean ± SD)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Males</th>
<th>n</th>
<th>Females</th>
<th>n</th>
<th>Total</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR&lt;sub&gt;max&lt;/sub&gt; (beats/min)</td>
<td>179.0 ± 6.1</td>
<td>14</td>
<td>175.3 ± 14.4</td>
<td>10</td>
<td>177.5 ± 10.3</td>
<td>24</td>
</tr>
<tr>
<td>V&lt;sub&gt;E&lt;/sub&gt;max (L/min)</td>
<td>70.6 ± 24.1</td>
<td>14</td>
<td>60.6 ± 19.9</td>
<td>10</td>
<td>66.5 ± 22.5</td>
<td>24</td>
</tr>
<tr>
<td>SaO&lt;sub&gt;2&lt;/sub&gt; at max (%)</td>
<td>95.0 ± 1.4</td>
<td>12</td>
<td>93.6 ± 3.6</td>
<td>9</td>
<td>94.4 ± 2.6</td>
<td>21</td>
</tr>
<tr>
<td>V&lt;sub&gt;O&lt;/sub&gt;2max (L/min)</td>
<td>1.5 ± 0.5</td>
<td>14</td>
<td>1.2 ± 0.4</td>
<td>10</td>
<td>1.4 ± 0.5</td>
<td>24</td>
</tr>
<tr>
<td>V&lt;sub&gt;O&lt;/sub&gt;2max (ml·kg&lt;sup&gt;-1&lt;/sup&gt;·min&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>39.7 ± 5.8</td>
<td>14</td>
<td>34.5 ± 7.9</td>
<td>10</td>
<td>37.5 ± 7.1</td>
<td>24</td>
</tr>
<tr>
<td>Wmax (% predicted)</td>
<td>82.2 ± 9.8</td>
<td>14</td>
<td>86.6 ± 19.1</td>
<td>10</td>
<td>84.0 ± 14.2</td>
<td>24</td>
</tr>
<tr>
<td>MVV</td>
<td>72.2 ± 26.1</td>
<td>15</td>
<td>64.4 ± 26.9</td>
<td>12</td>
<td>68.7 ± 26.3</td>
<td>27</td>
</tr>
<tr>
<td>V&lt;sub&gt;E&lt;/sub&gt;/MVV</td>
<td>97.0 ± 18.1</td>
<td>14</td>
<td>103.4 ± 35.4</td>
<td>10</td>
<td>99.7 ± 26.2</td>
<td>24</td>
</tr>
<tr>
<td>% body fat</td>
<td>12.5 ± 2.9</td>
<td>15</td>
<td>22.3 ± 3.2</td>
<td>11</td>
<td>16.7 ± 5.8</td>
<td>26</td>
</tr>
<tr>
<td>Lean body mass (kg)</td>
<td>32.3 ± 11.2</td>
<td>15</td>
<td>27.6 ± 9.6</td>
<td>11</td>
<td>30.3 ± 10.6</td>
<td>26</td>
</tr>
</tbody>
</table>

Max, parameter at maximal workload; Definition of abbreviations, see Appendix C

4.1.5 Compliance with Physiotherapy

Patients were asked to rank their compliance with physiotherapy from choices of 0, 1 or 2. The mean compliance value was 1.6 ± 0.6 (males, 1.7 ± 0.6; females, 1.5 ± 0.7), which indicated a high reported mean level of compliance with physiotherapy.

4.1.6 Parent Questionnaire

Parent questionnaires, comprised of six questions, were successfully completed by 97.5% of parents. One parent took the questionnaire home to complete because of time constraints in clinic, but did not return it to the study coordinator. The data are presented in Table 4.7

In Question 1, parents ranked their own level of physical activity participation, based on a scale of 1-5 (1, inactive; 5, vigorous physical activity). In Question 2, parents reported the number and type of organized physical activities in which their children were involved. The most
commonly listed organizations were a sport’s team or league (33.3%), and public park or recreation department activities (28.2%). In Question 3, the child’s accessibility to exercise related facilities in their community was assessed. The most commonly cited facilities were a public park (94.9%), playing field (82.1%), skating rink (74.4%), and public recreation center (71.8%). In Question 4, parent’s evaluated the safety of their neighborhood (1, very unsafe; 5, very safe). For Question 5, parents chose from a list of characteristics that best described their own neighborhood. This question was intended to estimate the number of neighborhood-related features that were either conducive or non-conducive to exercise. The most commonly cited features were a high frequency of people walking or exercising (84.6%), enjoyable scenery (82.1%), sidewalks (79.5%), and street lights (69.2%). Finally, in Question 6, parents estimated the number of exercise-related items in their home. The most commonly cited items were running shoes (100%), bicycle (97.4%), sports equipment (i.e., balls and racquets) (97.4%), and skates (89.7%).
Table 4.7: Potential correlates of physical activity participation (mean ± SD)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Males (n = 22)</th>
<th>Females (n = 17)</th>
<th>Total (n = 39)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent's activity level (range: 1 to 5)</td>
<td>2.6 ± 0.9</td>
<td>3.0 ± 1.0</td>
<td>2.8 ± 0.9</td>
</tr>
<tr>
<td>Number of organized physical activities (range: 0 to 8)</td>
<td>1.5 ± 1.4</td>
<td>1.2 ± 1.0</td>
<td>1.3 ± 1.3</td>
</tr>
<tr>
<td>Accessibility of facilities (range: 0 to 18)</td>
<td>9.3 ± 3.8</td>
<td>10.4 ± 4.4</td>
<td>9.8 ± 4.1</td>
</tr>
<tr>
<td>Neighborhood safety (range: 1 to 5)</td>
<td>4.9 ± 0.4</td>
<td>4.7 ± 0.5</td>
<td>4.8 ± 0.4</td>
</tr>
<tr>
<td>Neighborhood features conducive to exercise (range: -4 to +4)</td>
<td>2.4 ± 1.3</td>
<td>2.3 ± 1.3</td>
<td>2.4 ± 1.3</td>
</tr>
<tr>
<td>Exercise-related items in the home (range: 0 to 15)</td>
<td>7.0 ± 1.7</td>
<td>6.8 ± 1.9</td>
<td>6.9 ± 1.8</td>
</tr>
</tbody>
</table>

4.1.7 Activity Classification

The activity types reported by patients for Categories 4 to 9 of the Activity Diary represented activities of mild to vigorous intensity. The study coordinator compiled a list of approximately 200 terms used by patients to describe their activity. This list is found in Appendix H. Many activity types were listed under more than one category of intensity. Soccer, for example, was listed by the same individual in both Categories 8 and 9. The 200 terms were subsequently allocated to one of 8 classifications: personal care, domestic work, school-related, employment, unstructured play, walking, sport, and undefined. These classifications were chosen to encompass and describe all the different activity types in the most specific manner possible. The results of this activity classification are presented in Figures 4.3 to 4.8 for each of the six
categories (4 to 9). The results are presented in average daily minutes. The following section outlines the trends in the data according to activity classification.

4.1.7.1 Personal Care

*Personal care* encompassed activities such as getting ready for school or bed, and CF self-treatment. These types of activities were only reported for the two lowest intensity categories, categories 4 and 5. In Category 4, an average of 5.2 daily minutes was reported, with this number decreasing to 0.4 daily minutes in Category 5.

4.1.7.2 Domestic Work

*Domestic work* (household and outside chores) included cleaning, cooking, dusting, mowing the lawn, shopping, watering the plants, taking out the garbage, and raking. Activities included in this classification were reported in Categories 4, 5, and 6. The average time spent in this classification declined with increasing intensity of the category. In Category 4, 13.0 average daily minutes were reported, with this number decreasing to 4.0 and 2.3 minutes for Categories 5 and 6 respectively.

4.1.7.3 School-Related

Children also reported their participation in specific *school-related activities* such as classroom activity, homework, acting, helping the teacher, and school field trips. School-related activities were reported for Categories 4, 5 and 6 only, indicating that these activities were not of a high intensity. The highest report for these activities is 2.0 daily minutes for Category 4, followed by 0.9 minutes for Category 5 and 0.13 minutes for Category 6.

4.1.7.4 Employment

As this study sample was comprised of children as old as 18 years, an *employment* classification was included. Employment included after-school and weekend jobs, in addition to
delivering papers. These activities were listed in Categories 4 to 7, indicating the range of intensity requirements in these jobs. For Category 4, 6.2 average daily minutes were spent in employment, with this number decreasing dramatically to 0.13 minutes in Category 5. From Category 5 to Category 6 there was a large increase to 7.4 minutes, followed by a decrease to 0.8 minutes in Category 7.

4.1.7.5 Unstructured Play

Both children and adolescents engage in free play. Although this type of activity does not meet the structured definition of sport, it can nevertheless be quite demanding, and yet erratic in nature. Unstructured play was reported for all six categories, Categories 4 to 9. The activities that were labeled in this classification included group games (hide and seek, hopscotch), recess, playground activity, swinging, and ball playing. In Category 4, 4.6 average daily minutes were reported. A predominance of unstructured play was documented for Categories 5 (12.4 daily minutes) and 6 (13.1 daily minutes). Values for Categories 7 (4.6 minutes), 8 (0.8 minutes) and 9 (0.07 minutes), however, demonstrated that less time was spent in unstructured play at these higher intensities.

4.1.7.6. Walking

The definition used to describe the intensity levels of Categories 4 and 5 were walking indoors and walking outdoors respectively. Correspondingly, study patients reported the majority of walking time in these categories. Activities in this classification included going to lunch, socializing with friends, walking the dog, taking work breaks, and walking 'hard'. A total of 20.2 daily minutes were reported for Category 4 and 37.2 minutes for Category 5. Values for categories 6 (0.6 minutes) and 7 (0.7 minutes) indicated that children spent minimal time participating in high intensity walking.
4.1.7.7 Sport

Sport is a structured, definable activity that can be performed at many different intensity levels. For this study sample, sports were reported in all six categories and there were a wide range of activity types: running, biking, track and field, trampoline jumping, dancing, fishing, bowling, fighting, swimming, and lacrosse. For Categories 4 and 5, only 0.27 and 0.87 average daily minutes were reported, demonstrating that children did not rank their sporting activities in a low intensity category. Categories 6, 7, and 8 on the other hand, were comprised of 27.5, 35.9 and 18.4 daily minutes of activity respectively. By comparison, the total hours spent in sporting activities of higher intensity, category 9 (4.2 minutes) were relatively small. This suggested that this group of CF children were spending relatively little time in competitive sports compared with sporting activities of lower intensity.

4.1.7.8 Undefined

Some study patients did not complete the Activity Diary according to instructions, and subsequently, recorded the category intensity of the activity without listing the activity type. So as not to exclude this data from the activity profiles, the total number of hours at the specific intensity was classified in a separate classification, undefined.
Figure 4.3: Activity Classification (category 4)
Figure 4.4: Activity Classification (category 5)
Figure 4.5: Activity Classification (category 6)
Figure 4.6: Activity Classification (category 7)
Figure 4.7: Activity Classification (category 8)
Figure 4.8: Activity Classification (category 9)
4.2 Correlation Analyses

4.2.1 The HAES and the Activity Diary

Pearson's correlation coefficients were calculated to evaluate the relationship between the Activity scores of the HAES and the Activity Diary. A separate correlation was conducted between each Activity score of the HAES and the comparable Activity score of the Activity Diary. Table 4.8 illustrates the correlation between the Weekday, Weekend, and Weighted Total and High Activity scores of the HAES and the Activity Diary respectively.

Positive associations were confirmed for each pair of activity scores. A significant correlation was demonstrated for the Weekday High Activity scores of the HAES and the Diary, and for the Weekend Total Activity scores. For the Weighted Activity score, significant correlations were demonstrated between both the Total and High Activity scores of the two instruments. Although the strength of the correlation coefficients are similar to those reported between other pairs of self-report instruments, the relatively moderate values (R < 0.5) imply that the HAES and the Activity Diary were only capturing some of the same dimensions of habitual physical activity, or suggest the presence of different reporting biases for the two instruments.

Table 4.8: Correlation between the Total and High Activity scores of the HAES and the Activity Diary (n = 32)

<table>
<thead>
<tr>
<th></th>
<th>Weekday</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>p</td>
<td>R</td>
<td>p</td>
<td>R</td>
<td>p</td>
</tr>
<tr>
<td>Total Activity</td>
<td>.33</td>
<td>.07</td>
<td>.44</td>
<td>.01</td>
<td>.37</td>
<td>.04</td>
</tr>
<tr>
<td>High Activity</td>
<td>.41</td>
<td>.02</td>
<td>.31</td>
<td>.09</td>
<td>.49</td>
<td>.005</td>
</tr>
</tbody>
</table>
4.2.2 Habitual Physical Activity

Correlation analyses were conducted for both the HAES and the Activity Diary to evaluate the association of each of the Total and High Activity scores (weekday, weekend and weighted) with FEV\textsubscript{1}, % of ideal weight, age, gender, compliance with physiotherapy, Wmax and \( \dot{V}O_2_{\text{max}} \). Table 4.9 details Weekday Activity, Table 4.10 illustrates Weekend Activity, and Table 4.11 depicts the Weighted Activity score, a combination of weekday and weekend activity.

Table 4.9 demonstrates several important relationships. Positive, significant correlation coefficients were demonstrated for the associations of the Total and High Activity scores of the HAES with FEV\textsubscript{1}, % of ideal weight, and Wmax. Patterns for the Activity Diary were very different. A negative, significant relationship was demonstrated between the High Activity score and age, and a marginally significant positive correlation was seen between Total Activity and gender, suggesting higher Total Activity for females.

As documented in Table 4.10 for weekend activity, there was less overall correlation of Activity scores with candidate correlates. A positive, significant relationship was demonstrated between the HAES Total Activity score and FEV\textsubscript{1}, and between the HAES High Activity score and \( \dot{V}O_2_{\text{max}} \). For the Activity Diary, a negative, significant relationship was demonstrated for the Total Activity score with age, suggesting a decrease in Total Activity with age.

