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Activity Level and Body Mass Index: An Analysis of the Canadian Forces Health and Lifestyle Information Survey

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Activity Level and Body Mass Index: An Analysis of the Canadian Forces Health and Lifestyle Information Survey

by

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Abstract

The increasing prevalence of overweight status and obesity among the general population is a major public health concern. There is debate surrounding the role of recreational physical activity in the prevention of weight gain at the population level.

This study examined the cross-sectional association between overweight status and obesity and recreational physical activity in a large representative sample of members of the Canadian Armed Forces (n = 4749) using polytomous logistic modelling. A systematic review of the literature looking at the longitudinal relationship between activity level and body mass was conducted and a health promotion intervention was developed.

After adjustment for several significant covariates, recreational energy expenditure was significantly and inversely associated with the prevalence of class I obesity compared to normal weight classification (OR 0.94, 95% CI 0.90-0.97), but was not significantly associated with the odds of having a BMI classified as either overweight or obese class II/III (OR 1.01, 95% CI 0.98-1.03; OR 0.93, 95% CI 0.85-1.02) versus having a BMI classified as normal.

This study suggests efforts to prevent overweight status and obesity at the population level could profitably address physical activity habits but need to consider the multi-factorial nature of the problem.

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Chapter 1 Introduction

1.1 Background

Obesity, a condition of excessive body fat, is an increasing public health burden affecting millions of people worldwide(1). Recent evidence has shown that this problem is mirrored in the Canadian experience. The population prevalence of obesity has more than doubled between 1985 and 1998(2-4). Increased body weight has been associated with various adverse health outcomes. Excess weight and obesity are known risk factors for: diabetes, stroke, hypertension, heart disease, liver disease, osteoarthritis, gall bladder disease, respiratory problems (including asthma and sleep apnea), some forms of cancer (breast, endometrial, colorectal, prostate, kidney, and gallbladder) and perhaps depression(1, 5-18). The adverse health effects of obesity along with its increasing prevalence make obesity a major public health concern.

Body Mass Index (BMI) can be used to characterize both excess weight and obesity in adults. BMI, which describes relative weight for height, is significantly correlated with total body fat(16, 19-21). Increased BMI is also correlated with increased morbidity and mortality(16, 22-25). The World Health Organization and Health Canada have adopted a standardized classification of 'overweight' and 'obesity' based on BMI categories derived from population data(1, 16). The premise behind these guidelines is that the categories of BMI are related to the increased health risk associated with obesity. The weight classification system provides a scheme for categorizing health risk according to body weight, making BMI (kg/m^2) the most useful indicator to date of weight related health risk(16).

Recreational physical activity is the most variable part of the total energy expenditure in humans in developed countries(26). However, there is sparse knowledge about recreational physical activity as a preventive factor for weight gain at the population level(27). A brief review of the epidemiological evidence of the relationship between energy expenditure and obesity risk demonstrates conflicting results. There are no randomized controlled trials available to address whether physical activity can prevent weight gain in the general population. Several, frequently cited, large-scale longitudinal studies have assessed the role of regular physical activity in preventing the progression of weight gain from acceptable weight through overweight to obesity(28-34). Some population studies have reported that physical activity protects against weight gain in both men and women(35-39) while a few have reported that physical activity is protective in women only(40, 41), and one has reported inconclusive results(42). Overall the studies suggest that physical activity attenuates weight gain but does not necessarily prevent weight gain or promote weight loss. While a multifactor etiology is likely responsible for overweight and obesity, it seems intuitive that having a physically active lifestyle will improve the chance of having a normal weight.

Previous population studies which explored the relationship between physical activity and body weight have been conducted on the general population. Given that most adults are employed in sedentary occupations and most of the studies report low rates of leisure-time physical activity, it may be difficult to establish the expected association between physical activity and body mass. In contrast to the general population, members of the Canadian military participate in high levels of physical activity, both recreational and work related. The use of a study population with relatively high levels of physical activity may be more informative of the relationship between physical activity and body mass.

This thesis uses data from a cross-sectional survey of a large representative sample of male and female members of the Canadian military to assess the prevalence of being overweight or obese and explore the relationship between physical activity and BMI. Although the temporal relationship between physical activity and body mass can not be determined by this cross-sectional study, the use of a study population with high levels of physical activity will add information to the debate on the relative benefit of increased physical activity in the prevention of overweight and obesity.

1.2 Study Objectives

Primary Objective

To examine the association between recreational activity level and overweight and obesity (measured by BMI) in the Canadian Forces.

Secondary Objectives

To conduct a systematic review of the literature looking at the relationship between recreational energy expenditure and body mass.

To develop a health promotion intervention based on the results of the analysis and detailed literature review.

Chapter 2 Review of Literature

2.1 Design and Measurement Issues

2.1.1 Body Mass Index

Body mass index (BMI), a value that is determined by dividing body weight (in kilograms) by the square of height (in meters), is currently the most frequently used method for classifying an individual as overweight or obese. The ease of determining BMI, which can be calculated from self-reported values of height and weight, renders it the most useful measure of overweight status and obesity in epidemiological studies. In adults, being overweight is defined as having a BMI of ≥ 25.0 kg/m^2, and being obese is defined as having BMI of ≥ 30.0 kg/m^2 (with obesity further classified into three levels of increasing health risk). These cut-points, established by the World Health Organization and Health Canada, distinguish BMI categories based on increasing health risks(1, 16).

The chief limitation of BMI is that it does not differentiate between weight that is fat (i.e. fat mass) and weight that is muscle (i.e. fat-free mass). Although, this may lead to misclassification of very muscular individuals as overweight, there is evidence to suggest that such misclassification is uncommon in the population as a whole(43). In addition, there are some groups whose health risk may not be adequately indicated by their BMI categorization: older adults, members of certain ethnic or racial groups, as well as individuals who are physically fit, may not be at the level of health risk determined by their BMI categorization(16). With respect to physical fitness, research has shown that regular physical activity can decrease the risk of several health problems and improve health for a given BMI categorization(44, 45). However, further research is needed to validate whether cardio respiratory fitness can modify the negative effects of excess body weight and fat(16).

Despite these limitations, the use of BMI to assess weight-related health risk has gained acceptance because of the associations between BMI and adiposity(16, 46-48), BMI and disease risk(49), and BMI and mortality(50, 51).

2.1.2 Physical Activity

There are several different techniques used to evaluate physical activity. Although there is no widely accepted gold standard for the measurement of physical activity, a distinction is made concerning the accuracy of the techniques. In general, the different approaches to the assessment of physical activity can be broadly categorized into two types: direct monitoring and questionnaires.

The most accurate direct measurement of total energy expenditure over a 1-2 week period can be achieved with the use of double isotopically labelled water(52-55). This method has gained recognition for providing the most accurate estimates of energy expenditure(56-58). However, the technique is costly and requires equipment and expertise that limits its appropriateness for use in epidemiological studies. The next most accurate method involves the direct monitoring of the minute-by-minute types of activity throughout the day and measurement of the energy cost of the activities(59, 60). This method, like the first, is not a feasible option for extended periods of time or for large populations. Other direct monitoring methods include measurement of activity with various types of pedometers or tachometers, or treadmill testing (where an individual's treadmill capacity is used to infer the intensity of their regular physical activity)(61). Although these methods provide an objective assessment of physical activity they are less accurate than previously mentioned direct monitoring methods(62). Additionally, treadmill testing is not feasible for large populations and electronic monitoring devices are not appropriate for all recreational activities.

Questionnaires are the most commonly used approach to measuring physical activity in epidemiological studies. They can be used to assess different forms of activity: activity at work, travelling to and from work, and activity in leisure hours. Although they provide a method which could be used to assess physical activity levels in a large number of people, they give a less reliable measure of physical activity than direct monitoring methods especially if only limited indices of activity are used(63).

Questionnaires used to assess physical activity vary in their complexity and the time frame they cover. The level of complexity can range from self-administered, single-item questions (e.g. is the individual more active than their peers?; does the individual exercise long enough to break a sweat?) to interview-administered questionnaires of lifetime physical activity (64). Questionnaires can be used to assess physical activity over the past week, past month, past year, or even over a lifetime. While questionnaires that assess physical activity over a short time period are less likely to exhibit recall bias, questionnaires which cover a longer time frame are more likely to reflect usual activity patterns(65).

The types of physical activity covered by questionnaires vary according to the population being studied and the research objectives. Early epidemiological studies in physical activity focused on work activity(66). However, as physical activity at work has declined with industrialization, questionnaires assessing leisure-time physical activity have become more common and are assumed to be more representative of the level of physical activity in a population(67). While a focus on leisure-time physical activity may be valid for most populations, including younger and healthier populations, it may not be the best indicator of energy expenditure (above that of daily living) for certain populations: unindustrialized nations, children, the elderly, or diseased populations. Consequently, specialized questionnaires have been developed to assess physical activity characteristics for these populations(68, 69).

Although there is difficulty in establishing the validity of the activity measurements, it is recognized that physical activity is best measured as the total amount of energy expended. Total energy expenditure takes into account the frequency (average number of sessions during a given time frame), duration (average number of minutes per session), and estimates the intensity (metabolic or energy cost) of the activity(70). The original calculation of the energy cost of specific activities was done through direct monitoring of minute-by-minute activity and direct measurement of the energy cost of the activities. These values were then expressed as metabolic equivalent (MET) intensity levels, which is the ratio of work metabolic rate to standard resting metabolic rate (energy expended during rest)(71, 72). These MET values provide an activity classification system that standardises the MET intensities of physical activity used in survey research(73).

Incorporating standard intensity scores into the assessment of physical activity makes an assumption that individuals perform an activity at the same intensity. However, the energy expenditure across individuals who report the same amount of time in an activity can vary considerably. Also, because there is a tendency for individuals to overestimate physical activity time when completing surveys(74, 75), a common approach is to assign a MET value for each activity which corresponds to a low intensity when calculating energy expenditure(76, 77). This practice may result in some degree of underestimation of true physical activity (energy expenditure) levels.

In summary, questionnaires can provide a great deal of information about the physical activity patterns of large populations. These instruments, however, may lack acceptable validity when they are compared with more stringent measures. It is important to select an assessment tool that obtains accurate information on the components of energy expenditure that capture the greatest proportion of total energy expenditure in the research population(78).

2.1.3 Cross-Sectional Studies of Physical Activity and Weight

Ideally, any assessment of the effect of physical activity on attained weight and weight gain among the general population would involve longitudinal epidemiological studies with multiple measures of physical activity, diet and body weight. Studies which track physical activity patterns and body weight over 10-20 years with measurements taken at 2- to 5-year intervals are important to accurately describe the contribution of physical activity to long-term weight regulation(79). However, such studies are complex and time consuming. Hence, cross-sectional studies have also been performed to link physical activity and body weight.

Cross-sectional studies assess both exposure and outcome status simultaneously; therefore, it is not possible to use them to determine causal associations because the temporal sequence in which exposure and outcome occur is unclear. Thus, a cross-sectional study that finds an association between physical activity and obesity cannot establish the causal direction of the relationship. This is the major weakness of the cross-sectional study design. There is also the possibility that associations based on current exposure or outcome status may not be representative of past exposure or outcome status. BMI reflects long term caloric intake and expenditure. A cross-sectional study measures BMI and physical activity at one point in time and may not provide a valid measure of long term physical activity.

Despite these weaknesses, there are some strengths associated with cross-sectional studies. A strength, that is relevant to this study, is that the sample obtained in a cross-sectional study may be more representative than that obtained with other epidemiological study designs since it is generally easier to obtain a representative sample of the target population(80).

This thesis uses data from a large representative sample of male and female members of the Canadian military. Analysis of this cross-sectional data will provide insight into the relationship between physical activity and body mass in this unique population; however, no causal conclusions can be drawn. Conclusions about the relation between habitual physical activity and the prevention of overweight status and obesity in adults will be based on evidence from the longitudinal population based studies which are the focus of the systematic review of the literature which follows.

2.2 Systematic review of the epidemiological evidence of an association between physical activity and body mass

2.2.1 Introduction

In an effort to examine the association between physical activity and body mass this thesis initially undertook a systematic review of all available literature. In order to avoid the temporal limitations associated the cross-sectional study design and establish a causal association, the present review dealt strictly with population or large occupational cohort studies that examined the longitudinal relationship between activity level and body mass in adults. Due to clinical and methodological heterogeneity of the included studies, results were not pooled.