The correlation analysis for the Weighted Activity Scores of the Activity Diary and the HAES are shown in Table 4.11. No significant correlations were demonstrated for the Activity Diary. For the HAES, however, positive and significant relationships were demonstrated for the Total Activity category with FEV\textsubscript{1}, % of ideal weight, and Wmax. These results are similar to those seen for the Weekday Activity scores. Positive and significant relationships were also demonstrated for the High Activity category with FEV\textsubscript{1}, and \( \dot{V}O_2_{\text{max}} \).
Table 4.9: Correlation for *Weekday* Activity scores of the HAES and the Activity Diary

<table>
<thead>
<tr>
<th>Variable</th>
<th>HAES (n = 40)</th>
<th>Activity Diary (n = 32)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Activity</td>
<td>High Activity</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>p</td>
</tr>
<tr>
<td>FEV₁</td>
<td>.41</td>
<td>.008</td>
</tr>
<tr>
<td>% of ideal wt</td>
<td>.39</td>
<td>.01</td>
</tr>
<tr>
<td>Age</td>
<td>.25</td>
<td>.11</td>
</tr>
<tr>
<td>Gender</td>
<td>.09</td>
<td>.58</td>
</tr>
<tr>
<td>Physiotherapy compliance</td>
<td>-.14</td>
<td>.37</td>
</tr>
<tr>
<td>Wmax†</td>
<td>.40</td>
<td>.05</td>
</tr>
<tr>
<td>VO₂max†</td>
<td>.14</td>
<td>.52</td>
</tr>
</tbody>
</table>

† n = 24 for HAES, n = 18 for Diary
Table 4.10: Correlation for *Weekend* Activity scores of the HAES and the Activity Diary

<table>
<thead>
<tr>
<th>Variable</th>
<th>HAES (n = 40)</th>
<th>Activity Diary (n = 32)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Activity</td>
<td>High Activity</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>p</td>
</tr>
<tr>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;</td>
<td>.37</td>
<td>.02</td>
</tr>
<tr>
<td>% of ideal wt</td>
<td>.25</td>
<td>.12</td>
</tr>
<tr>
<td>Age</td>
<td>-.10</td>
<td>.55</td>
</tr>
<tr>
<td>Gender</td>
<td>.07</td>
<td>.68</td>
</tr>
<tr>
<td>Physiotherapy compliance</td>
<td>-.22</td>
<td>.18</td>
</tr>
<tr>
<td>Wmax&lt;sup&gt;+&lt;/sup&gt;</td>
<td>.35</td>
<td>.10</td>
</tr>
<tr>
<td>VO&lt;sub&gt;2max&lt;/sub&gt;&lt;sup&gt;+&lt;/sup&gt;</td>
<td>.35</td>
<td>.09</td>
</tr>
</tbody>
</table>

<sup>+</sup> n = 24 for HAES, n = 18 for Diary
Table 4.11: Correlation for *Weighted* Activity scores of the HAES and the Activity Diary

<table>
<thead>
<tr>
<th>Variable</th>
<th>HAES (n = 40)</th>
<th>Activity Diary (n = 32)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Activity</td>
<td>High Activity</td>
</tr>
<tr>
<td>FEV$_1$</td>
<td>.44</td>
<td>.40</td>
</tr>
<tr>
<td></td>
<td>.005</td>
<td>.01</td>
</tr>
<tr>
<td>% of ideal wt</td>
<td>.38</td>
<td>.29</td>
</tr>
<tr>
<td></td>
<td>.02</td>
<td>.07</td>
</tr>
<tr>
<td>Age</td>
<td>.16</td>
<td>-.19</td>
</tr>
<tr>
<td></td>
<td>.32</td>
<td>.23</td>
</tr>
<tr>
<td>Gender</td>
<td>.09</td>
<td>-.22</td>
</tr>
<tr>
<td></td>
<td>.58</td>
<td>.18</td>
</tr>
<tr>
<td>Physiotherapy compliance</td>
<td>-.18</td>
<td>-.15</td>
</tr>
<tr>
<td></td>
<td>.26</td>
<td>.34</td>
</tr>
<tr>
<td>Wmax$^+$</td>
<td>.41</td>
<td>.37</td>
</tr>
<tr>
<td></td>
<td>.05</td>
<td>.08</td>
</tr>
<tr>
<td>VO$_2$max$^+$</td>
<td>.21</td>
<td>.45</td>
</tr>
<tr>
<td></td>
<td>.32</td>
<td>.03</td>
</tr>
</tbody>
</table>

$^+$ n = 24 for HAES, n = 18 for Diary
4.2.3 Weekday and Weekend Activity

As presented in Table 4.12, correlation analysis demonstrated positive and significant correlations between Weekday and Weekend High and Total Activity scores for each of the HAES and the Activity Diary. These results demonstrated that children who reported being physically active during a typical weekday also reported high levels of physical activity for a typical weekend day.

Table 4.12: Correlation between Weekday and Weekend Activity scores

<table>
<thead>
<tr>
<th></th>
<th>Total Activity</th>
<th>High Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>p</td>
</tr>
<tr>
<td>HAES</td>
<td>.59</td>
<td>.0001</td>
</tr>
<tr>
<td>Activity Diary</td>
<td>.60</td>
<td>.0003</td>
</tr>
</tbody>
</table>

4.2.4 FEV₁

Table 4.13 demonstrates the correlation analyses for FEV₁ with % of ideal weight, age, gender, compliance with physiotherapy, Wmax and V̇O₂max. These analyses were important in beginning to understand the relationships between FEV₁ and those variables which may be important in the multiple regression models.

These data indicated a significant correlation for FEV₁ with % of ideal weight and Wmax. Although there are no other significant correlation coefficients, the direction of the correlation coefficient for age is consistent with previous studies that have shown FEV₁ to decline with age.⁸⁸
Table 4.13: Correlation Analysis for FEV\(_1\) (n = 40)

<table>
<thead>
<tr>
<th></th>
<th>% of ideal wt</th>
<th>Age</th>
<th>Gender</th>
<th>Physiotherapy Compliance</th>
<th>Wmax(^+)</th>
<th>VO(_2)max(^+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV(_1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>.47</td>
<td>-0.26</td>
<td>-.06</td>
<td>-.17</td>
<td>.40</td>
<td>.03</td>
</tr>
<tr>
<td>p</td>
<td>.002</td>
<td>.11</td>
<td>.71</td>
<td>.30</td>
<td>.05</td>
<td>.88</td>
</tr>
</tbody>
</table>
\(\dagger n = 24\)

4.2.5 Potential Correlates of Physical Activity Participation

The degree of association between each of the Activity Scores and the potential correlates of physical activity participation was evaluated by means of a correlation coefficient. The results are demonstrated in Table 4.14. The HAES Activity Scores demonstrated the strongest, positive relationships with two variables: parent's physical activity level and organized physical activity involvement. The Weekday, Weekend, and Weighted Total Activity scores demonstrated significant relationships with parent's physical activity level. The Weekend Total, Weekend High and Weighted High Activity scores demonstrated significant associations with organized physical activity. The Weekday and Weighted Total Activity scores of the HAES also showed a significant relationship with accessibility of exercise-related facilities. For the Activity Diary, on the other hand, there was only one positive, significant correlation: the Weighted Total Activity score with organized physical activity. The results suggested a positive relationship of parent's physical activity level, involvement in organized physical activity, and accessibility of exercise related facilities with habitual physical activity.
Table 4.14: Correlation between Activity scores and potential correlates of physical activity participation

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R  p</td>
<td>R  p</td>
<td>R  p</td>
<td>R  p</td>
<td>R  p</td>
<td>R  p</td>
</tr>
<tr>
<td>HAES (n=39)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekday T</td>
<td>.31 .05</td>
<td>.006 .97</td>
<td>.39 .02</td>
<td>.10 .53</td>
<td>.11 .49</td>
<td>-.02 .93</td>
</tr>
<tr>
<td></td>
<td>.16 .34</td>
<td>.27 .10</td>
<td>.20 .22</td>
<td>-.04 .82</td>
<td>.13 .43</td>
<td>-.14 .40</td>
</tr>
<tr>
<td>Weekend T</td>
<td>.43 .007</td>
<td>.38 .02</td>
<td>.09 .57</td>
<td>.03 .87</td>
<td>-.22 .19</td>
<td>.18 .28</td>
</tr>
<tr>
<td></td>
<td>.10 .55</td>
<td>.40 .01</td>
<td>-.03 .85</td>
<td>.07 .69</td>
<td>-.24 .14</td>
<td>-.08 .63</td>
</tr>
<tr>
<td>Weighted T</td>
<td>.38 .02</td>
<td>.13 .42</td>
<td>.33 .04</td>
<td>.09 .59</td>
<td>.01 .93</td>
<td>.05 .77</td>
</tr>
<tr>
<td></td>
<td>.15 .37</td>
<td>.37 .02</td>
<td>.11 .50</td>
<td>.01 .95</td>
<td>-.04 .82</td>
<td>-.13 .44</td>
</tr>
<tr>
<td>Activity Diary (n=32)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekday T</td>
<td>.26 .15</td>
<td>.34 .06</td>
<td>.19 .31</td>
<td>-.03 .90</td>
<td>-.26 .15</td>
<td>.21 .24</td>
</tr>
<tr>
<td>Weekday H</td>
<td>.06 .73</td>
<td>.28 .13</td>
<td>-.01 .94</td>
<td>.15 .41</td>
<td>-.01 .98</td>
<td>.16 .39</td>
</tr>
<tr>
<td>Weekend T</td>
<td>.02 .91</td>
<td>.28 .12</td>
<td>-.05 .78</td>
<td>.14 .46</td>
<td>-.16 .38</td>
<td>-.03 .89</td>
</tr>
<tr>
<td>Weekend H</td>
<td>.09 .61</td>
<td>.23 .21</td>
<td>-.01 .96</td>
<td>.08 .66</td>
<td>-.01 .98</td>
<td>.05 .79</td>
</tr>
<tr>
<td>Weighted T</td>
<td>.17 .34</td>
<td>.35 .05</td>
<td>.09 .61</td>
<td>.05 .79</td>
<td>-.24 .18</td>
<td>.12 .51</td>
</tr>
<tr>
<td></td>
<td>.08 .67</td>
<td>.27 .13</td>
<td>-.01 .94</td>
<td>.13 .48</td>
<td>-.01 .98</td>
<td>.12 .51</td>
</tr>
</tbody>
</table>

T, Total Activity; H, High Activity; Nbhd., Neighborhood; Equip., Equipment
4.2.6 A Summary of Results from Correlation Analyses

The correlation analyses were performed to probe the strength and direction of the relationships between the Activity scores of the Activity Diary and the HAES, and between the Activity scores and the other study variables, most importantly FEV$_1$. The intent of this process was to decide which Activity Scores were of most interest for further inclusion in multiple regression analysis.

Positive and significant associations were demonstrated between the HAES Activity scores and FEV$_1$. The Weekday High Activity score demonstrated the strongest, significant correlation with FEV$_1$, followed by the Weighted Total Activity score, the Weekday Total Activity score, the Weighted High Activity score, and finally, the Weekend Total Activity score. Only the Weekend High Activity score was not strongly correlated with FEV$_1$. Scatter plots demonstrated that these correlations were not artifactual; there were no outlying variables that greatly enhanced or obscured an overall pattern. Results from correlation analysis between the Activity Diary Activity scores and FEV$_1$, by comparison, demonstrated weak associations. Although further analysis of the Activity Diary scores took place, more emphasis was placed on the inclusion of the HAES Activity scores in multiple regression models, specifically those scores that demonstrated the highest correlation coefficients with FEV$_1$.

In determining which other study variables could be of importance in multiple regression, the correlation coefficients and p-values from Table 4.13 (Correlation Analysis for FEV$_1$) were assessed. Percent of ideal weight demonstrated the strongest correlation with FEV$_1$, followed by Wmax and age. Percent of ideal weight and age were expected to be important in further modeling of FEV$_1$ in this study. Due to the small sample of patients with data on exercise capacity (n = 24), Wmax and VO$_{2\text{max}}$ were not considered for inclusion in further analyses.
Their potential importance in a future study of habitual physical activity with a larger sample, however, should not discounted. Significant, positive correlations were also demonstrated for these exercise parameters with the HAES Activity scores.

Two of the study variables that were included in Pearson's correlation analysis, gender and compliance with physiotherapy, were not continuous. For gender, a binary variable, p-values for the test of no correlation between gender and measures of FEV₁ or activity reflected identical p-values for t-tests of no difference in mean values between males and females. The ordinal compliance score was developed in an attempt to quantify an underlying continuous measurement of physiotherapy compliance, and was therefore treated as a continuous variable for this study. Whether or not this score does in fact represent an underlying linear variable will be explored in future long-term study of a larger sample.

Although the Pearson's correlation coefficient may not be a valid estimate of the true population correlation coefficient for non-normal variables, R is still appropriate for the test of the null hypothesis of no correlation, provided that one of the variables is normal. The literature further suggests that a Pearson's correlation coefficient is appropriate for a categorical variable that is assigned meaningful numerical values.

Although the correlation of FEV₁ with gender and compliance with physiotherapy was neither strong nor statistically significant, both variables were retained for regression analysis due to an established relationship between age and FEV₁, and because of the potential importance of compliance with physiotherapy to both FEV₁ and habitual physical activity.

4.3 Regression Analyses

Although complete data was available for 18 of the 40 study patients, regression analyses were not conducted on this small sample of the total study population. Analyses were conducted
on either the total number of study patients (n = 40), or on the sample that completed the Activity Diaries (n = 32).

4.3.1 Multiple Correlation

Multiple correlation analyses were conducted by means of the all possible regression subsets technique. In separate analyses, either FEV₁ or one of the Activity scores was considered as the outcome variable. The other variable (FEV₁ or one of the Activity scores) was then included as an explanatory variable in addition to age, gender, compliance with physiotherapy and % of ideal weight. The two best models for each Activity score were chosen and have been presented in Tables 4.15 and 4.16. The best models were chosen with consideration to both the adjusted R-square value and the Cp Mallow statistic.

The R-square is the fraction of the variance in the dependent variable that the regression model explains. It always increases as more variables are added to the regression equation, even if these new variables have very little predictive value. The adjusted R-square ($R^2_{adj}$), on the other hand, makes you pay a penalty for using additional degrees of freedom. Therefore, the adjusted R-square allowed for a comparison of models with different numbers of parameters in this analysis. The best regression models were generally considered to be those with the largest adjusted R-square.

Although the adjusted R-square was the primary criterion in choosing the best models, the Cp Mallow statistic was also used to screen for the best regression models. The value for Cp had to be within an acceptable range, near to $p$ ($p = \text{# of parameters} = \text{# of predictor variables} + \text{intercept}$). Therefore, a combination of factors was considered in selecting the best and most parsimonious models for final regression analysis.
Table 4.15 demonstrates the inter-relationships between the Activity scores and the explanatory variables that best accounted for the variability in these scores. For the HAES Activity scores, the best individual predictors of these scores were FEV\textsubscript{l}, followed by percent of ideal weight. For the Activity Diary Activity scores, on the other hand, either age or gender was the best individual predictor variable, followed by compliance with physiotherapy. The highest adjusted R-squares were demonstrated for the HAES Activity scores. The explanatory variables accounted for less variability in the Activity Diary Activity scores, suggesting that other unknown variables were contributing to the variability seen for these scores. This effect was not due to the reduced sample size (n=32) because when analysis was conducted for this smaller subset, the R-square values were very similar. The strongest relationships were demonstrated for the HAES Weekday Total Activity score with age and FEV\textsubscript{l} (R\textsuperscript{2}\text{adj} = 0.27) and for the HAES Weighted Total Activity score with age and FEV\textsubscript{l} (R\textsuperscript{2}\text{adj} = 0.23).

Table 4.16 contains the results for multiple correlation analyses where FEV\textsubscript{l} was the outcome variable. The results are listed according to the Activity score that was included in the list of potential predictors. With inclusion of a HAES Activity score as a potential explanatory variable, percent of ideal weight was the best individual predictor of FEV\textsubscript{l}, followed by the HAES Activity score. When an Activity Diary score was included as the activity variable, percent of ideal weight was again the single best individual predictor of FEV\textsubscript{l}, followed by either the Activity Diary score or compliance with physiotherapy. The two best models contained one of two HAES Activity scores as a candidate predictor: the Weekday Total Activity score, or the Weighted Total Activity score. The multiple correlation of Weekday Total Activity, age, and percent of ideal weight with FEV\textsubscript{l} produced an adjusted R-square of 0.41. The correlation of the Weighted Total Activity score, age and percent of ideal weight with FEV\textsubscript{l} produced an adjusted
R-square of 0.40. A separate analysis conducted in the subset of patients who completed the Activity Diary (n =32) also indicated that the inclusion of these two HAES Activity scores in separate correlation analyses accounted for the most variability in FEV₁. These analyses demonstrated that these two HAES Activity scores should be included as potential explanatory variables in further multiple regression analyses on FEV₁.

4.3.1.1 Summary of Multiple Correlation

The primary intent of this multiple correlation analysis was to examine the potential predictors of FEV₁ in this study sample. Specifically, it was important to evaluate which Activity scores explained the most variability in FEV₁, the most important variable in describing lung disease in CF. FEV₁ has already been indicated as the best predictor of survival in CF patients, and is the primary outcome variable of interest in many CF clinical studies.

Multiple correlation analyses were conducted with either one of the Activity scores or with FEV₁ as the outcome variable. The results from these separate analyses confirmed a similar pattern: a positive relationship was demonstrated between FEV₁ and the Activity scores, and this relationship was strongest for the HAES Activity scores. Specifically, two HAES Activity scores were demonstrated to explain the most variability in FEV₁. Candidate explanatory variables also explained the most variability in these same two HAES Activity scores.

When FEV₁ was the outcome variable, the adjusted R-square values for the best multiple variable models were higher than the adjusted R-square values for the best models when the Activity scores were the outcome variable. When the HAES Activity scores were the outcome variable, the adjusted R-square values ranged from 0.11 to 0.27, meaning that 11% to 27% of the variability in these HAES Activity scores were explained by the candidate explanatory variables. When the Activity Diary scores were entered as the outcome variable, 5% to 17% of the
variability in these scores was explained by the explanatory variables. Finally, when \( \text{FEV}_1 \) was entered as the outcome variable, 33% to 41% of the variability was explained by the set of explanatory variables that included the HAES Activity scores, whereas 24% to 27% of the variability was explained by the set of explanatory variables that included the Activity Diary scores.

These results confirmed the importance of \( \text{FEV}_1 \) as the primary outcome variable for further multiple regression analysis, and clarified the significant role of the HAES Activity scores, as compared with the Activity Diary scores, as the candidate explanatory variables to represent habitual physical activity. In particular, two HAES Activity scores were indicated for inclusion as explanatory variables in the final regression models (Weekday Total and Weighted Total Activity). In addition to these two Activity scores, age and % of ideal weight were also indicated as potential explanatory variables based on their consistent presence as explanatory variables of \( \text{FEV}_1 \) in multiple correlation. Plots of \( \text{FEV}_1 \) by age, percent of ideal weight, Weekday Total Activity and Weighted Total Activity have been included in Figures 4.9-4.12 to illustrate the relationships between these variables.

Gender is an important variable in predicting prognosis of CF patients, and is therefore an important variable to include in any survival model. For this analysis, however, gender did not enter into any of the best models where \( \text{FEV}_1 \) was the outcome variable, even though it did consistently turn up in the models where the Activity scores were the outcome variable. When both the Activity score and gender were entered as candidate explanatory variables, the Activity score was always selected as the more important explanatory variable. This suggested that both variables were explaining similar variability in \( \text{FEV}_1 \). Within the narrow age range of this study sample, gender did not have any important predictive value in the model. This may reflect the
gender effect being to some extent explained by the Activity scores. These results do not undermine the importance of gender in predicting CF survival. Nonetheless, gender was not included as a candidate predictor variable in final regression analysis, which focused on the parameters for predicting FEV₁.
Table 4.15: Multiple correlation for the Activity scores

<table>
<thead>
<tr>
<th>Activity Score as the Outcome</th>
<th>Best Models</th>
<th>Adj. R-square</th>
<th>C(p) Mallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>WDTHAES</td>
<td>Age, FEV&lt;sub&gt;1&lt;/sub&gt;, Age, Gender, FEV&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0.27</td>
<td>1.9</td>
</tr>
<tr>
<td>WTTHAES</td>
<td>Age, FEV&lt;sub&gt;1&lt;/sub&gt;, Age, Gender, FEV&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0.23</td>
<td>1.7</td>
</tr>
<tr>
<td>WDHHAES</td>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;, % ideal wt, Age, FEV&lt;sub&gt;1&lt;/sub&gt;, % ideal wt</td>
<td>0.21</td>
<td>1.5</td>
</tr>
<tr>
<td>WETAD</td>
<td>Age, % ideal wt</td>
<td>0.17</td>
<td>-0.8</td>
</tr>
<tr>
<td>WTHHAES</td>
<td>Gender, FEV&lt;sub&gt;1&lt;/sub&gt;, Age, Gender, FEV&lt;sub&gt;1&lt;/sub&gt;, Compliance</td>
<td>0.15</td>
<td>2.4</td>
</tr>
<tr>
<td>WDTAD</td>
<td>Gender, FEV&lt;sub&gt;1&lt;/sub&gt;, Gender, FEV&lt;sub&gt;1&lt;/sub&gt;, % ideal wt</td>
<td>0.14</td>
<td>4.8</td>
</tr>
<tr>
<td>WETHAES</td>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;, Compliance</td>
<td>0.11</td>
<td>-0.2</td>
</tr>
<tr>
<td>WDHAD</td>
<td>Age, Gender</td>
<td>0.10</td>
<td>-0.6</td>
</tr>
<tr>
<td>WTTAD</td>
<td>Age, Gender, % ideal wt</td>
<td>0.08</td>
<td>1.7</td>
</tr>
<tr>
<td>WEHHAES</td>
<td>Age, Gender, Compliance</td>
<td>0.10</td>
<td>2.3</td>
</tr>
<tr>
<td>WTHAD</td>
<td>Age, Gender, Compliance</td>
<td>0.09</td>
<td>2.3</td>
</tr>
<tr>
<td>WEHAD</td>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;, Compliance, Gender, FEV&lt;sub&gt;1&lt;/sub&gt;, Compliance</td>
<td>0.05</td>
<td>1.8</td>
</tr>
</tbody>
</table>

AD, Activity Diary; compliance, compliance with physiotherapy; wt, weight; WDH, Weekday High; WDT, Weekday Total; WET, Weekend Total; WEH, Weekend High; WTT, Weighted Total; WTH, Weighted High
Table 4.16: Multiple correlation for FEV₁, with different Activity scores included among the candidate predictors

<table>
<thead>
<tr>
<th>Activity Score Included as a Candidate Predictor</th>
<th>Best Models</th>
<th>Adj. R-square</th>
<th>C(p) Mallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>WDTHAES</td>
<td>Age, WDTHAES, % ideal wt</td>
<td>0.41</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>Age, WDTHAES, Compliance, % ideal wt</td>
<td>0.42</td>
<td>4.4</td>
</tr>
<tr>
<td>WTHHAES</td>
<td>Age, WTHHAES, % ideal wt</td>
<td>0.40</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Age, WTHHAES, Compliance, % ideal wt</td>
<td>0.40</td>
<td>4.3</td>
</tr>
<tr>
<td>WDHHAES</td>
<td>Age, WDHHAES, % ideal wt</td>
<td>0.35</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>Age, WDHHAES, Compliance, % ideal wt</td>
<td>0.36</td>
<td>4.0</td>
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<td>WETHAES</td>
<td>Age, WETHAES, % ideal wt</td>
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<td>2.9</td>
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<td>4.1</td>
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<tr>
<td>WTHHAES</td>
<td>Age, WTHHAES, % ideal wt</td>
<td>0.33</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Age, WTHHAES, Compliance, % ideal wt</td>
<td>0.33</td>
<td>4.0</td>
</tr>
<tr>
<td>WEHHAES</td>
<td>Age, % ideal wt</td>
<td>0.31</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Age, Compliance, % ideal wt</td>
<td>0.32</td>
<td>2.1</td>
</tr>
<tr>
<td>WEHAD</td>
<td>Age, Compliance, % ideal wt</td>
<td>0.27</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Age, WEHAD, Compliance, % ideal wt</td>
<td>0.25</td>
<td>4.0</td>
</tr>
<tr>
<td>WTHAD</td>
<td>Age, Compliance, % ideal wt</td>
<td>0.27</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Age, WTHAD, Compliance, % ideal wt</td>
<td>0.25</td>
<td>4.0</td>
</tr>
<tr>
<td>WETAD</td>
<td>Age, Compliance, % ideal wt</td>
<td>0.27</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Age, WETAD, Compliance, % ideal wt</td>
<td>0.25</td>
<td>4.0</td>
</tr>
<tr>
<td>WDTAD</td>
<td>Age, Compliance, % ideal wt</td>
<td>0.27</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Age, WDTAD, Compliance, % ideal wt</td>
<td>0.25</td>
<td>4.1</td>
</tr>
<tr>
<td>WDHAD</td>
<td>Age, Compliance, % ideal wt</td>
<td>0.27</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>Age, WDHAD, Compliance, % ideal wt</td>
<td>0.25</td>
<td>4.0</td>
</tr>
<tr>
<td>WTTAD</td>
<td>Age, Compliance, % ideal wt</td>
<td>0.27</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Age, WTTAD, Compliance, % ideal wt</td>
<td>0.24</td>
<td>4.0</td>
</tr>
</tbody>
</table>

AD, Activity Diary; wt, weight; compliance, compliance with physiotherapy; WDH, Weekday High; WDT, Weekday Total; WET, Weekend Total; WEH, Weekend High; WTT, Weighted Total; WTH, Weighted High
Figure 4.9: Plot of FEV1 by Age
Figure 4.10: Plot of FEV1 by Percent of Ideal Weight
Figure 4.11: Plot of FEV1 by HAES Weekday Total Activity
Figure 4.12: Plot of FEV1 by HAES Weighted Total Activity
4.3.2 Modeling FEV₁ as the Outcome Variable

Multiple linear regression was performed to determine the nature of the individual and combined effects of three explanatory variables on FEV₁. The explanatory variables were: i) age, ii) percent of ideal weight, and iii) either the HAES Weekday Total Activity score or the HAES Weighted Total Activity score. As there were two Activity scores to consider, the same steps were followed to include each of these scores into the different potential models.

Although both FEV₁ and the Activity scores were outcome variables in the all possible regression analysis, only FEV₁ was an outcome variable in the final multiple regression because the primary relationship of interest was the explanation of variability in FEV₁ by habitual physical activity. In addition, only the HAES Activity score was used as an explanatory variable for activity in the final multiple regression analysis because the Activity Diary Activity scores demonstrated limited association with FEV₁ in both Pearson’s correlation and all possible regression.