2.2.2 Methods

Data sources

This systematic review incorporated several different search strategies to identify relevant studies: electronic database searches, hand-searches of selected journals, and searches of the reference lists of papers selected for review as well as any identified systematic reviews on the topic.

The electronic bibliographic database search, using an OVID interface, included Medline (1966-February 2004), Embase (1980- February 2004), and Current Contents (1993- February 2004). The preliminary search strategy, which incorporated both text based and controlled vocabulary based approaches, was tailored for each database. Keywords used included: 'body mass index', 'obesity', 'weight gain', 'body weight', 'exercise', 'physical activity', 'recreational activity', 'prospective study', 'longitudinal study', 'cohort study', 'survey', and 'cross-sectional study'. These words were connected with Boolean operators, and functions such as truncation and adjacency operators were used in order to maintain a high level of sensitivity. The search was regularly updated using the OVID auto-alert update function until April 2005.

An additional electronic search, with a filter to detect systematic reviews, meta-analyses, or narrative reviews, was conducted in Medline. Bibliographies from these reviews/meta-analyses, as well as from the papers selected for review, were examined for further references.

The search strategy was not restricted on the basis of publication year or language. However, the screening process selected only English-language publications. Although this was done due to resource restrictions, there is empirical evidence to suggest that restriction of reviews to English language articles does not lead to biased estimates of intervention effectiveness in meta-analyses(81). In any event, only one article was screened out on the basis of language.

Study selection

According to an a priori protocol, all population-based or occupational cohort studies in which it was possible to assess the longitudinal association between physical activity and body mass were considered for inclusion. The focus of this review was on adults between the ages of 18 and 55. In some cases, studies were included which had some subjects beyond these age ranges. However, those studies that focused exclusively on adolescents or seniors were excluded. Additionally, studies that focused on developing nations and women during the perinatal period were excluded. To be included, studies had to report on one or more of the following outcome measures: body mass index, waist circumference, or weight change. These criteria were chosen to ensure that included studies were comparable to the objectives of the thesis.

The search strategy identified 3062 unique citations. A first screen for eligibility was based on a review of the citation title. A two-rater calibration exercise of 330 articles (ten percent) demonstrated a high level of agreement (kappa = 0.93 (0.87, 1.00) (Cohen's kappa statistic and 95% confidence interval)) regarding study eligibility based on study title. The two reviewers met to discuss differences of opinion regarding study eligibility in an effort to further improve agreement. Each reviewer then screened the titles of half of the citations and identified citations to be included in the next phase of the review. Selection criteria were applied in a liberal manner in order to maximize sensitivity at this stage in the selection process.

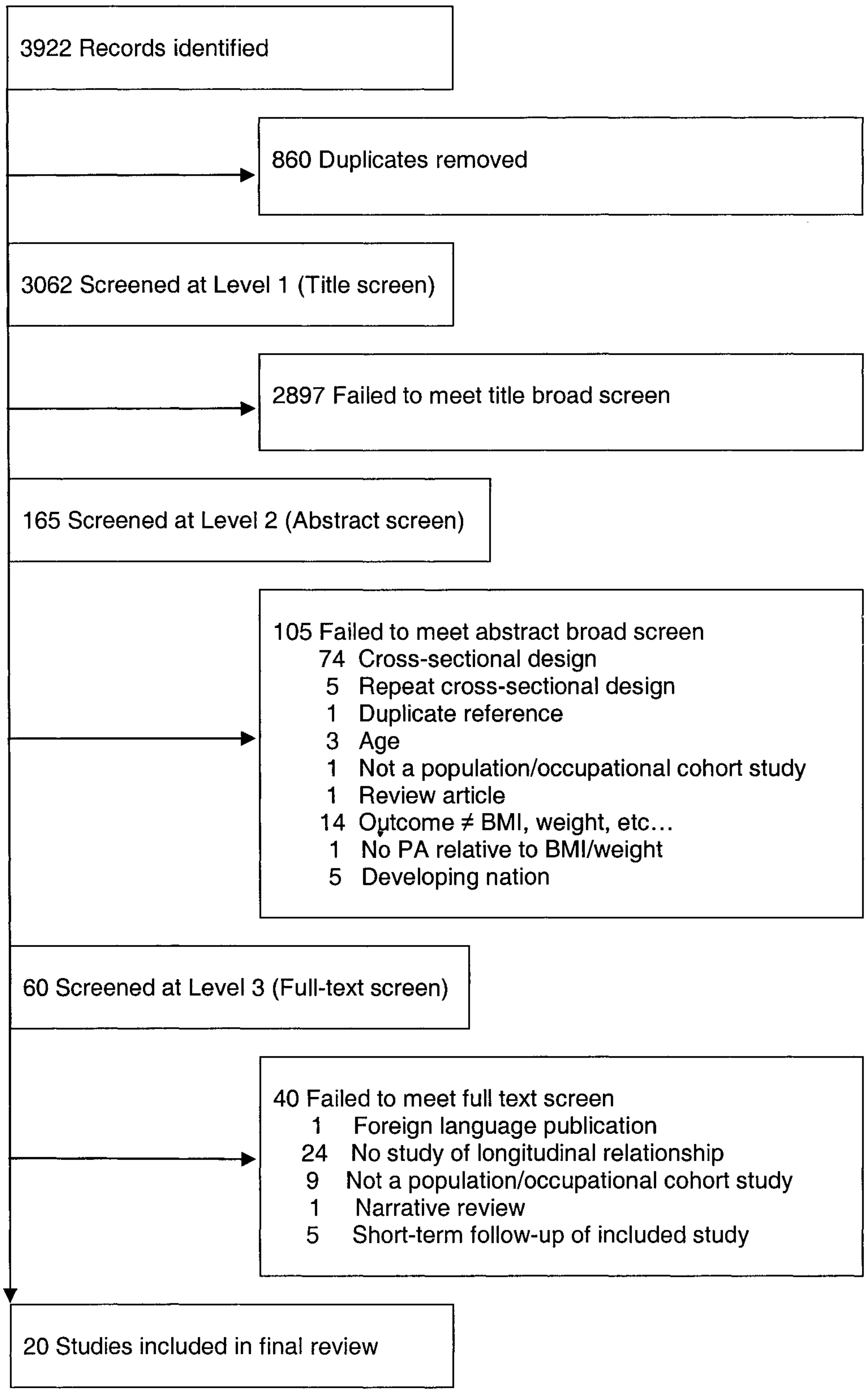
One hundred sixty-five citations passed through the first screen. These articles were all independently screened again by the same two reviewers, this time applying the inclusion/exclusion criteria to the abstracts. Articles which were declared ineligible by both reviewers were excluded from further consideration. All remaining citations (n=60) were retrieved for full text review. Figure 2.1 presents a flow diagram providing information about the number of studies identified, the number included, the number excluded, and the reasons for exclusion.

To formally determine final eligibility, two reviewers independently evaluated the 60 publications selected for full-text review using a pre-specified study relevance form. Where discrepancies existed, the two reviewers met to discuss the discrepancies and to reach a consensus. There were only seven discrepancies between the reviewers (kappa = 0.8; 95%CI (0.6, 0.9)) with all differences related to interpretation of the study (versus oversight or differences in interpretation of the inclusion criteria). 20 studies passed final eligibility screening.

Data extraction

The data extraction was done by one reviewer using a pre-determined extraction form. Details were recorded on study characteristics, study population, assessment of exposure and outcome, covariates controlled for in the analysis, and quality score for all studies meeting the eligibility criteria. For the primary outcome measures (body mass index,

FIGURE 2.1 Flow chart depicting results of selection process



waist circumference, weight change) specific details were collected to potentially allow for statistical pooling of results. The Newcastle-Ottawa Scale(82) was used to assess quality.

Data synthesis

Results from the identified studies were synthesized using a qualitative approach rather than by use of formal meta-analytic synthesis. The latter approach was not practical due to clinical heterogeneity (different durations of follow-up, differences in gender distribution) and methodological heterogeneity (different methods of measuring physical activity, different confounding factors included in adjusted analyses, difference in extent of loss to follow-up and difference of outcome measures) in the included studies.

2.2.3 Results

The systematic literature review yielded twenty studies that met all the inclusion/exclusion criteria(83-102). Information about the studies which were excluded after full-text review(103-142) and the reasons for their exclusion are presented in Appendix A. Four of the included studies had less than 1000 participants while two had more than 10 000. The mean duration of the follow-up was approximately 7 years, with a range from 2 to 15 years. Information from all of the included studies is presented in Table 2.1 by order of study date (most recent first).

Six(102, 143-147) of the studies which met all of the inclusion/exclusion criteria failed to find a statistically significant association between physical activity and weight change. One study(148) found a statistically significant association between physical activity and weight change which was opposite to the expected direction. The 13 remaining studies(149-161) supported the hypothesized beneficial effect of physical activity in the prevention of weight gain.

The next section will present a discussion of the methodological strengths and weaknesses of each study and the likely impact of these on study results. The studies have been grouped into negative studies (based on the failure to find a statistically significant association) and positive studies. The latter studies are further divided into occupational cohort studies and population based studies. The one study which found a statistically significant association opposite to the expected direction is included at the end of the section of negative studies.

Table 2.1 Summary of studies included in the systematic review

(abbreviations appear at the end of the table)

Study (first author, country and years of study)	Subjects (gender, age at entry)	Follow-up (years)	Assessment of PA	Statistical adjustments	Main effect of PA (adjusted)	Results	NOS
Sammel MD(162) US (published 2003) Penn Study of Ovarian Aging	336 F (35 – 47 y)	4	Averages of weekday and weekend activity computed	Baseline BMI	ns	None of the self-reported measures of PA were correlated with the risk of gaining >10 lbs, therefore they were not included in the multivariate model.	4/9
Ball K (163) Australia 1996-2000 Women's Health Australia Project	8726 F (18 - 23 y)	4	Physical activity score (intensity, frequency), categorized into four levels of physical activity.	None	ns	Physical activity was not associated with weight maintenance status in univariate analysis and was not entered into logistic regression analysis	4/9
Parkes KR(164) UK 1995-2000	1581 M (mean 38.7 y)	5	Physical activity level (PAL) at work categorized into 3 groups.	Age, baseline BMI, marital status, education, smoking status.	Physically demanding work Active ß −0.023 ($p<0.10$) Coefficient for age- PAL interaction	Increase in BMI with age tends to be less marked in those with physically demanding jobs	3/9

Table 2.1 *continued*

Study (first author, country and years of study)	Subjects (gender, age at entry)	Follow-up (years)	Assessment of PA	Statistical adjustments	Main effect of PA (adjusted)	Results	NOS
Drøyvold(165) Norway 1984-1997 HUNT 1 and 2	8305 M (20 – 69 y)	11	LTPA at baseline categorized into three levels.	Age, baseline BMI, smoking status, education level	Low (reference) Moderate -0.13 (-0.05, -0.21) p = 0.002 High -0.075 (0.04, -0.19) p=0.207 BMI regression coefficient (95%CI)	LTPA in men has a moderate effect on BMI. The physically active cohort gained less weight than the sedentary cohort. No inverse dose response relationship between increasing levels of LTPA and weight gain.	7/9
Koh-Banerjee(166) US 1986-1996 The Health Professionals Follow-up Study	16 587 M (40 – 75 y)	9	MET * hour score	Age, baseline BMI and waist circumference, diet, smoking status, alcohol	↓ > 3 MET 0.53 ± 0.17 ↑ 3-11 MET -0.38 ± 0.16 ↑ 12-24 MET -0.63 ± 0.17 ↑ ≥ 25 MET -0.90 ± 0.16 Waist change cm	Increased physical activity and weight training inversely associated with waist gain.	5/9
Schmitz KH(167) US 1985-1996 CARDIA study	5115 M & F (18 – 30 y)	10	PA at five examinations. Focus on moderate and vigorous activity.	Race, sex, and baseline BMI (stratified) alcohol, dietary % fat, education (time varying covariates) age, clinic center, smoking, parity.	Black M –0.38 F –1.12 White M –0.48 F –0.66 Mean weight change kg/year	A significant (p<0.005) inverse association between PA change and weight change which is strongly affected by initial relative weight status	6/9