Every possible combination of variables was examined. For each model, the regression coefficients and their standard errors were evaluated to determine the relative influence of each variable on FEV₁. The regression coefficient signifies the amount of change in the outcome variable per one unit change in the explanatory variable, while controlling for all other variables in the model. If the regression coefficient was large relative to its standard error, then that variable was considered to be a significant predictor of FEV₁. If the value of the regression coefficient remained stable with additional variables in the model, then the variable was deemed an independent predictor. If the regression coefficient did not remain stable with the addition of more variables, then confounding of the variable’s effect was indicated. The results are presented in Table 4.17.
4.3.2.1 Age

The negative association between age and FEV1 has been previously established, and is further confirmed by results from simple correlation between these two variables (R= -0.26, p=0.11). Although not statistically significant, the negative sign of the correlation coefficient suggested that FEV1 decreases with age. From multiple correlation, we see that age is the third best individual predictor of the variability in FEV1, following behind percent of ideal weight and the HAES Activity score. When age was entered into a model as the only predictor variable of FEV1, 4.0% of the variability in FEV1 was explained, as indicated by the adjusted R-square value. The regression coefficient demonstrated that for a one-year increase in age, FEV1 would decrease by 1.63% predicted. This regression coefficient, however, was not significant (p=0.11).

4.3.2.2 Percent of Ideal Weight

In addition to FEV1, nutritional status is also an indicator of disease severity in CF. From simple correlation, we see a correlation coefficient of 0.47 (p=0.002) between FEV1 and percent of ideal weight, demonstrating a positive and significant relationship between these variables. From the results of multiple correlation, percent of ideal weight was consistently the single best individual predictor of FEV1.

With percent of ideal weight entered individually into a model of FEV1, the adjusted R-square was much higher than the value seen when age was entered singly into a model. However, this was expected because a significant relationship was demonstrated between FEV1 and percent of ideal weight in simple correlation, but not between FEV1 and age. The adjusted R-square indicated that 20.0% of the variability in FEV1 was explained by percent of ideal weight for this study population. The regression coefficient, for which the p-value was significant (p = 0.002),
indicated that for an increase of 1% in percent of ideal weight, there was an increase of 1.05% predicted in FEV₁.

4.3.2.3 HAES Activity Scores

Although a causal relationship between FEV₁ and habitual physical activity has not been established, this study hypothesized that a positive relationship would be demonstrated between these two variables. Results from correlation analyses (simple and multiple) indicated that the HAES Activity scores, as compared with the Activity Diary Activity scores, had the strongest correlation with FEV₁ and thus explained more variability in FEV₁ than the Activity Diary scores. From the six possible HAES Activity scores, two were selected from multiple correlation analyses as the best potential predictors of FEV₁: Weekday Total Activity and Weighted Total Activity. These scores were factored into separate regression models.

By itself, the Weighted Activity score explained more of the variability in FEV₁ (17.0%) than did the Weekday Activity score (15.0%). The regression coefficients for the Weekday and Weighted Activity scores indicated that for a one-hour/day increase in Total Activity, FEV₁ would increase by 3.1% predicted (p = 0.008) and 3.5% predicted (p=0.005) respectively.

4.3.2.4 Multiple Variable Models

A second and third variable was added to each of the models containing only one explanatory variable, and the effects on the adjusted R-square, the regression coefficients and the standard errors were evaluated.

As a single predictor of FEV₁, age was not significant. When entered into a model with the Activity score or with percent of ideal weight, however, age became a significant predictor of FEV₁. In this two variable model, the effects of both explanatory variables (age + % ideal weight, or age + Activity score) on FEV₁ were augmented. For example, the effect of percent of
ideal weight on FEV₁ was enhanced when age differences were explained. While the estimates of standard error remained relatively stable, the parameter estimates increased. Consequently, the significance of these variables as predictors of FEV₁ increased, and confounding was indicated. Confounding is an association between two variables that is caused by a third variable (the confounder), which is correlated with the first two variables. This enhancement effect demonstrated the need to consider controlling for age, for example stratifying by age group, in a similar analysis of a larger sample size.

When percent of ideal weight and the Activity score were entered into the same two variable model, the effects of both variables were reduced, which also indicated confounding. This was not surprising because there was a moderate, yet significant correlation of the Activity score with percent of ideal weight. Therefore, these two variables were explaining some of the same variability in FEV₁. While the standard error estimates remained stable, the parameter estimates and the significance of these variables also decreased.

The best model included all three explanatory variables, age, the HAES Activity score (Weekday Total or Weighted Total), and percent of ideal weight. With the Weighted Activity score in the three variable model, the adjusted R-square indicated that 40.0% of the variability in FEV₁ was explained by the combined effects of age, percent of ideal weight, and the Weighted Activity score. This was an increase of 9.0% from the best two variable model, which included age and percent of ideal weight. The three variable model that included the Weekday Activity score demonstrated an adjusted R-square of 41.0%, which was an increase of 10.0% over the best two variable model (age and percent of ideal weight).

While Table 4.17 illustrates the total variability explained by the best multiple variable model (percent of ideal weight, age, and Weekday Total Activity score), the contribution of each
predictor variable to the total variability explained was examined by means of partial correlation. In this three variable model, percent of ideal weight, age and Weekday Total Activity respectively explained 20.0%, 11.0% and 10.0% of the variability in FEV₁.

Although gender did not contribute to any multivariable models, the possibility of gender interaction was considered. Age and gender were combined with each of the HAES Activity scores to form interaction terms. These terms were entered into different models with the other explanatory variables, including gender. The interaction terms, however, were not statistically significant, and did not effect change to the adjusted R-square value. A larger sample size may be necessary to detect a significant interaction between these variables.

4.3.2.5 Summary of Final Multiple Regression

The final model was chosen based on the principles of parsimony and common sense. The three variable model explained enough additional variability in FEV₁, as compared with the best two variable model, to justify inclusion of a third variable, the HAES Activity score. The relationship between FEV₁ and each of the three explanatory variables also makes biological sense, as has been previously discussed.

These results from multiple regression indicated a negative relationship between age and FEV₁ in this study sample, and a positive relationship for both percent of ideal weight and the HAES Activity scores with FEV₁. The choice of the HAES Activity score (Weekday Total or Weighted Total) did not affect the amount of variability explained in FEV₁ by the three variable model. The three explanatory variables were statistically significant predictors of FEV₁ in the final model. These results indicated that either of these two HAES Activity scores should be considered for inclusion in a model to explain variability in FEV₁ in CF patients.
Table 4.17: Modeling $FEV_1$ as the outcome variable

<table>
<thead>
<tr>
<th>Model</th>
<th>Adj. $R^2$</th>
<th>Intercept</th>
<th>Parameter Estimate</th>
<th>Standard Error</th>
<th>p-value</th>
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<td>AGE</td>
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<td>0.11</td>
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<td>% IDEAL WT</td>
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<td>WDTHAES</td>
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<td>3.10</td>
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<td>0.008</td>
</tr>
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<td>3.54</td>
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<td>0.005</td>
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<tr>
<td>AGE + % IDEAL WT</td>
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<tr>
<td>% Ideal Wt</td>
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<tr>
<td>% IDEAL WT + WDTHAES</td>
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<tr>
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<tr>
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<tr>
<td>% Ideal Wt</td>
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<tr>
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<tr>
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<tr>
<td>% Ideal Wt</td>
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<tr>
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<td>2.77</td>
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<td>0.02</td>
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</tbody>
</table>

WDTHAES, HAES Weekday Total Activity score; WTTHAES, HAES Weighted Total Activity score; wt, weight
CHAPTER 5

DISCUSSION

5.1 Interpretation of the Results

Results from this cross-sectional pilot study confirmed the hypothesis that a positive relationship would be demonstrated between FEV1, habitual physical activity scores, percent of ideal weight, and exercise capacity. In addition, regression analyses demonstrated that the two best Activity scores in predicting FEV1 were the HAES Weekday Total and HAES Weighted Total Activity scores. A combination of either of these scores with two other explanatory variables, age and percent of ideal weight, explained approximately 40% of the variability in FEV1, the most important variable in describing CF lung disease. These positive results, in addition to the physiological and psychological benefits that CF children may derive from regular physical activity, confirm the need for continued research to investigate the causal relationship between habitual physical activity and lung function.

5.1.1 Feasibility

A primary objective of this study was to determine the recruitment and compliance rates for the collection of habitual physical activity data using the HAES and the 7-Day Activity Diary. The non-invasive and relatively short nature of this study likely contributed to the high recruitment rate (89%) demonstrated for this CF clinic population. Separate compliance rates for the HAES (100%) and the Activity Diary (82%) demonstrated that most patients were returning the instruments, and following study protocol with regards to their accurate completion.

The compliance rate with the HAES was higher than with the Diary, likely as a result of the relative ease of administration for the HAES. The HAES was completed in approximately 15 minutes by most patients in clinic, whereas completion of the Diary required 15 to 20 minutes.
each day over a consecutive period of seven days. These differences, demonstrated in this pilot sample, suggest that the Diary would best serve specifically as a study tool to collect data on the type of activity being performed, information that cannot be captured by the HAES. The HAES, as has been previously suggested, could more easily be integrated into routine clinic follow-up. In addition, the HAES is sensitive to detect change in activity patterns in populations, and therefore is suited to longitudinal usage intended to chart activity patterns.

5.1.2 Habitual Physical Activity

5.1.2.1 Trends for the HAES and the Activity Diary

A comparison of Activity scores between this study sample, the healthy population and other groups of CF patients is advantageous in evaluating whether the habitual physical activity patterns of the study patients represented expected levels. Direct comparisons of Activity scores can be made between the current study and those investigations that also utilized the HAES and the Activity Diary in their study population. For investigations that have used alternate self-report methods to collect physical activity data, general trends in the data can be compared, including male versus female and weekday versus weekend activity patterns.

The Total Activity scores for the current study were consistently lower than those reported for other study populations. In a similarly aged group of 36 CF children, patients used the HAES to report their perceived average of usual weekday and weekend day activity. Males reported 8.1 hours/day and females reported 7.5 hours/day. The current study population also reported lower Total Activity scores than those documented for a group of healthy children (Males, 9.1 ± 0.4 hours; Females, 8.9 ± 0.4 hours), implying that the CF patients of the current study may have been less physically active than their healthy peers. Another study of habitual physical activity in CF seems to support this suggestion. CF patients reported fewer hours
engaged in vigorous physical activity compared with a healthy control group. The hours engaged in Total Activity, however, did not differ between groups.

The literature suggests that healthy males participate more frequently in vigorous activities than females. Although not statistically significant, males in the current study population consistently reported more time in High Activity than females, confirming the trend suggested by the literature. In a study of healthy youth, moderate to vigorous activity (High Activity) was assessed by means of the 3-day Activity Diary. Patterns in the data reveal that males reported consistently higher values for High Activity compared with females.

In contrast with High Activity scores, Total Activity scores were consistently higher in females compared with males for the current investigation. These results suggested that female patients spent more time in mild to moderate physical activities. Two other studies involving CF patients and healthy individuals respectively reported the opposite trend: higher Total Activity for males versus females. This indicates the need for further investigation of trends in physical activity participation for males and females in a larger sample of CF patients.

The pilot study results confirmed the importance of collecting weekday and weekend day activity separately. For all Activity scores, the reports of weekend day activity were significantly larger than reports for weekday activity. In general, the evidence is equivocal as to whether children are typically more active on a weekday or a weekend day. The literature does, however, agree that differences likely exist. One study suggested that children may be more active on the weekend due to the sedentary nature of school. Use of the 3-day Activity Diary in healthy study populations has ensured collection of habitual physical activity data for both weekday and weekend days, confirming the need to measure these activity intervals separately.
Positive, significant correlation coefficients were demonstrated between weekday and weekend Total and High Activity scores for the HAES and the Diary. These results suggested that children exhibit consistent patterns of physical activity participation throughout the week. These trends may result from influences in the home environment, such as parental encouragement of physical activity, or may be related to external environmental cues, such as accessibility of exercise-related facilities.

This study supported some of the trends in physical activity participation previously documented in the literature. Precautions must be taken, however, in drawing conclusions from a small sample of patients. Differences in Activity scores between males and females, for example, were not statistically significant, and a larger sample is needed to assess the true effects of gender on habitual physical activity participation. The higher values for Total Activity in females versus males have not been reported elsewhere, and may reflect a non-representative sample of study patients. Alternatively, these differences could be attributed to unique activity behaviors in this CF population. Research is still needed to further understand and profile the activity patterns of male and female CF patients in a larger sample.

5.1.2.2 Comparison of the HAES and the Activity Diary

A correlation coefficient was calculated between the HAES and the Activity Diary in this pilot study to evaluate the construct validity of the instruments. Construct validity can be confirmed if a hypothesized association between the survey measure and a measure of the same concept actually exists. The strength of the positive correlation between the HAES and the Diary was only moderate. In addition, study patients reported significantly more time for the High and Total Activity scores as reported with the HAES compared with the Diary. This suggested some differences between the two instruments.
Other studies have investigated the association between different self-report measures of activity. A comparison study of four habitual physical activity questionnaires\(^{92}\) in females demonstrated agreement between these instruments ranging from \(r = 0.17\) to \(r = 0.40\). A second study\(^{57}\) demonstrated correlation coefficients between survey instruments ranging from \(r = 0.22\) to \(r = 0.39\). These correlations are similar to the range of moderate correlation coefficients documented for the comparison of the HAES and the Diary (range from \(r = 0.31\) for Weekend High Activity to \(r = 0.49\) for Weighted High Activity).

The results from correlation analysis between the Activity Diary and the HAES are similar to those of other studies. However, the moderate strength of the correlations suggests that there may have been real differences between the report of activity using the Activity Diary and the recall of activity for HAES completion. Recall limitations, random error, or limitations due to proxy response may have affected the validity and reliability of the results.\(^{92}\) Further investigation in a larger sample is warranted to determine whether real differences exist between the Activity Diary and the HAES.