Table 2.1 *continued*

Study (first author, country and years of study)	Subjects (gender, age at entry)	Follow-up (years)	Assessment of PA	Statistical adjustments	Main effect of PA (adjusted)	Results	NOS
Guthrie JR(168) Australia 1991-1993	352 F (45 – 55 y)	3	LTPA (hours/week) calculated into change in energy expenditure (kcal/week)	Baseline BMI	ß −0.83 (SE 0.96) BMI regression coefficient	BMI showed (non-significant) improvement with increasing physical activity	5/9
Petersen L(169) Denmark 1976-1993 Copenhagen City Heart Study	2626 M 3653 F (25 – 83 y) (age at first follow-up)	15	LTPA at second survey (three categories)	Age, sex, baseline BMI, smoking, alcohol, education, occupational physical activity, family predisposition to obesity, LTPA at first survey	Medium M 1.35 (1.73,2.50) F 0.93 (0.59,1.45) High M 1.93 (1.03, 3.60) F 1.35 (0.83,2.18) OR (95% CI)	Significant association between level of LTPA at second survey and development of obesity by third survey ($p = 0.03$). Among the more active subjects there was higher incidence of obesity	7/9
Bak H(170) Denmark 1943-1993	1134 M (22 - 62 y) (age at first follow-up)	10	LTPA at first survey (three categories)	Age, baseline BMI, education, smoking, alcohol, occupational physical activity	Medium 1.17(0.31,4.49) High 1.10(0.28,4.34) OR (95% CI)	No significant effects of previous LTPA on the development of obesity	6/9

Table 2.1 *continued*

Study (first author, country and years of study)	Subjects (gender, age at entry)	Follow-up (years)	Assessment of PA	Statistical adjustments	Main effect of PA (adjusted)	Results	NOS
French SA(171) US 1987-1990 Healthy Worker Project	1639 M 1913 F (mean 38.1 y)	2	13-item exercise frequency recall categorized into: high intensity activity, moderate intensity, group and racket sports, and occupational activity.	Age, sex, marital status, education, occupation, dietary intake, dieting behaviours, smoking status	Walking M –0.86 (0.008) F –1.76 (0.0001) Intense activity M –3.54 (0.0001) F –1.39 (0.03) Weight change lb (p-value)	Increase in LTPA in the form of walking and high intensity activity was significantly associated with decreased body weight in men and women	4/9
Haapanen N(172) Finland 1980-1990	2564 M 2695 F (19 – 63 y)	10	LTPA (kcal/week) in tertiles PA assessed by four levels (vigour)	Age, sex, baseline BMI, smoking status, perceived health status, SES	↑ activity M 1.15 (0.76-1.73) F 1.07 (0.72-1.59) ↓activity M 1.96 (1.39-2.75) F 2.49 (1.72-3.60) Inactive always M 1.62 (1.18-2.20) F 1.61 (1.17-2.21) OR (95% CI)	Large body mass gain over a 10-year period was significantly ($p<0.001$) associated with those who became physically inactive or were physically inactive all the time (vs. those who were physically active at both interviews)	5/9
Wier LT(173) US 1990's	341 M 155 F	Mean 5.5	Total PA for previous 30 days at baseline and at follow-up. Graded activities 0-10.	Age, baseline weight, time lapsed.	M –0.91 (-1.40, -0.42) F –2.14 (-2.93, -1.35) Weight change kg (95% CI)	Physical activity score was significantly ($p<0.01$) associated with average weight change.	4/9

Table 2.1 *continued*

Study (first author, country and years of study)	Subjects (gender, age at entry)	Follow-up (years)	Assessment of PA	Statistical adjustments	Main effect of PA (adjusted)	Results	NOS
Sundquist J(174) Sweden 1980-1989 Swedish Annual Level-of-Living Survey	1871 M 1972 F (25 - 74 y)	8	Two levels: 'no to very light' (No) versus 'regular to heavy ' (Yes)	Age, sex, smoking, education, marital status, health status, ethnicity	M ß 0.32 (0.19, 0.46) F ß 0.30 (0.16, 0.44) Change in BMI regression coefficient (95% CI)	Not taking exercise (relative to baseline 'regular to heavy') was associated with an increased BMI for men and women.	4/9
Taylor CB(175) US 1979-1989 Stanford Five-City Project	568 M 668 F (20 – 60 y)	7	Rate of change in physical activity by regressing physical activity over time	Age, sex, smoking status	BMI-slope lower for those who increased activity	Age and relative activity consistently and strongly related to BMI slope	5/9
Kawachi I(176) US 1986-1988 Nurses' Health Study	9306 F (40 – 75 y)	2	LTPA MET-hours/week at baseline and follow-up.	Age, height, baseline weight, weight change prior to baseline, dietary fat intake, alcohol, hypertension, cholesterol, and stratified 1986 smoking status: H ≥ 25Cig/Day L 1-24 Cig/Day	No change in PA H 4.5 (3.9, 5.2) L 2.3 (1.9, 2.6) ↑ 8-16 MET H 2.5 (2.5, 5.3) L 1.8 (1.0, 2.5) ↑ >16 MET H 2.9 (1.5, 4.3) L 1.3 (0.7, 1.9) Predicted excess weight gain kg (95%CI)	Pre-cessation levels of smoking and post-cessation exercise patterns were significantly related to weight gain (referent group – smokers with no change in activity level).	6/9

Table 2.1 *continued*

Study (first author, country and years of study)	Subjects (gender, age at entry)	Follow-up (years)	Assessment of PA	Statistical adjustments	Main effect of PA (adjusted)	Results	NOS
Fortier MD(177) Canada 1981-1988 Campbell's Survey on Well-Being in Canadians	602 M 644 F (20 – 69 y)	7	Time on activity – total time per year on all LTPA Activity energy expenditure – frequency, duration, and MET	Age, sex, baseline BMI, smoking status, alcohol, income	TOA M ß –0.05 (SE 0.09) F ß -0.02 (SE 0.11) AEE M ß 0.01 (SE 0.16) F ß –0.10 (SE 0.20) Change in BMI regression coefficient	Neither AEE nor TOA are significant predictors of 7-year changes in BMI	5/9
Owens JF(178) US 1983-1987 Healthy Women Survey	500 F (42 –50 y)	3	Change in kcal expended weekly	Baseline weight, hormone and menopause status	-5.84×10^{-4} Regression coefficient - change in weight lb	Women who reported increased PA between the two examinations gained less weight (p=0.01)	4/9
Thune I(179) Norway 1979-1987	5220 M 5869 F (20 – 49 y)	7	LTPA baseline and follow-up four categories. (Category 3 and 4 combined for women).	Age, sex, smoking, coffee, dietary fat, menopause status.	↓ two levels M 1.0 F 1.2 ↓ one level M 0.8 F 1.0 Unchanged M 0.7 F 0.9 ↑one level M 0.6 F 0.7 ↑two levels M 0.2 F 0.4 Change in BMI ($p \leq 0.001$)	Sustained high or increased PA was significantly associated with less weight gain during the follow-up period.	5/9

Table 2.1 *continued*

Study (first author, country and years of study)	Subjects (gender, age at entry)	Follow-up (years)	Assessment of PA	Statistical adjustments	Main effect of PA (adjusted)	Results	NOS
Williamson DF(180) US 1971-1984 NHANES – I Follow-up Study	3515 M 5810 F (25 – 74 y)	10	Recreational PA coded on a three-point scale.	Age, sex, BMI, race, education, smoking status, alcohol, health status, parity, non-recreational physical activity.	Low weight gain M 1.1 (0.8,1.5) F 2.4 (1.6, 3.5) Moderate weight gain M 3.3 (1.7,6.3) F 1.3 (0.8, 2.2) High weight gain M 2.3 (1.0, 5.2) F 6.2 (1.9, 20.4) OR (95% CI)	Decreased PA over the study period was associated with increased weight gain (referent - high level of PA at baseline and follow-up).	6/9
Salonen JT(102) Finland 1972-1975	821 M 858 F (25 – 59 y)	3	LTPA four categories (Dichotomized for analysis of change in LTPA)	Age, sex, dietary changes	M -0.064 F -0.052 Change in BMI	Non-significant association between change in LTPA and change in BMI.	4/9

Abbreviations: AEE = activity energy expenditure, BMI = body mass index, CI = confidence interval, F = female, H = heavy, L = light, LTPA = leisure time physical activity, M = male, MET = metabolic equivalent (intensity level), NOS = Newcastle-Ottawa Scale, ns = not significant, OR = odds ratio, PA = physical activity, PAL = physical activity level, SE = standard error, SES = socio-economic status, TOA = time on activity.

Negative studies

Six studies(102, 181-185) failed to find a statistically significant association between physical activity and weight change

The first of these studies was a four-year follow-up of 8726 women aged 18-23 who had participated in the Australian Longitudinal Study on Women's Health (186). A physical activity (PA) score was derived from a baseline questionnaire which asked about 'vigorous' and 'less vigorous' exercise. The questionnaire generated an activity score which was categorized into four levels of physical activity: None, PA score<5; Low, PA score 5 to <15; Moderate, PA score 15 to <25; and High, PA score ≥ 25. BMI at baseline and follow-up was derived from self-reported height and weight. The primary outcome measure was weight change, classified as: 'maintainers', 'gainers', and 'losers'. 'Maintainers' were those subjects whose follow-up survey BMI was within five percent of their baseline survey BMI. 'Gainers' and 'losers' were those subjects whose follow-up survey BMI was greater than or less than five percent of their baseline survey BMI respectively. This study failed to find a significant association between physical activity and weight change in univariate analysis. The authors do not report any multivariate analyses of physical activity and BMI which adjusted for potential confounders. The study is limited in that the physical activity measure relied only on reports of frequency and excluded consideration of duration and intensity, and therefore it may have been insufficiently sensitive to differentiate between physical activity patterns of weight maintainers and gainers/losers. Additionally, the survey relied on self-reported data, which may be subject to recall or social desirability bias; and the assessment of exposure at one point in time (baseline) may be subject to misclassification bias.

The second of these studies was a four-year follow-up of 336 women who participated in the Penn Study of Ovarian Aging(187). The women were initially 35 – 47 years of age and completed a baseline questionnaire on self-reported physical activity which permitted the estimation of three activity measures: average number of blocks walked per day, average hours of vigorous activity per day, and average number of stairs climbed per day. The authors state that none of the measures were significantly associated with a risk of ≥ 10 pounds weight gain over the four years but the numerical results were not reported. The analysis, while adjusting for baseline BMI, failed to adjust for age or any other potential confounders. Self-reported physical activity may have been subject to recall or social desirability bias and the measure of physical activity may not have been sensitive enough to correlate with clinically significant weight gain, as considered by the authors.

A study by Guthrie et al(188) reported on the two year change in BMI of 352 women, aged 45-55, involved in the Melbourne Women's Midlife Health Project. Physical activity during the past year was assessed by a self-administered questionnaire at baseline and at three-year follow-up. The questionnaire took into account frequency and average time spent in thirty-five activities; energy expended (kcal/week) was calculated. Linear regression analysis demonstrated a non-significant reduction in BMI with increasing physical activity. The study failed to adjust for age which, given the limited age interval of the study participants, may not have affected the results. However, the analysis did adjust for baseline BMI. The study participants differed from non-participants in that they had a higher level of education, were more likely to participate in leisure-time activities, and had a lower mean BMI. These differences limit generalizability of the results.

Fortier et al(189) did not find evidence of an association between physical activity and seven-year changes in various indicators of adiposity (body mass, sum of five skin folds, and waist circumference). This study included males (n=602) and females (n=644), aged 20-69 years, who participated in both the 1981 Canadian Fitness Survey and the follow-up 1988 Campbell's Survey on Well-Being in Canadians. The study looked at several derived measures of physical activity: Time on Activity (TOA) determined the total time spent per year on all leisure-time activity; Active Energy Expenditure (AEE) derived from frequency, duration, and energy cost of activity; Physical Activity Level (PAL) which grouped subjects into one of four categories of AEE; and Physical Activity Intensity (PAI) which grouped subjects into four physical activity groups based on duration and intensity of activity. Additionally, a subset of males and females for whom physical activity measures were available at both baseline and follow-up was used to assess the effect of change in physical activity on changes in adiposity. Five activity-change groups were created based on movement between tertiles of activity from 1981 and 1988. After adjustment for a number of potential confounding factors (age, income, smoking status, alcohol use, and baseline measures of respective adiposity measures), linear regression analysis failed to demonstrate any statistically significant association between AEE and TOA with seven-year changes in adiposity ($p>0.05$). Neither of the baseline categorical physical activity variables (PAL and PAI) showed a significant pattern relating to changes in adiposity. And, ANCOVA results demonstrated no differences for seven-year body mass change between the groups in which physical activity increased, decreased or remained stable ($p = 0.6$ for males and $p = 0.7$ for females). The authors felt that these findings may reflect the fact that potential confounding variables (energy intake and work activity) had not been measured and thus could not be controlled for. As with all of the previous studies, use of a questionnaire to quantify physical activity was subject to recall/social desirability bias.

A study by Salonen et al(102) also failed to show a statistically significant relationship between change in physical activity and body weight. The study, which surveyed 821 males and 858 females between the ages of 25 and 59 years, provided three years of follow-up. Leisure time physical activity (LTPA) was measured by a four-category question. Change in LTPA was computed by dichotomizing the four-category question and subtracting the baseline value from the follow-up value. Despite concern of the authors that the formal assumptions of regression analysis were not met, least-squares regression was used to analyze the relationship between change in physical activity and change in body mass index. Changes in LTPA were negatively, although not significantly, related to weight change. The use of a crude measure of LTPA was the biggest weakness of this study but it is also subject to bias from self-report of physical activity and failed to control for baseline body weight.

A study by Bak et al(190)did not support a long-term effect of LTPA on the development of obesity. The study involved a group of men with juvenile onset obesity and a non-obese control group who were initially examined by the Danish draft boards (baseline, 1943-1977) and later participated in the Copenhagen City Heart Study surveys in 1982-84 and 1991-93 (follow-up 1 and 2 respectively). For the purposes of this review, only the analysis related to the control group will be considered. In the target age range of 22 and 62 years, there were 1134 men for whom the effect of LTPA on the subsequent odds of developing obesity was analyzed. The study population LTPA was classified into three levels based on a self-administered questionnaire (administered at follow-up 1): 'inactive' (none or less than 2 hours/week of exercise), 'medium activity' (2-4 hours of *light* exercise per week), and 'high activity' (2-4 hours of *moderate* exercise per week or more than 4 hours of exercise per week). Development of obesity was defined as having a BMI $\geq$ 30kg/m^2 at the second follow-up. The analysis adjusted for age, baseline BMI, education level, smoking status, alcohol consumption, and occupational physical activity. There was no significant effect of LTPA on the development of obesity at the 10-year follow-up (odds ratio [OR], 'medium activity' 1.17 95% confidence interval [95%CI] 0.31-4.49; OR, 'high activity' 1.10 95%CI 0.28-4.34). The assessment of physical activity at only a single point in time (the first follow-up) may have led to misclassification bias or the exposure status may have changed over the 10-year follow-up period. Additionally, the use of a self-reported measure of physical activity may be subject to recall or social desirability bias and the LTPA measure, which used a limited index of physical activity, may not have been sensitive enough to detect the expected association.

A second study involving the Copenhagen City Heart Study, reported by Petersen et al(191), found a statistically significant association between physical activity and weight change which was opposite to the expected direction. The study population, drawn from the Copenhagen Population Register, participated in three surveys 1976-78, 1981-83, and 1992-93. The study included both men (n=2626) and women (n=3653) between the ages of 25 and 83 years. LTPA was defined as in the study by Bak et al(192). Assessment of LTPA at the second survey was analyzed against the odds of developing obesity (BMI ≥ $30kg/m^2$) by the third survey. The study adjusted for a number of potential confounding factors (age, sex, baseline BMI, smoking status, alcohol consumption, education level, occupational physical activity, family predisposition to obesity, and LTPA at first survey). It found a higher risk of developing obesity by the third survey in men who reported higher levels of LTPA at the second survey. The effect of baseline LTPA on the development of obesity among men was: OR, 'medium activity' 1.35 (95%CI 0.73-2.50); OR, 'high activity' 1.93 (95%CI 1.03-3.60). This association was not observed in women where the odds ratios were as follows: 'medium activity' 0.93 (95% CI 0.59-1.45) and 'high activity' 1.35 (95% CI 0.83-2.18). While weak, the association did suggest that more active subjects were more likely to become obese in the succeeding 10 years. This is contrary to the hypothesized effect of PA on obesity. This may be reflective of the long time period between assessment of exposure and development of the outcome. The finding may be a false positive effect reflecting the possibility that men who were classified as highly active became less active over time, while those who were doing moderate levels of activity were able to maintain their level of activity. As well, this study may be subject to the previously mentioned biases associated with a self-reported measure of physical activity.

Occupational cohort studies which found a positive association

Five of the studies(193-197) included in this review demonstrated statistically significant results in the hypothesized direction. However, they involved occupational cohorts which somewhat limits the generalizability of their results.

Parkes et al(198) examined the relationship between work-related physical activity and five-year changes in BMI in offshore workers on North Sea oil and gas installations. The study involved 1581 men (mean age 38.7 years). Work-related activity was assessed by asking participants to provide a description of their job, including a rating (on a five-point scale) of the extent to which their job involved heavy physical activity. This information was then categorized into three activity groups. Age, baseline BMI, marital status, education level, and smoking status were all controlled for in the analysis. Although age was the only significant main effect, there was a weak interaction between age and physical activity level that produced statistically significant results. Overall, the increase in BMI with age tended to be less marked in those with physically demanding jobs. This study is subject to the usual biases associated with self-reported predictor and outcome variables. However, more notably, this study had a very poor follow-up rate (34.9%) subjecting it to a potential loss to follow-up bias.

The Health Professionals Follow-up Study is a prospective study of male health professionals aged 40-75 at baseline. Koh-Banerjee et at(199) found a statistically significant association between physical activity and nine-year gain in waist circumference in this cohort (n=16 587). Baseline and follow-up physical activity was obtained from a self-reported questionnaire assessing the average time per week spent in specific activities over the previous year. The time spent was then multiplied by the typical energy expenditure of each activity (expressed in METs) and summed over all activities, yielding a MET-hour score. Multivariate linear regression was used to assess whether changes in physical activity were associated with change in waist circumference (self-reported), controlling for age, baseline BMI and waist circumference, smoking status, alcohol consumption, and certain dietary factors. Relative to the group who did not change their physical activity level, an increase in physical activity by ≥ 25 MET-hours/week of activity (equivalent to approximately 3 hours of bicycling per week) was associated with a reduction in waist circumference of 0.90 cm ($p<0.001$). Conversely, a decrease in physical activity by > 3 MET-hours/week (equivalent to approximately .5 hours of bicycling per week) was associated with an increase in waist circumference of 0.53 cm ($p = 0.02$). This study is subject to the usual biases of self-reported measures of exposure and outcome. However, the reproducibility and validity of the waist circumference measure was assessed in a subset of the cohort with highly correlated results between self-reported measures and technician measurement (Pearson correlation = 0.95)(200).

French et al(201) looked at the association between changes in physical activity and body weight over a two year follow-up in a group of employees as part of the Healthy Worker Project (HWP). The HWP was a worksite intervention study designed to assess the impact of health behaviour change programs on smoking cessation and weight control. Only a small proportion of the subjects (<10%) used in this analysis participated in the intervention program the rest were originally part of the control group. Overall, there were 1639 men and 1913 women included in the analysis. Physical activity was assessed using a 13-item retrospective recall questionnaire categorized in to four groups: high intensity activities, moderate intensity activities, group and racket sports, and occupational activity. Linear regression, stratified by sex, was used to examine the relationship between physical activity and follow-up body weight using baseline body weight as a covariate. Other variables controlled for in the analysis included: age, marital status, educational level, occupational status, dieting behaviours, dietary intake, smoking status and treatment group assignment (intervention versus control). For women, an increase of one moderate intensity session per week was associated with a decrease in body weight of 1.76 lb ($p = 0.0001$) and an increase of one high intensity training session per week was associated with a decrease in body weight of 1.39 lb ($p = 0.03$) over the two year period. Among men, an increase of one moderate intensity session per week was associated with a decrease in body weight of 0.86 lb ($p = 0.008$) and an increase of one high intensity training session per week was associated with a decrease in body weight of 3.54 lb ($p = 0.0001$) over the two year period. Participation in group sports and occupational activity were not significantly associated with weight change. Although the investigators did not rely on self-reported measure of body weight, there is no indication that the outcome assessor was blind to exposure status.

An occupation cohort study by Wier et at(202) found average weight gain among men and women to be progressively limited at increasing levels of physical activity. This study consisted of 341 male (mean age 42.1 years) and 155 female (mean age 36.1 years) NASA/Johnson Space Center employees who participated in a fitness testing program for a minimum of two years (quarterly assessment), with follow-up ranging between 2 and 15 years (mean 5.5 years). Physical activity was assessed, at baseline and each follow-up assessment, by self-report measures of the total physical activity over the previous thirty days, graded from 0-10 (NASA activity scale [NAS]). The mean of all NAS scores (between baseline and last follow-up) was used to define the employee's level of physical activity. Multiple regression analysis, adjusting for age, baseline weight, sex (stratified), and time between baseline and follow-up, was performed. Analysis showed that physical activity was a significant predictor of weight change. For men, a one unit increase in mean NAS score was associated with a 0.91 kg decrease in body weight ($p< 0.01$) over 5 years. For women, a one unit increase in mean NAS score was associated with a 2.14 kg ($p<0.01$) decrease in body weight over 5 years. As acknowledged by the authors, the subjects in this study were not typical of the general population. They were motivated individuals who participated long-term in an employee wellness program.

The focus of a study by Kawachi et al(203) was to determine whether exercise could modify the weight gain which tends to occur after smoking cessation. The study involved a cohort of women, between the ages of 40 and 75, from a 2-year follow-up period (1986-1988) of the Nurses' Health Study. Leisure time physical activity was assessed using a validated questionnaire(204) assessing the levels of regular physical activity during the previous year. The researchers were able to calculate a total activity score measured in MET-hours per week which was used to define three groups: those who maintained their pre-cessation levels of activity (within ± 7 MET-hours per week), those who increased their exercise by 8-16 MET-hours per week, and those who increased their exercise by more than 16 MET-hours per week. The researchers' primary hypothesis concerned the benefit of increased exercise among women who quit smoking and therefore they did not include women who quit smoking and reduced their level of physical activity or women who continued smoking and changed their level of exercise. Multiple linear regression (adjusted for age, height, baseline weight, weight change prior to baseline, dietary fat intake, alcohol intake, and personal history of hypertension or high serum cholesterol), stratified by level of smoking prior to smoking cessation (light smoker: 1-24 cigarettes per day; heavy smoker: ≥ 25 cigarettes per day), was used to examine the impact of physical activity on post-cessation weight gain. The referent group for the analysis was smokers who did not change their level of activity. Relative to women in the referent group, women who quit smoking without changing their level of activity gained the most excess weight (i.e. weight gain in excess of the referent group) over the two-year period (light smoker 2.3 kg (95% CI 1.9, 2.6), heavy smoker 4.5 kg (95% CI 3.9, 5.2)). The excess weight gain was much less for women who increased their level of physical activity. Light smokers who increased their activity by 8-16 MET-hours/week gained an excess of 1.8 kg (95% CI 1.0, 2.5) and those who increased activity by >16 MET-hours/week gained an excess of 1.3 kg (95% CI 0.7, 1.9). Heavy smokers who increased physical activity by 8-16 MET-hours/week gained an excess of 3.9 kg (95% CI 2.5, 5.3) and those who increased their activity by >16 MET-hours/week gained an excess of 2.9 kg (95% CI 1.5, 4.3). Although this study relied on self-reported measures of weight, the validity of self-reported weight was established in a sub-study of this cohort. The correlation between self-reported weight and directly measured weight was 0.96 and misestimation of weight did not differ by BMI. The primary weakness of this study was that information was not available on the length of time since quitting smoking. If recent quitters exercised more heavily than longer-term quitters, there may have been a spurious association between exercise and less weight gain.

Population based studies which found a positive association

This review found eight population based longitudinal studies(205-212) which found statistically significant positive associations between physical activity and body weight.