5.1.3 Exercise Capacity

A positive, significant correlation was demonstrated for the HAES Activity scores with maximal work capacity and maximal oxygen consumption. Two other studies have demonstrated similar results in healthy children,\(^{96,97}\) although the HAES was not used to quantify habitual physical activity. The relationship between physical activity level and exercise capacity is still equivocal. In a 3-year exercise intervention trial in CF patients,\(^{3}\) a minimum of three weekly aerobic sessions was enough to effect change in pulmonary function, however, insufficient to effect any change in exercise capacity. A training effect may not have been demonstrated because of the patients relatively high fitness levels at baseline. Establishing thresholds of
physical activity participation for a training effect has many challenges in CF: the start and stop nature of young children’s physical activity patterns, the demanding daily treatment routines of a CF family, and the potential apathy toward exercising in the adolescent group. These factors must be considered if future activity intervention studies are to be conducted.

In further investigating the association between physical activity and exercise capacity, several factors must be considered, including the methods used to evaluate habitual physical activity patterns and exercise capacity status, and the contribution of genetic endowment to both physical activity and physical fitness. In CF, the longitudinal follow-up of exercise capacity and habitual physical activity in a large number of patients will allow for a heightened understanding of this relationship.

5.1.4 Compliance with Physiotherapy

The compliance with physiotherapy scores did not contribute as predictors of FEV$_1$ in the current study. Although compliance with physiotherapy was the third best individual predictor of the Activity Diary scores, it did not contribute to the explanation of variability in multiple correlation for FEV$_1$. In the CF population, the accuracy of compliance with physiotherapy scores, and their actual correlation with lung function status are challenging issues. Patients who comply with physiotherapy are likely healthier than those who do not. On the other hand, some patients who feel healthy do not comply with their prescribed physiotherapy because they personally deem it to be unnecessary. This extreme variability in actual compliance with physiotherapy may have rendered it unimportant in this cross-sectional regression analysis.

5.1.5 Parent Questionnaire

Analysis of data from the parent questionnaire revealed several potentially important relationships for physical activity participation with accessibility of facilities, parent’s physical
activity level and organized physical activity involvement. The mean score for neighborhood safety suggested that the majority of parents felt they lived in extremely safe neighborhoods. As there was minimal variability in the scores, there were also no important correlations with the Activity scores. In a larger study sample, there may have been more variability in this score, and therefore a larger effect.

These results suggested associations common to other studies. Children of active and less active parents exhibited similar physical activity patterns as their parents in one such study. An examination of the relationship between a mile walk/run test of physical fitness and correlates of activity participation demonstrated that involvement in organized physical activity was correlated with a fitness test. Physical activity level, however, was not assessed in this investigation.

Common relationships seen between this study and the literature suggested that physical activity participation in CF patients may be affected by factors common to the healthy population. The significant relationships for the Activity Diary and the HAES with previously documented correlates of physical activity participation implied further relevance for the use of these two instruments in this population.

5.1.6 Activity Classification

The classification system developed for the activity types listed by this CF study population could eventually allow for comparisons across populations, and could help in the determination of which activities may be useful for effecting change in health status in intervention trials. Trends in the classification of activity type according to category intensities from the Activity Diary suggested that the study population was assigning the suitable intensity to their activity types. Common sense suggested that personal care activities, for example, would
not be listed in categories higher than intensity 4 or 5, the two categories of most mild intensity. This was the case. Similarly, there were relatively few activities in the sport classification listed at lower intensities, or for the most physically demanding category, indicating that most children reported sport participation at a moderate intensity. These results were also expected, as it is unlikely, for example, that many children would be involved in competitive sport. The need for an undefined category, however, suggested that children do require more explicit instructions on detailing their activity so that they will be more specific in their activity descriptions.

5.1.7 Simple Correlation of Activity Score with FEV\textsubscript{1}

Trends in the data suggested a stronger association for FEV\textsubscript{1} with the HAES Activity scores than with the Activity Diary Activity scores. Some of the potential differences between the instruments that could have contributed to these discrepancies have already been suggested. There was also stronger correlation between FEV\textsubscript{1} and the Weekday Activity scores than with the Weekend Activity scores. These results may have been attributed to more variability in weekend activity compared with weekday activity. Patterns of habitual physical activity may be more consistent during the school week as school routines are such that most children have an opportunity to participate in at least some physical activity. On the weekend, children may range from totally inactive to highly active.

Although these results may insinuate that a record of weekend activity is of little value, it is still important to measure physical activity for both weekdays and weekend days. In a larger sample, weekend activity may be indicated as important, especially if some children perform the majority of their physical activity on Saturday and Sunday. This amount of physical activity may be enough to demonstrate a positive and important relationship with lung function.
For the current study, a positive and significant correlation was demonstrated for the HAES Activity score with lung function and nutritional status, suggesting that those with decreased lung function or inadequate bodyweight are less active. Similarly, in the healthy population, a significant negative relationship has been demonstrated between physical activity level and fatness. This association suggests that children who are nutritionally sound, neither too fat nor too thin, are more likely to be engaged in regular physical activity. For the CF population where many patients are nutritionally compromised, these results suggest the importance of longitudinal follow-up of this relationship to determine whether changes in habitual physical activity are related to change in nutritional status. Only properly designed intervention studies will be able to evaluate whether participation in habitual physical activity can effect change in nutritional status.

Only two other studies have examined the specific relationship of lung function with habitual physical activity in CF children and adolescents. The results from these two studies differed from those of the current investigation. In 36 CF patients, a significant relationship was demonstrated between the Total Activity score of the HAES and nutritional status in children with clinically significant lung disease. However, there was no relationship between activity level and lung function in these patients. In a study by Nixon et al., activity level was unrelated to both exercise tolerance and pulmonary function in 30 CF patients.

Results of these two studies likely differed from those of the current study due to the use of different measurement tools, the cross-sectional nature of the study designs, varying disease status, small numbers of patients, seasonal differences in the periods of activity data collection, and different activity intervals measured (weekday versus weekend). Rather than suggesting a lack of consistent association between important study variables in CF, these discrepant results
further clarify the need for a longitudinal study in the CF population with repeated measurement and follow-up of habitual physical activity, lung function, nutritional status, and exercise capacity.

The results from simple correlation suggested that lung function and the HAES Activity score were related in a positive direction. Although more research is needed to determine the direction of causality for these two variables, they may act upon one another within a positive feedback loop. For example, relatively stable lung functioning may promote participation in regular physical activity. In turn, physical activity participation may act to further maintain or even improve lung function. Establishing causality, however, will require long-term follow-up of CF patients into adulthood, and studies of specific activity interventions to alter physical activity patterns.

5.1.8 Regression Analyses

These results from multiple regression indicated a negative relationship between age and FEV₁ in this study sample, and a positive relationship for both percent of ideal weight and the HAES Activity scores with FEV₁. The choice of the HAES Activity score (Weekday Total or Weighted Total) did not affect the amount of variability explained in FEV₁ by the three variable model. These results indicated that either of these two HAES Activity scores could be considered for inclusion in a model to explain variability in FEV₁ in CF patients.

5.2 Methodological Issues

5.2.1 Study Limitations

This study indicated the importance of continuing to evaluate the relationship between habitual physical activity and lung function in CF, such that the direction of causality between these two variables can be established. Prior to further investigation, however, it is important to
identify study limitations, and to provide recommendations for future research in this area. The following sections outline some of the challenges and recommendations incurred in conducting this pilot study.

5.2.1.1 Compliance with, and Return of, the 7-Day Activity Diary

Experience from this pilot study indicated that regular phone contact during the week of data collection was necessary to ensure proper completion and return of the Activity Diary. If the Activity Diary was not returned by mail, patients were asked to bring in their completed Activity Diary to their next clinic visit. Clear instructions, detailed examples of a sample day, and encouragement to fill out the Activity Diary as close as possible to the time of the clinic visit were also important.

Although the relatively high compliance rate with the Activity Diary suggested that a 7-day Diary was a feasible method of collecting habitual physical activity data, a 3-day Activity Diary may ensure even higher compliance. A 3-day Diary\textsuperscript{49} would include self-report of two weekdays and one weekend day, and could be especially useful as a study tool in longitudinal follow-up of CF patients where more than one completion of the Activity Diary is necessary.

5.2.1.2 Random and Systematic Error in Self-Report of Activity

In any self-report of physical activity, there is a risk of random or systematic (bias) error.\textsuperscript{47} Although the assessment of habitual physical activity from the HAES and the Activity Diary was subject to this risk, specific design features were intended to minimize the potential for these types of errors.

The potential for random error during self-administration of the survey instruments was addressed in this study. For the Activity Diary, there was a risk for unintentional errors during the recording of activity intensity. In part to minimize this risk, subjects were asked to
specifically describe the activity type next to their entry for activity intensity. This enabled the
study coordinator to check one entry against the other to ensure that the intensity matched the
type. For the HAES, potential errors in recording were immediately assessed upon the patient’s
completion of it. If the assigned percentages for each time period, as provided by the patient, did
not add up to 100%, the study coordinator documented this discrepancy, and consulted with the
patient to rectify the inconsistency. If patients perceived difficulties in correctly assigning
percentage values to each activity level, the study coordinator completed a sample entry with
them, or invoked the assistance of the parent.

Both the Activity Diary and the HAES required self-report of activity for all levels of
intensity. This was intended to reduce a patient’s tendency to over-estimate physical activity
participation or to engage in non-representative activity patterns during the week of recording.
When patients were first introduced to the study protocol in clinic, the study coordinator
emphasized the importance of recording usual activity patterns. Examples of many different
types and intensities of daily activities were provided to patients, ranging from sleep and
television viewing to involvement in competitive sport. These guidelines were followed with
each newly recruited patient to decrease the chance of obtaining a biased estimate of habitual
physical activity.

5.2.1.3 Generalizability of the Results

Due to the short-term nature of this study, habitual physical activity was collected for
only the spring season (March-June). Research has suggested that there is variation in the
physical activity participation according to the time of year. While one study documented a
marked increase in activity during the summer months,16 another study suggested a decline in
activity levels during the summer.99 Therefore, as activity patterns potentially vary by season, the
results from this pilot study cannot be generalized to other seasonal periods during the year. In future long-term studies, the collection of habitual physical activity data should be appropriately timed to capture physical activity data during all four seasons so that a seasonal effect can be estimated.

5.2.1.4 Direction of Causality

The cross-sectional design and small sample size of this study limited any efforts to evaluate the direction of causality between habitual physical activity and pulmonary function. Instead, the presence of a positive, statistical association between Activity scores derived from the HAES and FEV1 suggested the need for longitudinal follow-up of habitual physical activity patterns in CF patients. Routine assessment of habitual physical activity, in addition to the collection of pulmonary function, nutritional status and exercise data already available through regular clinical follow-up, would be instrumental in beginning to address the issue of causality.

5.2.2 Suggested Modifications of the Current Protocol

Results from the current study are equivocal regarding the use of the 7-Day Activity Diary in quantifying habitual physical in CF. The Activity Diary did not demonstrate a significant or strong relationship with the primary outcome variable, FEV1, and this finding warrants further investigation. The Activity Diary and the HAES may have been capturing different dimensions of habitual physical activity in the CF patients. Alternately, the time-consuming nature of accurate completion of the 7-day Activity Diary may render it impractical for longitudinal usage. Future research may indicate the importance of quantifying habitual physical activity by means of a single instrument that would function to collect information on all dimensions of activity at one time period. This type of instrument could potentially combine features from both the HAES and the Activity Diary.
A survey instrument of this design may entail having patients complete the HAES in clinic, while correspondingly listing the usual activity types. In addition to providing data on activity type, patients would also be accountable for the percentage estimates that they recorded. This option, however, needs further consideration with regards to its feasibility and accuracy.

5.3 Future Directions

5.3.1 Proposal for a Longitudinal Study

Survival regression studies in CF have demonstrated how pulmonary function and nutritional status affect survival. It has been previously established that FEV_1 is the best predictor of survival,^{6,73} and consequently, this variable is widely accepted as a surrogate for mortality risk in CF. Research has examined factors that determine the severity of lung disease in order to clarify the survival model,^{6} which is essential for the timing of procedures such as lung transplant. In addition to FEV_1 and nutritional status, other important predictors of survival are age, gender and specific gene mutations.

A measure of habitual physical activity may further explain some of the variance in FEV_1, and thus enhance the CF survival model. Habitual physical activity, however, has neither been followed longitudinally in the CF population, nor considered for inclusion in the survival model. Prior to the inception of a longitudinal study, a quantifiable measure of habitual physical activity that could be incorporated into the clinical follow-up of patients was needed. The current pilot study was designed to investigate this issue.

This pilot study examined the feasibility and compliance rates for the collection of quantifiable data on habitual physical activity. This study also explored the direction and strength of the relationship between habitual physical activity and FEV_1, while taking into consideration other variables that may influence this relationship. Results implied a positive relationship
between FEV₁ and habitual physical activity. On the basis of these encouraging results, a longitudinal study has been proposed, and the project protocol submitted for funding in October 1999 to the Canadian Cystic Fibrosis Foundation.

The purpose of the proposed project is to establish if habitual physical activity is a significant predictor of the change in FEV₁. Patients will be recruited from the CF clinics at two study centers, HSC and Montreal Children’s Hospital, between which there is a long history of collaboration. The inclusion of two study centers will increase the sample size and allow for stronger conclusions to be drawn from the data. Data collected over a two-year period from both the HAES and a 3-day Activity Diary will permit the creation of a comprehensive profile of habitual physical activity in a large study population. The 3-day Diary, a modification of the 7-day Activity Diary used in the pilot study, has been proposed to encourage compliance over the two-year study period. Exercise capacity, nutritional status, and pulmonary function data will also be routinely collected from clinic records in keeping with the protocol of the pilot study. However, this longitudinal study will allow for more complete collection of data on exercise capacity, and permit the inclusion of this data in regression analyses. A power calculation, conducted for the grant application, has been included in Appendix G.

The short-term goals of this proposed project include the integration of the HAES into regular clinic procedures for all CF patients, and inclusion of this measure into the Toronto CF database. From the combined results of the 3-day Activity Diary and the HAES, a comprehensive CF activity profile will be created, which will enable better understanding of activity behaviors in the CF population. A quantification of activity level will allow us to evaluate the relationship of pulmonary function with habitual physical activity, nutritional status and exercise capacity in a large study population. Capturing activity on a regular basis will allow
for the assessment of the effects of seasonal variability on activity patterns, and subsequently on lung function.