A recently published study by Drøyvold et al(213) looked at the association between leisure time physical activity and BMI change in 8305 men between the ages of 20 and 69 years who were living in a county in Norway and were followed-up for a period of 11 years. This study included only those men whose baseline BMI was within the normal range according to WHO guidelines. Physical activity was assessed by a self-administered questionnaire regarding frequency, duration and intensity of leisure time physical activity (LTPA). LTPA was then categorized into low, moderate, and high levels. Regression analysis, adjusting for age, baseline BMI, smoking status, and education level with LTPA as a categorical variable, was carried out. A U-shaped association was found for BMI at follow-up and baseline activity level. Participants with low levels (reference) and high levels of LTPA gained more weight than those with moderate levels of LTPA. Those with moderate levels of LTPA at baseline gained 0.13 kg/m^2 (95% CI 0.05, 0.21) less than those with low levels. There was no significant difference in BMI between low and high levels of LTPA. A separate analysis, adjusting for age and baseline BMI was done to assess the effect of exercise intensity (low, high) on change in BMI. Participants reporting high intensity level of

LTPA (at baseline) gained 0.15 kg/m^2 (95% CI 0.04, 0.25) less than those reporting low intensity level. This study used standardized methods for measuring weight and height; however, there was no mention of blinding the investigator to exposure status. The failure to find a dose response relationship may be due to the long (11 years) follow-up period during which a change in level of physical activity may have occurred. Subjects who reported a high level of exercise at baseline may have been less capable of maintaining exercise levels than those reporting moderate levels (at baseline).

Schmitz et al(214) found a significant inverse association between physical activity change and weight gain over a 10 year study of 5115 males and females aged 18-30 at baseline. Physical activity was assessed at each of five follow-up examinations using a validated interviewer-based questionnaire(215, 216). Participants were asked about the frequency of participation in thirteen categories of sports and exercise in the previous year; there was no assessment of the duration of the activity. An 'exercise unit' (EU) score was derived from the frequency and intensity of the reported activities. Body weight and height were also measured at each examination. Repeated measures regression was used to assess the association of change in physical activity and change in body weight. The analysis was stratified by gender and race. To examine the interaction of initial weight with physical activity on body weight changes the researchers also stratified baseline BMI based on the sex-specific 75th percentile for BMI from a representative US national cohort (BMI ≥ 26.3 for men, BMI ≥ 24.9 for women). Covariates controlled for in the analysis included: age, smoking status, parity, alcohol consumption, dietary fat intake, education level, and clinic centre. The attenuation of weight gain associated with increase in physical activity was significant in all race and sex sub-groups ($p<0.005$). A reported increase in physical activity of 200 EU (equivalent to stationary bicycling 2 hours/week for 11 months per year or regularly engaging in exercise at 6 METs) was associated with a 1.12 kg, 0.66 kg, 0.38 kg, and 0.48 kg attenuation of weight gain in black women, white women, black men, and white men respectively. With the exception of black men, the attenuation of weight gain associated with a 200 EU increase in physical activity exceeded the observed yearly weight gain (mean weight change regardless of physical activity change). When the analysis was stratified by baseline BMI, the impact of a change in physical activity on body weight was consistently inverse but was 4-7 times larger in participants who were in the stratum of high baseline BMI versus those who were in the stratum of low baseline BMI ($p<0.0001$). Less than 60% of the original cohort was included in the analysis and there was no description of those lost to follow-up, which may be a potential source of bias. A strength of this study lies in the long follow-up period with repeated assessment of both physical activity and body weight.

Haapanen et al(217) found a significant association ($p<0.001$) between physical inactivity and large body mass gain over a 10-year period in a cohort of Finnish adults. The study consisted of 2564 males and 2695 females aged 19-63 years at baseline. The primary outcome was clinically significant body mass gain defined as ≥ 5kg gain and BMI ≥ $26kg/m^2$ at the end of the 10-year follow-up period. LTPA was assessed by three measures: LTPA (kcal/week), based on questionnaire responses, grouped in tertiles (assessed at baseline); global self-assessment of physical activity grouped into four levels of vigour (assessed at baseline and 10-year follow-up); and 'history of physical activity' during follow-up (increased, decreased, inactive always, active always) based on change in self-assessments of global physical activity between baseline survey and follow-up. Logistic regression was used to assess the odds of the primary outcome at the end of follow-up, according to the measures of leisure time physical activity. Potentially confounding variables (age, sex, baseline BMI, smoking status, perceived health status, and socioeconomic status) were controlled for in the analysis. Baseline LTPA and the baseline single-item self-assessment of vigour were weakly associated with body mass change among men and women. The self-reported measure of changes in physical activity during the 10 years of follow-up was significantly ($p<0.001$) associated with the body mass change during the same time period. For those who decreased their level of activity, the odds ratio for body mass gain was 1.96 (95% CI 1.39, 2.75) for men and 2.49 (95% CI 1.72, 3.60) for women compared with those who remained physically active. The odds ratios for those who were physically inactive all the time were also statistically significantly higher than those who were physically active all the time. For men the odds ratio was 1.62 (95% CI 1.18, 2.20) and for women the odds ratio was 1.61 (95% CI 1.17, 2.21).

Sundquist et al(218) focused on the relationship between socioeconomic status and ethnicity and its influence on body mass index. However, they also examined the effect of exercise on change in BMI. The study included 1972 women and 1871 men between the ages of 25 and 74 who were interviewed in 1980/81 and re-interviewed in 1988/89. Exercise was classified into two levels: very light exercise (including no exercise) and regular to heavy exercise. Linear regression was used to analyze the change in BMI related to baseline exercise status, adjusting for age, sex, smoking status, education level, marital status, health status, and ethnicity. A low level of exercise at baseline was related to an increase in BMI of 0.32 kg/m^2 (95% CI 0.19, 0.46) for men and 0.30 kg/m^2 (95% CI 0.16, 0.44) for women relative to those who reported regular to heavy levels of exercise. This study used self-reported height and weight and a very crude estimate of leisure-time physical activity. The study also failed to control for baseline BMI.

Taylor et al(219) looked at the seven year relationship between physical activity and BMI in a cohort of 568 men and 668 women between the ages of 20 and 60 years. Baseline measurements were obtained in 1980-1982, and subjects were measured bi-annually until 1989. The rate of change in BMI was estimated by regressing BMI on time (BMI-slope). Physical activity equalled the sum of annual participation in moderate level activities (e.g. walking instead of driving, walking on lunch hour, climbing stairs instead of using the elevator, or parking further away from destination to be able to walk more: any participation = 1) and heavy activities (e.g. jogging ten miles or more per week, racquet sports, other strenuous sport: any participation = 1). A physical activity slope was calculated by regressing annual participation on time. Linear regression analysis adjusted for age, sex, and smoking status (the dietary variables were not found to be statistically significant therefore they were not entered into multivariate analysis). Increased physical activity, compared to stable or decreased physical activity, was associated with less weight gain. The use of multiple measures to estimate a slope for both exposure and outcome variables may have led to a more stable measure of the association than the use of change scores.

Owens et al(220) found both higher baseline physical activity and increased physical activity were significantly associated with less weight gain over 3 years in a cohort of 500 women between the ages of 42 and 50 years. Height and weight were measured at baseline and follow-up (there was no mention of blinding to exposure status), and physical activity was assessed by a questionnaire. The questionnaire measured habitual physical activity at leisure and the researchers converted the response to kilocalories expended per week. Linear regression analysis was used to assess the importance of baseline physical activity and change in physical activity on weight change. Covariates controlled for in the analysis included: baseline weight, hormone use, and menopausal status. Smoking status and dietary variables reportedly did not affect the results and were not included in the final multivariate analysis. Regression analysis showed that the women who were least active at baseline and those who reported the greatest decreases in physical activity between the two examinations gained the most amount of weight. Although the findings were statistically significant ($p<0.01$), the differences in weight loss were small; an increase of 300 kcal/week (roughly equivalent to walking three times per week for twenty minutes) was associated with 0.2 lb less weight gain ($p=0.01$) over the three years.

A study by Thune et al(221) showed that an increase in physical activity or maintenance of a high level of activity was significantly associated with less weight gain during a seven year follow-up period. This large population based cohort study included male (n=5220) and female (n=5869) subjects between the ages of 20 and 49 years. Leisure time physical activity was graded from 1 to 4 as follows: Grade 1, sedentary – reading, watching television, or other sedentary activity; Grade 2, moderate – walking, bicycling, or physical activity at least 4hr/week; Grade 3, hard – exercises to keep fit at least 4hr/week; Grade 4, very hard – regular hard training several times per week for competition. Changes in the level of leisure activity were classified into five groups defined as follows: ≤ -2, reduced at least two levels of activity; -1, reduced one level of activity; 0, unchanged level of activity; +1, increased one level of activity; ≥ 2, increased at least two levels of activity. A reduction in physical activity was significantly associated with weight gain in both men ($p<0.001$) and women ($p=0.001$). Women who decreased their physical activity the most (≤ -2) over the follow-up period had a BMI increase of 1.2 kg/m^2 after seven years, whereas women who increased their physical activity the most (≥ 2) experienced only a 0.4 kg/m^2 increase in BMI. Men who decreased their physical activity the most (≤ -2) had a 1.0 kg/m^2 increase in BMI after seven years, whereas men who increased their physical activity the most (≥ 2) only had a 0.2 kg/m^2 increase in BMI. This study controlled for age, sex, smoking status, coffee intake, dietary fat intake, and menopause status but failed to control for baseline BMI. There was no description of how BMI was assessed and the physical activity measure is subject to the usual biases of self-reported exposure status.

Williamson et al(222) found that a decrease in physical activity was significantly associated with increased weight gain but failed to find a significant association between baseline physical activity and ten-year weight change in a cohort of 5315 males and 5869 females aged 20 to 74. Participants' self-perceived level of recreational activity was recorded on a three-point scale (low, moderate, high). For analysis of the effect of change in physical activity on weight change, physical activity scores were coded as: low at both interviews, moderate at both interviews, high at both interviews (referent group for the exposure variable), increased activity from baseline to follow-up, and decreased activity from baseline to follow-up. Polychotomous logistic regression was used to estimate the odds ratios for three weight gain categories versus ≤ 3.0 kg (referent group for the outcome variable): low (3.1-8.0 kg); moderate (8.1-13.0 kg); and high (>13 kg). Recreational physical activity reported at baseline had little relationship to the relative odds of gaining different levels of weight during the study follow-up period for both men and women. Among men, change in physical activity had no effect on the odds of low weight gain and only a modest effect on the odds of high weight gain. Recreational physical activity was strongly related to moderate weight gain (versus weight gain ≤ 3.0 kg). Compared to men who maintained a high level of recreational physical activity at both interviews, those who decreased their physical activity had an odds ratio of 3.3 (95% CI 1.7, 6.3) for moderate weight gain, while those who increased their activity level had an odds ratio of 2.4 (95% CI 1.2, 4.6). Those who reported low activity at both interviews had an odds ratio of 3.9 (95% CI 1.9, 7.8) for moderate weight gain, while those who reported moderate activity at both interviews had and odds ratio of 2.0 (95% CI 1.0, 4.0). Among women, there was little effect of change in physical activity on moderate weight gain and a modest effect on low weight gain. However, there was a strong effect on the odds of gaining more than 13.0 kg. Compared to women who consistently reported a high level of recreational physical activity, women who decreased their level of activity had an odds ratio of 6.2 (95% CI 1.9, 20.4) for high weight gain, while those who increased their level of activity had an odds ratio of 3.4 (95% CI 1.0, 11.1). Women who maintained a low level of activity at both interviews had an odds ratio of 7.1 (95% CI 2.2, 23.3) for high weight gain, while those who maintained a moderate level of physical activity had an odds ratio of 3.4 (95% CI 1.0, 11.1). A weakness of this study is that the question on recreational physical activity may have been too unreliable to adequately classify persons, thus biasing effect estimates to the null. The physical activity question failed to assess type, duration, frequency, or intensity of recreational physical activity. The design of the study did not allow identification of whether misspecification of physical activity levels over time prevented finding an association between baseline recreational physical activity and subsequent weight gain. Lastly, the wide 95% confidence intervals around the point estimates for women may be reflective of sample size problems.

2.3 Summary

The hypothesized association between physical activity levels and body mass index is supported by current epidemiological evidence. The majority of the studies in this review supported the role of physical activity as a component in the prevention of weight gain. However, one study found a negative association and six studies failed to find a statistically significant association. Of those studies finding a statistically significant relationship between recreational physical activity and weight change, there is evidence to indicate that high levels of physical activity may be required to prevent weight gain while lower levels attenuate weight gain. While the weight of the evidence from longitudinal studies supports the hypothesis that physical activity is protective against weight gain, the association between physical activity and weight change is complex and a variety of factors influence the distribution of body mass index in a population.