There are no known longitudinal studies that have examined and monitored habitual activity patterns and the relationship to disease progression in CF. This proposed project will encourage the follow-up of CF activity patterns into adulthood, such that the causal relationship between activity level and disease progression can be addressed. As demonstrated by the pilot study, the activity measures employed in this investigation are well suited for clinic use, and the HAES may allow for longitudinal tracking of activity patterns. Long-term goals include the development of recommendations for exercise prescription, and future collaboration with the Clinical Studies Network (CSN) to develop a plan for longitudinal, multi-center intervention studies throughout Canadian CF clinics. An understanding of the inter-relationship of pulmonary function with habitual physical activity level, nutritional status, and exercise capacity, will allow for improvements to our model of survival in CF.

5.4 Conclusions

This pilot study met its primary objectives. The results suggested a positive association of weekday activity level (HAES) with both nutritional status and pulmonary function, and supported the hypothesis that CF patients would be receptive to providing data on their activity patterns. While this study has begun to demonstrate the practicality of using the HAES and the Activity Diary in CF patients to quantify habitual physical activity, preliminary cross-sectional trends indicate the need for longitudinal follow-up.

Exercise training programs are difficult to foster in the CF population where demanding treatment regimens can consume much of the CF patient’s spare time. The promotion of increased habitual physical activity, however, is hypothesized to effect change in the clinical
status of these patients, and is likely easier to foster than compliance with an exercise training program. The current study was intended to gather supportive evidence necessary to warrant a longitudinal study of the relationship between FEV$_1$ and habitual physical activity. A longitudinal study, based on the results of this pilot study, may eventually establish whether habitual physical activity can help to explain variability in the survival of CF patients. If the answer is yes, the importance of encouraging regular physical activity participation in CF patients will be confirmed.
REFERENCE LIST


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APPENDIX A

A SUMMARY OF EXERCISE INTERVENTION STUDIES IN CF
<table>
<thead>
<tr>
<th>Investigator, Year</th>
<th>Sample Attributes</th>
<th>Subject Selection</th>
<th>Study Duration</th>
<th>Type of Exercise Program</th>
<th>Duration, Frequency, and Intensity</th>
<th>Means of Comparison</th>
<th>Results</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heijerman et al., 1991</td>
<td>n=16, mean age=28.7 yrs</td>
<td>Patients with advanced lung disease &amp; adequate motivation</td>
<td>3-13 weeks, mean=5.4 weeks</td>
<td>Cycle ergometer</td>
<td>20 minutes, twice per day; 75% of maximal working capacity</td>
<td>Pre- and post-training values</td>
<td>Significant improvements in exercise capacity, body weight &amp; forced expiratory volume in 1 second</td>
<td>Oxygen assisted training with hyperalimentation is safe in patients with severe lung disease</td>
</tr>
<tr>
<td>Cerny et al., 1989</td>
<td>Exercise group: n=9, mean age=15.4 yrs Control group: n=8, mean age=15.9 yrs</td>
<td>Patients admitted to hospital with acute exacerbation of pulmonary disease</td>
<td>Mean=13 days</td>
<td>Cycle ergometer</td>
<td>5-20 minutes, twice per day; moderate intensity, adjusted to attain target heart rate</td>
<td>Exercise: 2 sessions exercise + 1 session physiotherapy Control: 3 sessions physiotherapy</td>
<td>Significant improvements in pulmonary function and exercise capacity for both groups</td>
<td>In some hospitalized patients, exercise may be substituted for at least part of standard physiotherapy</td>
</tr>
<tr>
<td>Braggion et al., 1989</td>
<td>n=10, median age=12.5 yrs</td>
<td>Age &amp; absence of any previous physical training</td>
<td>2 consecutive periods, each lasting 8 weeks</td>
<td>Warm-up, jogging, and circuit training</td>
<td>1-hour, 3 times per week; heart rate not to exceed 150 beats per minute</td>
<td>Time 1: usual activity Time 2: training program</td>
<td>Significant yet small increase in maximal work capacity &amp; no change in lung function</td>
<td>Small improvement in exercise capacity due to short duration &amp; low intensity of training program</td>
</tr>
<tr>
<td>Stanghelle et al., 1988</td>
<td>n=8, mean age=11.5 yrs</td>
<td>Patients volunteered</td>
<td>2 consecutive periods, each lasting 8 weeks</td>
<td>Trampoline exercise, including rocking, jogging &amp; jumping</td>
<td>Range: 56 minutes per week to 109 minutes per week, 3 times daily; 70% of maximal heart rate</td>
<td>Time 1: usual activity Time 2: training program &amp; pre- and post-training values</td>
<td>Significant increase in forced vital capacity over the study period &amp; in maximal oxygen consumption with training</td>
<td>Trampoline exercise may be used as one of several activities for endurance training to avoid monotony in exercise programs</td>
</tr>
<tr>
<td>Stanghelle et al., 1988</td>
<td>Course 1: n=8, mean age=11 yrs Course 2: n=10, mean age=15 yrs</td>
<td>Patients (&gt; 7 yrs) who participated in one of two training courses</td>
<td>2 weeks per course</td>
<td>Seasonally dependent aerobic activities (i.e., cycling, skiing) Course 1: winter Course 2: summer</td>
<td>Range: 4-6 hrs per day, 2 weeks; 70% of maximal heart rate</td>
<td>Pre- and post-training values</td>
<td>Course 1: no significant changes in pulmonary function Course 2: significant improvement in pulmonary function Both courses: significant increase in maximal work capacity</td>
<td>Patients can be motivated for exercise at a high enough level to replace lung physiotherapy over short time periods</td>
</tr>
<tr>
<td>Investigator, Year</td>
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<tr>
<td>Edlund et al., 1986</td>
<td>n=23, age range=7-14 yrs</td>
<td>CF clinic patients, allocation to study group based on proximity to facility &amp; available transport</td>
<td>12 weeks</td>
<td>Swimming, including instruction, endurance &amp; free play</td>
<td>60 minutes, 3 days per week; 60%-85% of maximal heart rate</td>
<td>Control patients, asked not to participate in additional exercise</td>
<td>No significant improvement in pulmonary function or exercise capacity (except predicted post-maximal oxygen consumption) &amp; a significant 5 days per week; starting intensity at 50% of peak work capacity with</td>
<td>Dual running program appears to be an excellent form of therapy for improving the clinical status and quality of life in CF patients</td>
</tr>
<tr>
<td>Zach et al., 1982</td>
<td>n=12, median age=10.5 yrs</td>
<td>Stable clinical condition &amp; a willingness to participate</td>
<td>17 days</td>
<td>Swimming, jogging, hiking, gymnastics, skipping, soccer, table tennis, mini-golf</td>
<td>Total activity=128 hours, 17 consecutive days; intensity adjusted to the capabilities of the majority</td>
<td>Pre- and post-training values</td>
<td>Significant improvement in pulmonary function</td>
<td>Regular physical exercise of high intensity may be a substitute for physiotherapy in some children</td>
</tr>
<tr>
<td>Zach et al., 1981</td>
<td>n=11 yrs, median age=10 yrs</td>
<td>Proximity to hospital &amp; stable clinical condition</td>
<td>7 weeks</td>
<td>Swimming, including instruction, floating, diving &amp; games</td>
<td>17 lessons of 1 hour; variable intensity</td>
<td>Pre- and post-training values</td>
<td>Significant improvement in pulmonary function &amp; significantly higher sputum clearance on swimming days</td>
<td>The maintenance of improved pulmonary function may have depended on the swimming itself</td>
</tr>
<tr>
<td>Orenstein et al., 1981</td>
<td>Exercise group: n=21 Control group: n=10, age range=10-30 yrs</td>
<td>Patients volunteered, allocation to study group based on proximity to facility</td>
<td>3 months</td>
<td>Running, including warm-up, jog-walk, cool-down &amp; fun</td>
<td>1 hour, 3 times per week; 70%-85% of maximal heart rate</td>
<td>Control patients, asked not to change their usual activity</td>
<td>Significant increase in exercise capacity for the exercise group &amp; forced expiratory volume in 1 second significantly lower in control group after study</td>
<td>A running program can increase the exercise capacity of CF patients through increased respiratory muscle tolerance</td>
</tr>
<tr>
<td>Keens et al., 1977</td>
<td>n=7, mean age=13.4 yrs</td>
<td>Patients at CF summer camp</td>
<td>4 weeks</td>
<td>Swimming &amp; canoeing</td>
<td>1.5 hours, 4 consecutive weeks; intensive activity</td>
<td>Pre- and post-training values</td>
<td>56.7% increase in ventilatory muscle endurance</td>
<td>Ventilatory muscle endurance can be improved by upper body endurance exercise</td>
</tr>
<tr>
<td>Investigator, Year</td>
<td>Sample Attributes</td>
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<tr>
<td>Schneiderman-Walker et al., 1999</td>
<td>Exercise group: n=36, Control group: n=36, age range=7-19 yrs</td>
<td>Patients volunteered</td>
<td>3 years</td>
<td>Aerobic activity at home, individual's choice of activities</td>
<td>Minimal 20 minutes, 3 times per week; 75%-80% of maximal heart rate</td>
<td>Control group: continued normal activity</td>
<td>Significantly slower mean annual rate of decline in forced vital capacity for the exercise group</td>
<td>Regular aerobic exercise appears to offer positive benefit to lung function</td>
</tr>
<tr>
<td>de Jong et al., 1994</td>
<td>n=10, mean age=20.6 yrs</td>
<td>Patients volunteered</td>
<td>3 months</td>
<td>Cycle training at home</td>
<td>15 minutes per day, 12 weeks; submaximal workload</td>
<td>8 week control period, patients continued normal activity</td>
<td>Significant improvement in exercise capacity with training</td>
<td>Home exercise is effective in improving physical performance &amp; easy to maintain</td>
</tr>
<tr>
<td>Salh et al., 1989</td>
<td>n=19, mean age=21 yrs</td>
<td>Patients volunteered</td>
<td>2 months</td>
<td>Cycle ergometer training at home</td>
<td>10 minutes per day, 5 days per week; starting intensity at 50% of peak work capacity with gradual increases over time</td>
<td>Pre- and post-training values</td>
<td>Significant increase in exercise capacity &amp; non-significant increase in sputum production</td>
<td>A safe, yet strenuous home exercise program may affect benefit to exercise capacity and sputum production in patients with severe lung disease</td>
</tr>
<tr>
<td>O'Neill et al., 1987</td>
<td>n=8, mean age=20 yrs</td>
<td>Patients volunteered</td>
<td>2 months</td>
<td>Royal Canadian Air Force training protocol: sprints, push-ups, jogging</td>
<td>11 minutes per day, 8 weeks; 50%-70% of maximal working capacity</td>
<td>Pre- and post-training values</td>
<td>Significant reduction in breathlessness with training &amp; no change in pulmonary function or exercise capacity</td>
<td>Breathlessness can be favorably influenced by exercise training &amp; patients reported feeling better while performing exercise</td>
</tr>
<tr>
<td>Andresson et al., 1987</td>
<td>n=7, mean age=10.4 yrs</td>
<td>Patients receiving conventional physiotherapy with no regular exercise</td>
<td>30 months</td>
<td>Sit ups, skipping, trampoline, jogging &amp; swimming</td>
<td>Minimal 30 daily minutes; heart rate of at least 160 beats per minute</td>
<td>Pre- and post-training values</td>
<td>All parameters showed improved or unchanged lung function &amp; a more productive cough was noted</td>
<td>Patients were able to preserve lung function, working capacity, and clinical condition with daily exercise</td>
</tr>
</tbody>
</table>
Table A.2: Unsupervised exercise programs (continued)

<table>
<thead>
<tr>
<th>Investigator, Year</th>
<th>Sample Attributes</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Blomquist et al., 1986</td>
<td>n=14, mean age=17.8 yrs</td>
<td>Patient motivation, interest, clinical stability and proximity to hospital</td>
<td>Phase A: 6 months Phase B: 6 months</td>
<td>Phase A: Aerobic exercise by personal choice, plus standard physiotherapy Phase B: Continued exercise, plus self-treatment with physiotherapy</td>
<td>Phase A &amp; B: 15 minutes, twice per day; 75% of maximal work capacity</td>
<td>Baseline versus Phase A versus Phase B</td>
<td>Non-significant improvement in pulmonary function</td>
<td>CF patients can use self-treatment plus physical activity during daily life—this combined treatment offers similar results to conventional physiotherapy</td>
</tr>
<tr>
<td>Holzer et al., 1984</td>
<td>Exercise group: n=41, age range=8-14 yrs</td>
<td>Patients volunteered</td>
<td>3 months</td>
<td>Royal Canadian Airforce training protocol: sprints, push-ups, jogging</td>
<td>30 minutes daily, 3 months; variable intensity</td>
<td>Control patients, asked to not change usual activity</td>
<td>No significant difference in pulmonary function between the exercise and control groups &amp; significant increase in maximal oxygen consumption for the exercise group</td>
<td>Regular exercise is important in CF patients, although the unsupervised nature of this program appeared to be insufficient to improve ventilatory muscle function</td>
</tr>
<tr>
<td>Investigator, Year</td>
<td>Sample Attributes</td>
<td>Subject Selection</td>
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<tr>
<td>Heijerman et al., 1992</td>
<td>n=10, mean age=28.3 yrs</td>
<td>Patients with severe pulmonary dysfunction volunteered</td>
<td>3 week clinical training period and 1 year unsupervised follow-up</td>
<td>Stationary bicycle</td>
<td>20 minutes, twice per day; 75% of maximal work capacity</td>
<td>Pre- and post-training value</td>
<td>Significant improvement in forced expiratory volume in 1 second after hospitalization &amp; in exercise capacity after home treatment</td>
<td>Exercise training is beneficial if patients participate in both in-patient &amp; voluntary outpatient training programs</td>
</tr>
</tbody>
</table>
APPENDIX B

CONSENT AND ASSENT FORMS

Consent Form

Title of Research Project

HABITUAL PHYSICAL ACTIVITY AND THE ASSOCIATION WITH DISEASE SEVERITY AND EXERCISE CAPACITY IN CYSTIC FIBROSIS: A PILOT STUDY

Investigators

1) Sue Pollock, BPE
Master of Science Candidate in Epidemiology, Department of Public Health Sciences, The University of Toronto (supervised by Dr. Mary Corey)
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Phone: (416) 813-5751

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3) Jane Schneiderman-Walker, MSc
Exercise Physiologist, Division of Respiratory Medicine, The Hospital for Sick Children
Phone: (416) 813-7654 (extension: 4407)

4) Dr. Joe Reisman, MD, FRCP(C), MBA
Pediatric Respiriologist, Division of Respiratory Medicine, The Hospital for Sick Children
Associate Professor, The Faculty of Medicine, The University of Toronto
Phone: (416) 813-6167
Purpose of the Research

We are conducting this study to document the daily activity patterns of cystic fibrosis patients. One of our aims is to evaluate the relationship of different amounts, intensities, and types of activity with pulmonary function and exercise performance. Knowledge gained from this study may help us better understand the unique role of other therapies, such as exercise, in the treatment of cystic fibrosis. Additionally, we plan to investigate household and family-related factors that may promote participation in specific activities. This will help us make recommendations towards improving compliance to specific therapy programs.

Description of the Research

If you choose to participate, the time we require from you, as outlined below, will be minimal.

i) During your clinic visit, one of the study investigators will be available to answer any questions you may have, and to further explain this research project. Your participation in this study will not interfere with your standard treatment.

ii) If you agree to sign the consent form, you will be given a questionnaire to complete while at the clinic. This questionnaire asks you about your usual activity, and should take approximately 15 minutes to complete. There are also a few questions for parents to answer related to their own activity levels and other household factors.

iii) Next, we will provide you with an activity diary to take home. We will ask you to fill out this diary for the 7 days following your clinic visit, detailing all your activities (sleep included!). Upon completion of your activity record, you will need to send it back to us at the hospital. We may telephone you during the study period to offer support.

iv) For children less than 12 years of age, parents will need to help with both the questionnaire and the activity diary. Investigators will need access to patient health records to obtain information on pulmonary function, exercise testing, and clinical status. We may require further input, by phone, to clarify information after the study.

Potential Harms, Injuries, Discomforts or Inconvenience

There are no known harms associated with participation in this study. However, you may find completion of the 7-day activity diary to be a minor time inconvenience.

Potential Benefits

Although you (or your child) will not directly benefit from this study, we hope that the information we collect on your activity levels will help us better understand the role that other therapies, such as exercise therapy, could play in the management of cystic fibrosis. At the end of the study, we will send you a summary of your overall activity level.
Confidentiality

Confidentiality will be respected, and no information that discloses the identity of the subject will be released or published without consent unless required by law. For your information, the research consent form will be inserted in the patient health record.

Participation

Participation in research is voluntary. If you choose not to participate, you and your family will continue to have access to quality care at HSC. If you choose on behalf of your child to participate in this study, you can withdraw your child from the study at any time. Again, you and your family will continue to have access to quality care at HSC.
For participants 16 years of age and older:

"I acknowledge that the research procedures described above have been explained to me and that any questions that I have asked have been answered to my satisfaction. I have been informed of the alternatives to participation in this study, including the right not to participate and the right to withdraw without compromising the quality of medical care at The Hospital for Sick Children for me and for other members of my family. As well, the potential harms and discomforts have been explained to me and I also understand the benefits (if any) of participating in the research study. I know that I may ask now, or in the future, any questions I have about the study or the research procedures. I have been assured that records relating to me and my care will be kept confidential and that no information will be released or printed that would disclose personal identity without my permission unless required by law."

I hereby consent to participate.

________________________________________________________________________
Name of Patient and Age

________________________________________________________________________
Signature (if 16 yrs. or over)

________________________________________________________________________
Name of person who obtained consent

________________________________________________________________________
Signature

________________________________________________________________________
Date

The Person who may be contacted about the research is:

________________________________________________________________________
who may be reached at telephone #:
For parents of participants less than 16 years of age:

"I acknowledge that the research procedures described above have been explained to me and that any questions that I have asked have been answered to my satisfaction. I have been informed of the alternatives to participation in this study, including the right not to participate and the right to withdraw without compromising the quality of medical care at The Hospital for Sick Children for my child and for other members of my family. As well, the potential harms and discomforts have been explained to me and I also understand the benefits (if any) of participating in the research study. I know that I may ask now, or in the future, any questions I have about the study or the research procedures. I have been assured that records relating to my child and my child’s care will be kept confidential and that no information will be released or printed that would disclose personal identity without my permission unless required by law."

I hereby consent for my child _______________________________ to participate.

__________________________________________
Name of Parent

__________________________________________
Signature

The Person who may be contacted about the research is:

__________________________________________
who may be reached at telephone #:

__________________________________________
Name of person who obtained consent.

__________________________________________
Signature

__________________________________________
Date
**Assent Form**

**Title of Study**

HABITUAL PHYSICAL ACTIVITY AND THE ASSOCIATION WITH DISEASE SEVERITY AND EXERCISE CAPACITY IN CYSTIC FIBROSIS: A PILOT STUDY

**Investigators**

1) Sue Pollock, BPE  
- Research Assistant, The Hospital for Sick Children  
- Graduate Student, The University of Toronto

2) Dr. Mary Corey, PhD  
- Scientist and Epidemiologist, The Hospital for Sick Children  
- Associate Professor, The University of Toronto

3) Jane Schneiderman-Walker, MSc  
- Exercise Physiologist, The Hospital for Sick Children

4) Dr. Joe Reisman, MD, FRCP(C), MBA  
- Pediatric Respirologist, The Hospital for Sick Children  
- Associate Professor, The University of Toronto

**Questions you may have about the study:**

**Why are we doing this study?**

At the cystic fibrosis clinic, doctors, nurses and physiotherapists are interested in your activity patterns. Researchers at the hospital also want to know how you spend your time, including how much TV you watch, how often you go shopping with friends, and how many sports you play. This study will allow us to describe your activity levels, and compare them with other children and other CF clinics. We would also like to know why you choose the activities that you do. For example, why do some kids spend their summers at the local pool, while others prefer to play on the computer? This information will help us encourage all CF kids to make good choices about their chosen activities.
What will happen during this study?

At your clinic visit, you will meet one of the study investigators. She will explain the study to you. If you and your parents agree to participate, we will give you a short questionnaire to fill out, asking you about the amount of time that you spend each day at high and low activity levels. If you are less than 13 years old, your parents will help you to fill out this questionnaire. Parents will also have their own questions to answer about themselves and your neighborhood. We will also give you an activity diary to take home. This is a record of your daily activities over a one week time period. After 7 days of filling out the diary, you will need to send it back to the hospital. We will provide you with a stamped, addressed envelope to send it in.

Are there good things and bad things about the study?

We don't think that there is anything bad about this study. In fact, we think it will be fun for you to describe your activity patterns, and to find out how you spend your time each day. At the end of the study, we will send you a summary of your overall activity level.

Who will know about what I did in the study?

Any information that we collect about you during this study will only be shared with the other study investigators. If we need to identify you, we will only use your hospital identification number.

Can I decide if I want to be in the study?

Yes. If you do not want to join this study, or decide halfway through that you no longer want to participate, notify the hospital or your parents. We will respect any decision you make about your own participation.
For participants less than 16 years of age:

"I was present when ____________________________ read this form and gave his/her verbal assent."

______________________________
Name of person who obtained assent

______________________________
Signature

______________________________
Date
APPENDIX C

GLOSSARY OF TERMS and ABBREVIATIONS

**Forced Expiratory Flow Rate** (FEF_{25-75}): The average forced expiratory flow rate over the middle 50% of the forced vital capacity test.\(^{100}\)

**Forced Expiratory Volume in one second** (FEV\(_1\)): The volume of air exhaled in the first second of the forced vital capacity test.\(^{100}\)

**Forced Vital Capacity** (FVC): A maneuver in which the subjects exhales as rapidly and completely as possible following a maximal inspiration.\(^{100}\)

**Maximal heart rate** (**HR\(_\text{max}\)**): A measure of the number of times the heart beats per minute at maximal exercise.\(^{84}\)

**Maximal minute ventilation** (**\(\dot{V}_\text{Emax}\)**): The amount of air that a subject inspires or expires in one minute at maximal exercise.\(^{84}\)

**Maximal oxygen saturation** (**\(\text{SaO}_2\) at max**): An assessment of pulmonary gas exchange at maximal exercise.\(^{84}\)

**Peak expiratory flow rate** (**PEF**): The maximal expiratory flow rate that occurs shortly after the onset of expiration in the FVC test.\(^{100}\)

**Maximal oxygen consumption** (**\(\dot{V}_\text{O}_2\text{max}\)**): The maximal rate at which oxygen can be consumed per minute. It is considered to be the best physiologic indicator of an individual’s ability to transport and utilize oxygen, and is a measure of an individual’s aerobic capacity.\(^{84}\)

**Maximal work capacity** (**Wmax**): The maximal workload a subject achieves during exercise testing.\(^{84}\)

**Ventilatory reserve** (**\(\dot{V}_E/MVV\)**): The ratio of maximal ventilation to maximum voluntary ventilation. The test involved for maximal voluntary ventilation requires the subject to breathe
hard and fast for 15 seconds. These results are extrapolated to 60 seconds, and reported in L/minute.
APPENDIX D

THE HABITUAL ACTIVITY ESTIMATION SCALE (HAES)
THE HABITUAL ACTIVITY ESTIMATION SCALE (HAES)

Date: __________________________

Name: __________________________

This questionnaire contains specific questions about your activities of daily living. Try to answer each question as best as you possibly can.

Please read the all the directions carefully before completing the questionnaire. This will make the task easier for you.

Instructions

This form asks you to estimate your level of activity during different time periods throughout an average weekday (Monday to Friday) and weekend (Saturday or Sunday). Please recall the activities of one typical day within the past several weeks. For each time period, please estimate the percentage of time that you spent in each of 4 different activity levels. The different activity levels are described below. For each of the time periods, the total time spent in all activity levels must add up to 100%.

Following is a sample question and answer series. When completing the form, only give the percentage of time in each category. You do not need to write in what you were actually doing!

Sample:

From when you finished breakfast until you started lunch, please estimate the percentage of time that you spent in each of the following activity levels:

a) inactive 5% (i.e., having a nap)

b) somewhat inactive 60% (i.e., watching TV)

c) somewhat active 25% (i.e., shopping)

d) active 10% (i.e., riding a bicycle)

e) total 100%

There are also a series of questions asking about the timing and length of meals and sleeping habits. Please answer all of these questions completely.
ACTIVITY LEVEL DESCRIPTIONS

These descriptions give you examples of activities that are typical of each activity level. You should refer back to these descriptions as often as you need when completing your estimates.

a) **inactive** – sleeping, lying down, resting, napping

b) **somewhat inactive** – sitting, reading, watching television, playing video games, time in front of the computer, playing games or activities which are mostly done sitting down

c) **somewhat active** – walking, shopping, light household chores

d) **active** – running, jumping, skipping, bicycling, skating, swimming, games that require lots of movement and make you breathe/sweat hard
**Weekday Activity:**
For an average weekday (i.e., Monday, Tuesday, Wednesday, Thursday or Friday), please estimate the percentage of time that you spent in each activity level.

1) After getting out of bed until starting breakfast:
   a) inactive  
   b) somewhat inactive  
   c) somewhat active  
   d) active  
   e) total  

2) After finishing breakfast until starting lunch:
   a) inactive  
   b) somewhat inactive  
   c) somewhat active  
   d) active  
   e) total  

3) After finishing lunch until starting supper:
   a) inactive  
   b) somewhat inactive  
   c) somewhat active  
   d) active  
   e) total  

4) After finishing supper until bedtime:
   a) inactive  
   b) somewhat inactive  
   c) somewhat active  
   d) active  
   e) total
For the average weekday that you are referring to, please answer the following questions as accurately as possible in the spaces provided.

5) At what time did you get out of bed in the morning?  

6) At what time did you start eating breakfast?  

7) How long did you spend eating breakfast?  

8) At what time did you start eating lunch?  

9) How long did you spend eating lunch?  

10) At what time did you start eating supper?  

11) How long did you spend eating supper?  

12) At what time did you go to bed that evening?  

13) For the average weekday that this questionnaire has asked you about, would you rate your overall level of activity as being: (please circle)  

   a) very inactive  
   b) inactive  
   c) somewhat inactive  
   d) somewhat active  
   e) active  
   f) very active  

14) Compared to other recent weekdays, would you rate yourself on this chosen day as being: (please circle)  

   a) much less active than usual  
   b) a little less active than usual  
   c) about the same as usual  
   d) a little more active  
   e) much more active than usual
Weekend Activity:
For an average weekend day (i.e., Saturday or Sunday), please estimate the percentage of time that you spent in each activity level.

15) After getting out of bed until starting breakfast:
   a) inactive
   b) somewhat inactive
   c) somewhat active
   d) active
   e) total

16) After finishing breakfast until starting lunch:
   a) inactive
   b) somewhat inactive
   c) somewhat active
   d) active
   e) total

17) After finishing lunch until starting supper:
   a) inactive
   b) somewhat inactive
   c) somewhat active
   d) active
   e) total

18) After finishing supper until bedtime:
   a) inactive
   b) somewhat inactive
   c) somewhat active
   d) active
   e) total
For the average weekend day that you are referring to, please answer the following questions as accurately as possible in the spaces provided.