It has been suggested that several methodological issues contribute to the inconsistent longitudinal findings and make it difficult to accurately determine the impact of physical activity on body weight and adiposity(223, 224). The issues include: the low prevalence of higher-intensity physical activity in the general population; measurement error with regard to self-reported activity; inappropriate time frame of the physical activity assessment; and sample sizes that do not allow ample power for stratification and statistical control of important confounding variables.

Although cross-sectional studies that show a relationship between body weight and physical activity can not determine whether physical activity is a cause or a consequence of changes in body weight, there is still room for them to inform the debate when the above issues are addressed. This thesis examines the influence of physical activity on body mass using a population that participates in high levels of physical activity. The large sample size and numerous variables allows for control of many potential confounding variables. Lastly, the questionnaire includes many activities and components of energy expenditure to generate an estimate of total energy expenditure.

Chapter 3 Methods

3.1 Data source

This study used data from the Canadian Forces 2000 Health and Lifestyle Information Survey (HLIS). This mail-out survey was conducted as a census of all serving Canadian Force (CF) members in 2000 with the goal of establishing baseline health status in order to support planning and evaluation of health promotion programs. Overall 27,615 Regular Force members completed the survey (48% response rate).

All participants completed a common core section of questions on: socio-demographic characteristics; physical and mental health status; occupational health and safety issues; awareness and actions to improve health and well being; and specific questions relating to women's and men's health. In addition, they completed additional questions from one of four versions (A, B, C, and D) of the questionnaire which addressed further constructs of relevance to the objectives of the survey. The alternative versions were used in order to reduce the number of items asked of each subject. Subjects were randomly assigned to receive one of the four versions. This thesis was restricted to the sub-sample that was administered version A of the questionnaire. Version A (n = 6910) included questions concerning a number of factors related to health promotion and disease or injury prevention. The other three versions were not used in this study.

The complete database containing the results of the Canadian Forces 2000 HLIS was provided by DND in SPSS format. The dataset and missing values were transposed into SAS format and then modified to limit the dataset to only those CF members who completed version A of the survey questionnaire containing questions related to physical activity. One hundred thirty subjects were excluded due to missing (n = 102) or extreme/implausible values (n = 28) for weight, height or BMI (Table 3.1). In addition, we excluded 17 subjects with very low BMI: between 17.0 – 18.49 which is considered 'below normal' by Health Canada.

As a result of the above exclusions, the sample size was reduced to 6763 subjects who were used in descriptive analyses. However, the final sample size was further reduced as a result of elimination of subjects with missing values for covariates which were included in the final regression model.

Table 3.1 Variable limits.

Variable	Lower Limit	Upper Limit	n
Height	145 cm (57 inches)	213 cm (84 inches)	6
Weight	38 kg (85 lbs)	160 kg (353 lbs)	9
BMI	17.0	50	13

3.2 Estimation of body mass index

Body mass index (BMI) was estimated from self-reported height and weight using the standard formula: weight/height^2 (kg/m^2). Using the cut-off points established by Health Canada for the purpose of identifying different levels of health risk associated with excess weight, a five-level outcome variable was defined as follows:

	0:	18.5 – 24.9	Normal weight
	1:	25.0 – 29.9	Overweight
Outcome =	2:	30.0 – 34.9	Obese Class I
	3:	35.0 – 39.9	Obese Class II
	4:	≥ 40.0	Obese Class III

However, due to the small number of subjects in the highest class of obesity, Obese Class II (n=120) and Obese Class III (n=27) were combined for analysis.

3.3 Estimation of recreational activity level

The 2000 HLIS survey collected information on the duration and frequency of participation in twenty-two recreational physical activities, using a questionnaire modeled on the National Population Health Survey (NPHS)(76). The questionnaire did not collect information on the intensity with which the subject participated in each activity. Using the standards set by Statistics Canada for analysis of the 1998-1999 NPHS(76), recreational activity was measured as energy expenditure expressed in kilocalories per kilogram of body weight per day. In order to quantify recreational activity, the reported information (the frequency of performing the activity per month and the duration of participation in minutes) was combined into a summary activity score which took into account both the reported participation and standard activity intensity levels as measured by the activity specific metabolic equivalent (MET) intensity level.

MET intensity levels are estimates of the activity intensity compared to the standard resting metabolic rate 1 MET, considered the amount of energy an adult individual expends during quiet sitting (approximately equal to 1 kilocalorie per kilogram of body weight per hour). Thus, a 4-MET activity requires four times the metabolic energy expenditure of sitting quietly. MET levels for a wide range of activities are available from published sources(225, 226). For most activities, the MET levels are provided for different levels of intensity. Because individuals tend to overestimate the frequency and duration of their activities(227, 228), the MET levels used in this study (Table 3.2) correspond to the low intensity value of each activity.

Table 3.2 Assigned MET levels for activities included in the 2000 HLIS

Activity	MET level (kcal/kg/hour)
Walking for exercise	3
Gardening or yard work	3
Swimming	3
Bicycling	4
Popular or social dance	3
Home exercises	3
Ice hockey	6
Ice skating	4
In-line skating or rollerblading	5
Jogging or running	9.5
Golfing	4
Exercise class or aerobics	4
Downhill skiing	4
Bowling	2
Baseball or softball	3
Tennis	4
Weight-training	3
Fishing	3
Volleyball	5
Basketball	6
Other 1*	4
Other 2*	4

* The met value used was the average of the listed activities

In order to estimate LTPA, there is a need to know how long a subject performs each activity and how often it is performed. The 2000 HLIS categorized duration of activity into 4 intervals with a maximum category of 'more than one hour'. For calculation purposes the following times, which were also used by Statistics Canada for analysis of the 1998-1999 NPHS(76), were applied for each interval:

Time Recorded	Average duration assigned
1 – 15 minutes	13 minutes (.2167 hour)
16 – 30 minutes	23 minutes (.3833 hour)
31 – 60 minutes	45 minutes (.75 hour)
> 60 minutes	60 minutes (1 hour)

Frequency was recorded as the number of times the subject performed an activity over a three month period.

Once the duration, frequency and MET values had been coded, they were multiplied together to produce the activity specific score. Each subject had twenty-two such scores. The activity specific scores were then summed. Total leisure time physical activity was measured as energy expenditure expressed in kilocalories per kilogram per day (EE). A sample calculation of EE is provided in Appendix B.

The original data set had many missing responses for the physical activity question. Exclusion of all subjects with any missing data would have reduced the dataset substantially. However, examination of the patterns of missing data suggested that it was reasonable to impute responses for many of the missing values.

For each activity, the questionnaire first asked respondents to indicate if they had participated in the activity within the preceding three months (yes/no). If they had participated in the activity, they were then asked to report the frequency of participation (number of times in the past 3 months), and the average duration (four categories) of their participation. Missing values occurred in all of these fields.

Overall, 10.6% of subjects had at least one missing value in the activity participation fields. Subjects who had at least one missing value in any of the participation fields fell into four categories: those who had missing values for all of the activity participation variables (0.5%), those who had a combination of 'yes' and 'missing' responses (2.6%), those who had a combination of 'no' and 'missing' responses (0.07%), and those who had a combination of 'yes', 'no', and 'missing' responses (7.4%). In all cases where the participation field was blank or 'missing', the frequency and duration fields for the respective activity were also blank suggesting that the subject did not do the activity and simply neglected to check the 'no' response in the participation field. It was therefore assumed that subjects who had 'missing' values for all of the participation fields did not participate in any of the listed activities; their participation fields were imputed to 'no'. A similar decision was made for the subjects who had a combination of 'yes' and 'missing' responses to their participation: it was assumed that they had reported information for only the activities which they performed. In this situation, a 'missing' response in the participation field for one activity was assumed to imply that a subject did not participate in that activity, and the missing participation variable was imputed as 'no'. On the other hand, for the subjects in the other two groups (who had completed 'no' for some activities but had left others blank or reported 'yes'), it was not reasonable to assume that they did not take part in that activity left blank. Accordingly, subjects who displayed either variation of the 'no' and 'missing' combination were excluded from analysis.

The questionnaire permitted subjects to report 'other activities'. Subjects who left the participation field of the 'other activity' questions blank were assumed to have no other activities in which they participated. They were still included in the analysis, with a 'no' being imputed for the missing variable.

In cases where the subject indicated that they participated in an activity but either the frequency or duration fields were missing, an activity-specific MET score could not be computed and the subject was excluded from final analysis.

One further restriction was added to the physical activity variable. Subjects (n=15) who reported a frequency for an activity which exceeded 270 times over a three-month period (three times per day on average) were excluded since this was felt to be beyond a reasonable limit.

Overall, 1857 (27%) subjects were excluded from the final analysis by the above criteria on missing physical activity values.

3.4 Covariates

Variables that had been identified in previous research as correlates of obesity, as well as those that were considered as potential confounders (or effect modifiers) of the association between the BMI and recreational energy expenditure, were included in this analysis. Table 3.3 summarizes the covariates considered.

Sex was a dichotomous variable (male/female) with female serving as the reference category.

Age was originally recorded as a continuous variable. Forty–three subjects who had missing information for this variable and three subjects who had values beyond plausible limits for a Canadian Regular Force Member (under age 17 or over age 60) were excluded from the final analysis. Based on results of linearity analysis, age was reclassified as a categorical variable: 19–29, 30–34, 35–39, 40–44, 45–58. The youngest age group served as the reference category for all analyses.

Marital status was classified into three categories: single (never married), divorced/separated/widowed, and married/common-law/same sex partnership. 'Single, never married' served as the reference group.

Education represented the highest level achieved and was classified into: less than high school, high school completed, or post-secondary completed. The latter category was used as the reference group.

Two, military specific, occupational variables were included in this analysis. The first, *Rank,* was classified into four groups (with the first group serving as the reference category): Junior Non-Commissioned Members (Junior NCM), Senior Non-Commissioned Members (Senior NCM), Junior Officers, and Senior Officers (for specifics of the ranks within each group see Appendix C). The second, *Service Element*, was classified as Air, Land, or Sea, with 'Sea' serving as the reference category.

Several variables concerning physical and/or mental health were defined. There were two general questions in the survey asking whether the respondent had a health or medical condition that limited their (1) *employment* or (2) *deployment.* The reference category for both variables was taken as 'not having a health-related limitation'. A separate, more detailed question, asked the respondent to indicate whether they experienced any of a number of chronic health conditions. The health problems (which were based on the list used in the NPHS(76)) were combined into a continuous variable - number of chronic health problems reported.

Two indicators relevant to mental health were included. *Mental distress*, as measured in the 2000 HLIS, is a state characterized by symptoms of anxiety and depression(229). Employing the method used by Statistics Canada for analysis of the 1994/95 NPHS(229), the amount of distress was assessed by a six-item symptom checklist yielding a score of 0-24 (for each of the six symptoms, 0 points were assigned for experiencing the symptom 'none of the time' with 4 points being assigned for experiencing the symptom 'all of the time'). On the basis of the distribution, high distress was defined as a score of seven or greater(229, 230).

The second mental health indicator, *Depression* (a condition characterized by persistent feelings of sadness, sometimes accompanied by a sense of hopelessness, irritability and physical symptoms such as fatigue), also was measured using a questionnaire which derives from the 1994/95 NPHS(229). The 2000 HLIS measured a major depression (MD) episode with a subset of questions from the Composite International Diagnostic Interview – Short Form (CIDI - SF)(231). These questions covered a cluster of symptoms, listed in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV)(232), for a depressive disorder. Depression scores were based on responses to 27 questions and a scoring algorithm that established the probability of suffering a major depressive episode(233). Using the CIDI – SF scoring system, a dichotomous outcome variable was created which classified respondents as probable cases or probable non-cases based on whether they had a MD score of seven or more. This classification has a 0.90 probability of correctly diagnosing a major depression(231).

Sedentary activity, a continuous variable, was derived from a question asking respondents to indicate the number of hours per week, on average, that they spent on four activities: watching television/videos, playing video games, on the internet, and reading books/magazines/newspapers. Respondents were asked to exclude work activity from their estimates. Total Sedentary Activity was estimated by summing the four activities' times. While most subjects (88.5%) provided numerical responses for all four activities, some subjects failed to provide responses to all four activities: 1.2% of subjects had missing responses for all of the activities, 9.4% of subjects had a combination of non-zero numeric and missing responses, while 0.9% of subjects had a combination of numeric, zero, and missing responses. For those subjects who had all missing values or a combination of numeric and missing values, zero hours were imputed for the missing values since it was inferred that they failed to record a time for activities they did not perform. However, when missing values and '0' hours were recorded, this inference is less clear. As a result, subjects who reported numeric, missing, and '0' responses were excluded from further analysis. There were a number of extreme values noted for this variable, including values that exceeded the total number of hours in a week (e.g. 192 hours). Based on a 40-hour workweek, 6 hours of sleep per day, and 7 hours per week of miscellaneous activity such as eating, it is unreasonable for subjects to spend more than 79 hours of sedentary activity per week. Subjects whose sedentary activity ranged between 80 and 192 hours per week were recoded as missing (n=70).