19) At what time did you get out of bed in the morning? ________

20) At what time did you start eating breakfast? ________

21) How long did you spend eating breakfast? ________ minutes

22) At what time did you start eating lunch? ________

23) How long did you spend eating lunch? ________ minutes

24) At what time did you start eating supper? ________

25) How long did you spend eating supper? ________ minutes

26) At what time did you go to bed that evening? ________

27) For the average weekend day that this questionnaire has asked you about, would you rate your overall level of activity as being: (please circle)
   a) very inactive
   b) inactive
   c) somewhat inactive
   d) somewhat active
   e) active
   f) very active

28) Compared to other recent weekend days, would you rate yourself on this chosen day as being: (please circle)
   a) much less active than usual
   b) a little less active than usual
   c) about the same as usual
   d) a little more active
   e) much more active than usual

29) If you have any comments about your activity patterns that you think are important, please mention them in the space below.
APPENDIX E

THE 7-DAY ACTIVITY DIARY
Instructions—Each square of this activity diary should be filled with:

i) a number (#), indicating the intensity of the activity during a 15-minute period,

or

ii) the specific type (Type) of activity performed during a 15-minute period.

SAMPLE DIARY

<table>
<thead>
<tr>
<th>0-15 minutes</th>
<th>16-30 minutes</th>
<th>31-45 minutes</th>
<th>46-60 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>#</td>
<td>#</td>
<td>#</td>
</tr>
</tbody>
</table>

If you spend a lot of time doing one continuous activity (i.e., sleeping), use arrows to fill up all the boxes that apply. If you’re doing more than one activity during the 15-minute time period, record the activity that you spent the most time in.

After filling out your diary for 3-days with a one week period (2 weekdays and 1 weekend day), you will be finished! Please return it immediately to the Hospital for Sick Children in the envelope provided. It is important not to change your normal activity for this week. If you become sick during the week, or think you are unable to complete the diary, please contact the study coordinator.
The following numbers (#) should be used to categorize your activity in the squares labeled with #. Please assign only one number per 15-minute time period. If you are unsure of which number best fits your activity, choose the closest number that seems to fit. In the squares labeled with 'Type', write down the name of your activity, or briefly describe it.

<table>
<thead>
<tr>
<th>#</th>
<th>Type (examples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SLEEPING: resting in bed, napping</td>
</tr>
<tr>
<td>2</td>
<td>SITTING: eating, writing, reading, homework, watching TV, working on the computer, arts and crafts, playing board games, having a bath, playing a musical instrument</td>
</tr>
<tr>
<td>3</td>
<td>STANDING: washing, combing, cooking, waiting for a bus, standing in line, having a shower</td>
</tr>
<tr>
<td>4</td>
<td>WALKING INDOORS: shopping, washing dishes, cleaning room</td>
</tr>
<tr>
<td>5</td>
<td>WALKING OUTDOORS: walking at normal pace to school, walking the dog</td>
</tr>
<tr>
<td>6</td>
<td>LEISURE ACTIVITIES/ LOW INTENSITY: golf, table tennis, easy biking, volleyball, gymnastics, recess games (playground, hopscotch, dodgeball)</td>
</tr>
<tr>
<td>7</td>
<td>LEISURE ACTIVITIES/ INTERMITTENT SPORTS OF MODERATE INTENSITY: jogging, moderate biking, hiking, horseback riding, dance classes, softball, swimming lessons, downhill skiing, weight training, recess running games (i.e., tag)</td>
</tr>
<tr>
<td>8</td>
<td>LEISURE ACTIVITIES/ CONTINUOUS SPORTS OF HIGH INTENSITY: running, soccer, tennis, basketball, track and field, badminton, ice hockey, swimming, aerobics</td>
</tr>
<tr>
<td>9</td>
<td>SPORTS ACTIVITIES/ VERY HIGH TO MAXIMAL INTENSITY: cross-country skiing, any competitive sport</td>
</tr>
<tr>
<td>Time</td>
<td>0-15 minutes</td>
</tr>
<tr>
<td>-------</td>
<td>--------------</td>
</tr>
<tr>
<td>8 am</td>
<td></td>
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<tr>
<td>9 am</td>
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<td>10 am</td>
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<td>2 pm</td>
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<tr>
<td>3 pm</td>
<td></td>
</tr>
</tbody>
</table>

**Category #**

1 = Sleeping  
2 = Sitting  
3 = Standing  
4 = Walking  
5 = Walking Indoors  
6 = Walking Outdoors  
7 = Leisure activities/ sports of low intensity (easy)  
8 = Leisure activities/ sports of medium intensity  
9 = Leisure activities/ sports of high intensity (hard)  
10 = sports of maximal intensity
<table>
<thead>
<tr>
<th>Time</th>
<th>0-15 minutes</th>
<th>16-30 minutes</th>
<th>31-45 minutes</th>
<th>46-60 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#</td>
<td>#</td>
<td>#</td>
<td>#</td>
</tr>
<tr>
<td>4 pm</td>
<td>Type</td>
<td>Type</td>
<td>Type</td>
<td>Type</td>
</tr>
<tr>
<td>5 pm</td>
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<tr>
<td>11 pm</td>
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<td></td>
</tr>
</tbody>
</table>

**Category #**

1 = Sleeping  
2 = Sitting  
3 = Standing  
4 = Walking Indoors  
5 = Walking Outdoors  
6 = Leisure activities/ sports of low intensity (easy)  
7 = Leisure activities/ sports of medium intensity  
8 = Leisure activities/ sports of high intensity (hard)  
9 = sports of maximal intensity
APPENDIX F

PARENT QUESTIONNAIRE
**PARENT QUESTIONNAIRE**

Dear parents,

In order to complete our study on pediatric activity patterns in cystic fibrosis, we also need to ask you a few questions about your own habits, household, and your child’s involvement in activities. Please answer as accurately as possible.

Child’s name  
________________________________________

Name of person completing this questionnaire  
________________________________________

Relationship to child  
________________________________________

Date  
________________________________________

1. Place an X next to the *one section* which best describes YOUR current level of daily physical activity:

1. _____

   You have a sit-down job and no regular physical activity.

2. _____

   Three to four hours of accumulated walking or standing in your working day are usual. You have no regular organized physical activity during leisure time.

3. _____

   You are sporadically involved in recreational activities, such as weekend golf or tennis, occasional jogging, swimming, or cycling.

4. _____

   Usual job activities might include lifting or stair climbing, or you participate regularly in recreational/fitness activities such as jogging, swimming or cycling at least three times per week for 30 to 60 minutes each time.

5. _____

   You participate in extensive physical activity for 60 minutes or more at least four days per week.
2. Now we will ask you about YOUR CHILD'S participation in community based physical activities. Please circle either YES or NO.

At the present time, is YOUR CHILD involved in:

<table>
<thead>
<tr>
<th>Activity</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. public park or recreation department activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. physical activities within a church group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. sports team or league</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. YMCA, YWCA or similar organization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. health club, or private sports lessons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. Brownies, Cub Scouts, or other scouting group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. 4-H or other farm club</td>
<td></td>
<td></td>
</tr>
<tr>
<td>h. another organization that promotes physical activity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If “Yes”, please specify type/name organization(s)

________________________________________________________________________

________________________________________________________________________
3. For each of these places where you can exercise, please indicate if it is on a frequently traveled route, and/or easily accessible to you (i.e., within a 5-minute drive from your child’s school or home).

   a. aerobic dance studio
   b. basketball court
   c. beach or lake
   d. bike lane or trails
   e. golf course
   f. health spa/gym
   g. martial arts studio
   h. playing field (soccer, football, softball)
   i. public park
   j. public recreation center
   k. racquetball/squash court
   l. running track
   m. skating rink
   n. sports store
   o. swimming pool
   p. walking/hiking trail
   q. tennis court
   r. dance studio

4. How safe do you feel walking in your neighborhood during the day?
   Please circle only one number from 1 – 5, where 1 = very unsafe and 5 = very safe.

   1  2  3  4  5
5. Please indicate which of the following apply to your neighborhood.

a. sidewalks
b. heavy traffic
c. hills
d. street lights
e. dogs that are unattended
f. enjoyable scenery
g. frequently see people walking/exercising
h. high crime

6. Please indicate which items you have in your home, yard, or apartment complex

a. stationary aerobic equipment
b. bicycle
c. dog
d. trampoline
e. running shoes
f. swimming pool
g. weightlifting equipment, i.e., free weights, Universal gym, Nautilus equipment
h. toning devices, i.e., ankle weights, Dynabands, Thighmaster
i. aerobic workout video or audiotapes
j. step aerobics, slide aerobics
k. skates (roller blades, ice skates)
l. sports equipment (balls, racquets)
m. surf board, boogie board, windsurf board
n. canoe, row boat, kayak
o. skis (water skis, downhill skis, cross-country skis)
APPENDIX G

POWER CALCULATION

Given 188 eligible patients and an estimated 75% response rate, we expect 140 patients to participate in a longitudinal study. An estimate (based on objective monitoring) of the overall percentage of adolescents in the healthy population engaged in regular moderate to vigorous activity is 50%, therefore, we project approximately 70 patients in each of the active and inactive groups. The primary outcome variable for our study, percent predicted FEV₁, was found to have a standard deviation of 18.6 in a similarly aged sample of cystic fibrosis children.³ At a 5% significance level, this sample of 140 patients has 89% power to detect a clinically significant difference in mean FEV₁ of 10% predicted between high and low activity groups of equal numbers.

\[
Z_\beta = \frac{d}{\sigma} \ast \left(\frac{(n^r)/(r+1))^{1/2}}{Z \alpha/2}\right)
\]

where:

\(Z_\beta\) = unknown
\(d\) = 10% predicted (the magnitude of difference we are interested in detecting between mean FEV₁ percent predicted for the active versus inactive groups
\(\sigma\) = 18.6
\(n\) = the estimated number of exposed individuals=70
\(r\) = the ratio of unexposed to exposed individuals=1/1
\(Z \alpha/2\) = 1.96

\[
Z_\beta = \frac{10}{18.6} \ast \left(\left(\frac{(70\times1)/(1+1))^{1/2}}{1.96}\right) - 1.96\right)
\]

= \[\frac{10}{18.6}\]

= 1.22

1 - \(\beta\) = 88.9% power
APPENDIX H

SUMMARY OF ACTIVITY TYPES

CATEGORY 4

*Personal Care*

CF treatment
Crying
Getting Dressed
Getting Ready for Bed
Getting Ready for School
Getting Ready for Sports
Searching for Something

*Domestic Work*

Cleaning
Cleaning (room)
Cooking
Dusting
Taking out the Garbage
Making Bed
Mowing Lawn
Packing up Supplies
Putting Away Groceries
Raking Lawn
Shopping
Shopping for Groceries
Watering Plants/Grass

*School-Related*

Acting
Classes
Drama Classes
Computer Work
Helping Teacher
Homework

*Employment*

After-school / weekend job

*Unstructured Play*
Hide and Seek
Playing
Playing with Family
Singing and Clapping
Recess

Walking
Going to Lunch
Socializing
Walking Around
Walking Dog
Walking Indoors
Work Break

Sport
Gym Class

CATEGORY 5

Personal Care
Drying Self Off
Searching for Something

Domestic Work
Outside Chores
Cleaning Bike
Mowing the Lawn
Packing up Stuff
Raking the Lawn
Shopping
Sweeping the Stairs
Washing the Car
Watering the Grass/Plants

School-Related
Classes
School Field Trip
Homework

Employment
Delivering Papers
Unstructured Play

Ball Playing
Sidewalk Chalk Drawing
Party Games
Amusement Park
Carnival
Group Games
Hide and Seek
Hopscotch
Outside Play
Playing Video Games
Playground
Recess
Swinging

Walking

Socializing
Walking Dog
Walking Outdoors
Walking to Bus
Walk To/From School
Walking to Work
Work Break

Sport

Bike
Hoola Hoop
Hopping
Running
Yoga

CATEGORY 6

Domestic Work

Carrying Stuff
Cleaning
Cleaning (room)
Housework
Washing Car
Watering Plants
Yard Work

School-Related
Drama Classes

Employment

After-School/Weekend Work

Unstructured Play

Hopscotch
Game: 4-square
Playing in the Gym
Playground
Playing
Playing in the School Yard
Playing with Sister
Recess
Swinging

Walking

Walking Dog
Walking Hard

Sport

Bali Playing
Baseball
Basketball
Bike
Bowling
Playing Catch
PE Class
Cool-Down, Post-Soccer
Dancing
Dirt Biking
Dodgeball
Fighting
Fishing
Tag
Golf
Gym
Gymnastics
Hockey
Rollerblade
Running/Jogging
Skateboarding
Skipping
Soccer
Soccer-Baseball

162
Running Stairs
Swim
T-Ball
Track & Field
Trampoline

CATEGORY 7

Employment

After-School and Weekend Work

Unstructured Play

Chasing Someone
Playing
Recess

Walking

Walking Hard

Sport

Badminton
Ball Playing
Baseball
Basketball
Bike
Dancing
Dodgeball
Football
Tag
Gym Class
Gymnastics
Hockey
Hula Hoop
Lacrosse
Running
Squash
Running Stairs
Soccer
Soccer-Baseball
Swim
Tae-Bo
Track and Field
Trampoline
Warm-Up, Pre-Soccer
CATEGORY 8

Unstructured Play

Playground
Playing
Recess

Sport

Aerobics
Badminton
Ball Playing
Bike
Dancing
Dodgeball
Tag
Gym Class
Gym Class (Capture the Flag,)
Gym Class (Scooters)
Hockey
Lacrosse
Karate
Rollerblading
Roller-skating
Running
Soccer-Drills
Soccer-Scrimmage
Running Stairs
Track and Field

CATEGORY 9

Unstructured Play

Recess

Sport

Basketball
Bike
Dance
Rollerblading
Soccer
Track and Field