Work Activity was classified into four categories based on subjects' response to a question asking them to indicate which statement best describes their usual work activity: Sedentary - 'usually sit during the day and don't walk around very much'; Light - 'stand or walk quite a lot during the day but don't have to carry or lift things very often'; Moderate - 'usually carry or lift loads, or have to climb stairs or hills often'; and Heavy - 'do heavy work or carry very heavy loads'. Sedentary work activity was used as the reference category.

Table 3.3 List of Potential Confounding Variables

Variable	Type of Variable	Levels
Sex	Categorical	Female (ref) Male
Age	Categorical	19-29 (ref) 30-34 35-39 40-44 45-58
Marital Status	Categorical	Single, never married (ref) Divorced/separated/widowed Married/common-law/same sex partnership
Education	Categorical	Post-secondary completed (ref) High school complete Less than high school
Rank	Categorical	Junior NCM (ref) Senior NCM Junior officer Senior officer
Service Element	Categorical	Sea (ref) Air Land
Medical condition limiting employment	Categorical	No (ref) Yes
Medical condition limiting deployment	Categorical	No (ref) Yes
Number of chronic health conditions	Continuous	
Mental distress	Categorical	No (ref) Yes
Depression	Categorical	No (ref) Yes
Sedentary activity	Continuous	
Work activity	Categorical	Sedentary (ref) Light Moderate Heavy

Abbreviations: NCM = non-commissioned member; ref = reference category.

3.5 Testing for linearity of predictor variables

Four of the predictor variables (recreational energy expenditure, age, number of chronic health conditions, and sedentary activity) were originally measured on a continuous scale. Linearity of the predictor variable with the logit of the outcome variable needed to be evaluated in order to determine whether the variables could be treated as continuous for logistic regression analysis(234). Since the outcome (BMI) has four categories, linearity was examined separately for three separate binary regressions (BMI ≥ 25 versus BMI < 25, BMI ≥ 30 versus BMI < 30, and BMI ≥ 35 versus BMI < 35).

This analysis was done in two ways. First, based on the distribution in the full sample, the predictor variable was divided into quartiles and linearity on the logit scale was assessed using the likelihood ratio test comparing the models treating the categorized predictor variable as continuous and as a categorical variable. Second, a LOESS smoothing on the logit scale was performed for each of the BMI cut-points; the shape of the smoothed plot provided an idea about the parametric relationship between the outcome and the covariate(234).

3.6 Descriptive statistics

3.6.1 Group comparisons using descriptive statistics

Descriptive statistics of the dependent and all independent variables considered in the analysis were produced for the full sample (n = 6763), the final analytical sample (n = 4749), and those excluded from final analysis (n = 2014). Subjects were excluded from final analysis if they were missing values for recreational energy expenditure or any of the covariates selected for inclusion in the final model. The four BMI groups were also compared using descriptive statistics of the continuous and categorical predictor variables for the final analytical sample.

3.6.2 Comparison to outside group

A limited comparison of the HLIS data to the 2000-2001 Canadian Community Health Survey (CCHS)(77) was done. Variables examined for comparisons were BMI (by sex), and recreational energy expenditure. For this comparison, the CCHS sample was limited to subjects over the age of 19 and under the age of 60.

3.6.3 Variables related to health promotion

The survey included questions regarding: the subject's self-perceived health status; actions which the subject felt would improve their health and well-being; obstacles to taking action to improve their health; and barriers to exercise at work. Descriptive analyses of these select variables relating to the secondary objective of this thesis (development of a health promotion intervention) were done.

3.7 Modeling approach

3.7.1 Ordinal logistic regression, method selection

Many indicators of health status are inherently continuous or measured on an ordinal scale. However, in the interest of estimating the risk of an adverse event (risk or odds ratio), epidemiologists and clinical researchers will often choose to dichotomize outcomes for analysis. Although such an approach can be valid and useful, it can result in both information loss and loss of statistical power(235). Use of ordinal logistic regression models makes fuller use of the available information and can result in a gain in statistical power, reflected in more efficient parameter estimates(236).

With ordinal logistic regression, the standard logistic regression model is extended to handle outcome variables that have more than two ordered categories(237). Assuming that the ordinal outcome variable, Y, can take on k + 1 values, the values 0,1,...,k act as labels for the k ordered response categories(234, 238). We denote a general expression for the probability that the outcome is equal to k as:

$$Pr[Y = k \mid x] = \Phi_k(x).$$

In all ordinal regression models, the probabilities are conditional on a vector, x, of p covariates (234, 239).

Several different regression models have been developed to analyse ordinal outcomes. Adding confusion to the process, there are a number of different names for the same models. The models are related to the most general model (the Baseline Logit Model) and involve imposing various restrictions on the model parameters. Three models were most relevant to the current analysis. Table 3.4 summarizes the comparison of these three models.

Table 3.4 Comparison of cut-points between proportional odds model, continuation ratio model and baseline logit model based on a 4-level ordinal outcome.

Cut-point	Baseline logit model	Proportional odds model	Continuation ratio model
1	0 vs. 1	0 vs. 1, 2, 3,	0 vs. 1,2,3
2	0 vs. 2	0,1 vs. 2,3	1 vs. 2,3
3	0 vs. 3	0,1,2 vs. 3	2 vs. 3

The **baseline logit model**(234), also called polytomous logistic model(240), is the most flexible model to analyse multinomial responses and can be used for both ordinal and nominal outcome groups. It does not utilize any information about the ordering of the response categories instead allowing each outcome to be compared to a reference group. The baseline logit model allows the detail of the coding of the outcome variable to be retained without imposing the restrictions on the parameters (which require certain assumptions to be met) of other ordinal logistic regression models.

The **proportional odds model**(241), also called the cumulative logit model(242), ordinal logistic model(243), or the cumulative odds model(244, 245), compares the probability of an equal or smaller response to the probability of a larger response. This model makes the assumptions that the odds ratio associated with a predictor is independent of the cut-point used. So, for example, suppose that males have 2.3 times the risk of having a BMI of 25 or over (compared to under 25) using females as the reference group. Then under the proportional odds model, males will also have 2.3 times the risk of having of having a BMI of 30 or greater (compared to a BMI under 30). Hence, the odds ratios estimated from the proportional odds model are independent of the cut-point used to classify the outcome variable and are therefore valid over all cut-points simultaneously. The assumption of homogeneity of the log-odds ratios across the k-cut points (proportional odds assumption) can be tested with a X^2 Score test. It has been noted, however, that this test has limitations and should be augmented by graphical tests to assess the validity of the assumption(246, 247).

The **continuation-ratio model** compares each response to all higher responses (or to all lower responses) and has been likened to the Cox proportional-hazards model(234, 248-250). The continuation-ratio model is best suited to situations where individual categories of the outcome variable are of fundamental interest, not merely an arbitrary grouping of an underlying continuous variable, and comparison of a group to the extremes makes clinical sense(234, 251). The continuation-ratio model has four variations related to two modelling decisions. First, the models can either compare an outcome category to all outcome categories higher than it or could compare an outcome category to all outcome categories lower than it. The two models are not equivalent and arguments have been made for both approaches(234, 249, 252). Second, the model can either be constrained or unconstrained. In the unconstrained version, the continuation-ratio logits have different constant terms and slopes for each logit and can be estimated through a nested series of regular logistic regression models(234). More commonly, the model can be constrained to have a common vector of slope coefficients and different intercepts(234, 249, 253, 254).

These models were used to analyse the HLIS data and the validity of each model was assessed prior to final selection of the modeling approach.

3.7.2 Confounding and effect modification

The purpose of this analysis was to understand and describe the relationship between BMI and activity level in a military population. Therefore, in building the model, the decision to add a variable was not based on its statistical significance, but rather on whether the presence of that variable in the model significantly changed the relationship between BMI and recreational energy expenditure.

Confounding exists in the data if meaningfully different interpretations of the relationship of interest occur when an extraneous variable is included or excluded from analysis(255). Assessment of confounding requires a comparison between the crude estimate of an association and an adjusted estimate of an association(255). The crude estimate is calculated without considering the effect of an extraneous factor, and the adjusted estimate controls for an extraneous factor. Variables are selected for control only if the adjusted and unadjusted effect estimates differ by some meaningful amount. The criteria used for this analysis was a 10% change in the Beta estimate for the recreational energy expenditure variable.

Each of the variables identified in Table 3.3 was entered separately into the model along with recreational energy expenditure. If the Beta value for recreational energy expenditure changed more than 10% for at least one of the levels, the covariate was retained for the preliminary multivariate model(256). Additionally, all variables that were significant at the p=0.10 level were also entered into a preliminary multivariate model. The impact of each variable in the multivariate model was re-evaluated by removing each variable that was not significant at the p=0.05, one at a time, and checking the impact on the Beta value for recreational energy expenditure(234, 257). Two criteria were then employed: if removal of the covariate did not change the Beta value for recreational energy expenditure, at any of the outcome levels, by more than 10% and if the likelihood ratio test statistic comparing the models with and without the covariate was not significant, the covariate was dropped from the model(234, 257).

Effect modifiers are variables that have a significant interaction with the risk factor. Evidence of interaction is seen when the relationship of interest is different at different levels of the extraneous variable(255). Three criteria were used to determine whether a variable acted as an effect modifier. The first criterion was that the interaction between the variable and recreational energy expenditure had to be significant at the 0.05 level. The second criterion was whether the stratum specific odds ratios differed materially in magnitude or direction. The third criterion was that the interaction term had to be biologically meaningful.

The goal of this analysis was to understand the relationship between recreational activity level and BMI by estimating adjusted odds ratios. The final model adjusted for all variables which were found to be significant confounders or effect modifiers of the relationship between recreational energy expenditure and BMI.

Chapter 4 Results

4.1 Descriptive

4.1.1 Description of the sample

There were 6763 subjects who formed the eligible group. After exclusion of subjects missing values for one or more of the variables included in the final model (n = 2014), 4749 subjects were included in the final analysis. Descriptive information about demographic and physical activity for the participants is presented in Table 4.1 (categorical factors) and Table 4.2 (continuous factors). These tables also provide a comparison of the characteristics of the subjects who were included in the final analysis and those who were excluded from final analysis. Although some differences between included and excluded subjects can be observed, the magnitudes of these differences are quite small and likely of little clinical importance. Therefore, the findings summarized below will focus on the final analytical sample only.

The sample, consisting of 88.2% males and 11.8% females, is representative of the CF population as a whole(258). The mean age of the subjects was 38.6 years. The sample had a smaller representation of subjects in the 19-29 (12.7%) and 30-34 (15.2%) age categories compared to the older age categories. 50% of the sample was between the age of 35 and 44 years, 21% of the sample was over the age of 45 years.

The average body mass index of the sample was 26.9 kg/m^2. The majority of the subjects (52.4%) were in the overweight BMI category while 30.2% were classified as normal. 17.4% of the subjects were classified as obese (class I, II and III).

Approximately three-quarters of the sample (75.5%) were married or living common-law while 15.9% of the subjects were single, never having been married. The remainder of the sample was divorced or separated. Over 90% of the respondents had completed a high

Table 4.1 Description of final analytical sample compared to whole sample and excluded subjects – categorical variables.

Characteristic (number of subjects missing variable)	Total sample n = 6763	Included subjects n = 4749	Excluded subjects n = 2014
Age (n = 46)			
19-29	905 (13.5%)	604 (12.7%)	301 (15.3%)
30-34	1049 (15.6%)	724 (15.2%)	325 (16.5%)
35-39	1703 (25.4%)	1206 (25.4%)	497 (25.3%)
40-44	1687 (25.1%)	1220 (25.7%)	467 (23.7%)
45-58	1373 (20.4%)	995 (21.0%)	378 (19.2%)
Sex (n = 13)			
Male	5908 (87.5%)	4190 (88.2%)	1718 (85.9%)
Female	842 (12.5%)	559 (11.8%)	283 (14.2%)
Body mass index			
18.5 to 24.9	2090 (30.9%)	1435 (30.2%)	655 (32.5%)
25 to 29.9	3526 (52.1%)	2490 (52.4%)	1036 (51.4%)
30 to 34.9	1000 (14.8%)	718 (15.1%)	282 (14.0%)
35 to 39.9	120 (1.8%)	88 (1.9%)	32 (1.6%)
40 to 50	27 (0.4%)	18 (0.4%)	9 (0.5%)
Marital status (n = 11)			
Single, never married	1146 (17.0%)	755 (15.9%)	391 (19.5%)
Divorced/separated	614 (9.1%)	407 (8.6%)	207 (10.3%)
Married/common-law	4977 (73.9%)	3572 (75.5%)	1405 (70.1%)
Educational level (n = 1)			
Post-secondary completed	1904 (28.2%)	1395 (29.4%)	509 (25.3%)
High school completed	4289 (63.5%)	2980 (62.8%)	1309 (65.0%)
Less than high school	567 (8.4%)	372 (7.8%)	195 (9.7%)
Rank (n = 8)			
Junior NCM	3171 (47.0%)	2124 (44.7%)	1048 (52.2%)
Senior NCM	1829 (27.1%)	1322 (27.8%)	507 (25.3%)
Junior officer	1063 (15.7%)	775 (16.3%)	288 (14.4%)
Senior officer	690 (10.2%)	527 (11.1%)	163 (8.1%)
Element (n = 34)			
Air	2510 (37.3%)	1829 (38.5%)	681 (34.4%)
Land	3016 (44.8%)	2042 (43.0%)	974 (49.2%)
Sea	1203 (17.9%)	878 (18.5%)	325 (16.4%)
Work activity (n = 81)			
Sedentary	2544 (38.6%)	1874 (40.3%)	670 (34.6%)
Light	2854 (43.3%)	1978 (42.5%)	876 (45.3%)
Moderate	1007 (15.3%)	678 (14.6%)	329 (17.0%)
Heavy	182 (2.8%)	124 (2.7%)	58 (3.0%)
Medical condition limiting employment (n = 29)			
Yes	668 (9.9%)	454 (9.6%)	214 (10.8%)
No	6066 (90.1%)	4295 (90.4%)	1771 (89.2 %)
Medical condition limiting deployment (n = 24)			
Yes	673 (10.0%)	455 (9.6%)	218 (11.0%)
No	6059 (90.0%)	4287 (90.4%)	1772 (89.1%)
Mental distress (n = 23)			
Yes	1072 (16.0%)	733 (15.5%)	339 (17.0%)
No	5635 (84.0%)	3983 (84.5%)	1652 (83.0%)
Depression (n = 28)			
Yes	579 (8.6%)	404 (8.6%)	175 (8.8%)
No	6124 (91.4%)	4313 (91.4%)	1811 (91.2%)

Abbreviations: NCM = non-commissioned member

Table 4.2 Description of final analytical sample compared to whole sample and excluded subjects – continuous variables.

Characteristic	Total Sample		Final Analysis Group		Excluded Subjects	
	n	Mean (range)	n	Mean (range)	n	Mean (range)
Age	6718	38.4 (18, 58)	4749	38.6 (19, 58)	1969	37.8 (18, 57)
Body Mass Index (kg/m^2)	6763	26.8 (18.5, 47.9)	4749	26.9 (18.5, 46.9)	2014	26.7 (18.5, 47.9)
Number of chronic health conditions	6763	0.8 (0, 9)	4749	0.7 (0, 9)	2014	0.7 (0, 6)
Recreational Energy Expenditure (kcal/kg/day)	4906	2.8 (0, 29.1)	4749	2.9 (0, 29.1)	157	2.6 (0, 17.7)
Sedentary Activity (hours/week)	6629	23.9 (0, 79)	4749	24.3 (0, 78)	1880	22.7 (0, 79)

school education with 29.4% of the subjects having completed some form of post-secondary education. Fewer then 8% of the sample had less than a high school diploma.

The majority of the sample were assigned to the air (38.5%) or land (43.0%) elements while slightly less than 19% were members of the sea element. This is representative of the CF population(258).

Very few subjects reported any chronic health problems: out of a maximum possible number of 21 chronic health problems, the mean number of health problems reported per subject was 0.7. Less than 10% of the sample reported having a medical condition which limited their employment, the same proportion that reported having a condition which limited their deployment. According to the short screening scale of psychological distress(259), 15.5% of the sample had an elevated level of distress. Less than 9% of the sample have symptoms in keeping with a major depressive episode according to the CIDI short form(231).

Despite the perception that CF members have physically demanding jobs, only 18% of subjects reported working at a job which required moderate or heavy physical exertion. Outside of work, respondents reported doing an average of 24.3 hours per week of sedentary activity, with a range of values between 0 and 78 hours per week (Figure 4.1).

The range of values for recreational energy expenditure was from 0 to 29.1 kcal/kg/day (Figure 4.2). However, the distribution was not Gaussian and, while mean recreational energy expenditure was 2.9 kcal/kg/day, the median value was 2.1 kcal/kg/day. Table 4.3 displays the number of subjects who reported participating in each of the listed recreational activities. The most commonly reported recreational activity was 'walking for exercise' (75.7%) followed by 'gardening or yard work' (56%) and 'jogging or running' (54.9%). Less than 10% of the sample participated in each of the following activities: in-line skating, downhill skiing, tennis, and basketball. These patterns may be reflective of the time frame of the survey. It was administered in late November/early December and asked respondents to report on the previous three months activity.

Figure 4.1 Mean number of hours per week spent in sedentary activity for the final analytical sample

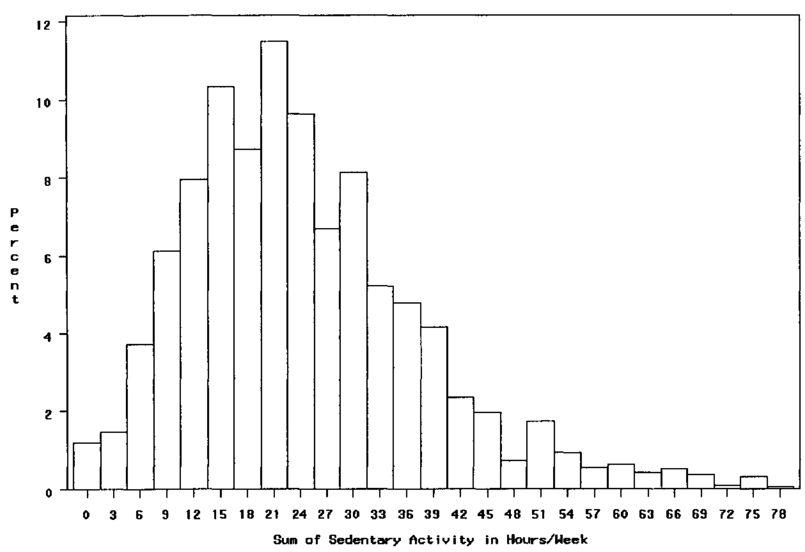


Figure 4.2 Recreational energy expenditure (kcal/kg/day) for the final analytical sample

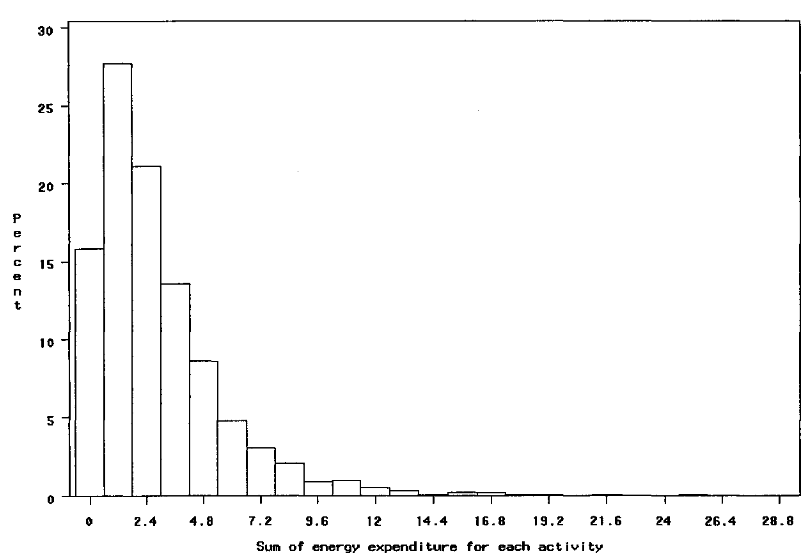


Table 4.3 Number of subjects in the final analytical sample reporting participation in activities included in the 2000 HLIS

Activity	Number of subjects reporting participation n = 4749
Walking for exercise	3596 (75.7%)
Gardening or yard work	2661 (56.0%)
Jogging or running	2605 (54.9%)
Bicycling	2048 (43.1%)
Weight-training	1794 (37.8%)
Home exercises	1569 (33.0%)
Swimming	1341 (28.2%)
Golfing	1102 (23.2%)
Popular or social dance	1015 (21.4%)
Other	867 (18.3%)
Ice hockey	763 (16.1%)
Exercise class or aerobics	717 (15.1%)
Ice skating	673 (14.2%)
Bowling	639 (13.5%)
Volleyball	624 (13.1%)
Fishing	572 (12.0%)
Baseball or softball	489 (10.3%)
In-line skating or rollerblading	444 (9.4%)
Basketball	347 (7.3%)
Downhill skiing	317 (6.7%)
Tennis	137 (2.9%)

4.1.2 Sub-group comparison

The univariate comparison of demographic and physical activity variables is presented in Table 4.4 (categorical factors) and Table 4.5 (continuous factors). These tables include all subjects in the final analytical sample and present the results within BMI level. The distribution of BMI was significantly different across levels for all factors except work activity and mental distress.

Overall, the proportion of individuals with a normal BMI decreased with age. Similarly, except for the highest age and BMI group, the proportion of individuals with an overweight or obese BMI classification increased with age.

The majority of males were classified as being overweight or obese (73%) while only 47% of the females were so classified. The distribution within the two obese BMI categories was fairly similar for males and females.

Single subjects were more likely to have a normal BMI classification than married subjects (42% versus 27%). Conversely, subjects who were married or living in a common-law relationship were more likely to be classified as overweight or obese (73%) than subjects who were either single (59%) or divorced/separated (63%). However, the marital status categories were similarly distributed amongst the highest BMI category.

Education was related to BMI levels. Subjects with higher education were less likely to be obese and were more likely to have a normal BMI. However, even for the highest level of education, over 50% of the subjects were still classified as being overweight.

Three factors reported in Table 4.4 measured aspects of the occupation of the subjects: rank, service element, and work activity. Within each rank category, the BMI distribution was fairly similar. However, there was a slightly smaller proportion of senior non-commissioned members and a larger proportion of junior officers in the normal BMI category. Overall, a smaller proportion of officers than non-commissioned members were

Table 4.4 Comparison of final analytical sample by BMI group – categorical variables.

Characteristic	n	BMI 18.5 to 24.9 n = 1435	BMI 25 to 29.9 n = 2490	BMI 30 to 34.9 n = 718	BMI 35 to 50 n = 106	Chi-square Significance test
Age						
20-29	604	281 (46.5%)*	272 (45.0%)*	44 (7.3%)*	7 (1.2%)*	127.8, 12df
30-34	724	236 (32.6%)	376 (51.9%)	101 (14.0%)	11 (1.5%)	p<0.0001
35-39	1206	355 (29.4%)	618 (51.2%)	202 (16.8%)	31 (2.3%)	
40-44	1220	316 (25.9%)	662 (54.3%)	201 (16.5%)	41 (3.4%)	
45-58	995	247 (24.8%)	562 (56.5%)	170 (17.1%)	16 (1.6%)	
Sex						
Male	4190	1141 (27.2%)	2302 (54.9%)	651 (15.5%)	96 (2.3%)	152.4, 3df
Female	559	294 (52.6%)	188 (33.6%)	67 (12.0%)	10 (1.8%)	p<0.0001
Marital Status						
Single, never married	755	313 (41.5%)	346 (45.8%)	84 (11.1%)	12 (1.6%)	81.1, 6df
Divorced/separated	407	152 (37.4%)	189 (46.4%)	51 (12.5%)	15 (3.7%)	p<0.0001
Married/common-law	3572	964 (27.0%)	1950 (54.6%)	580 (16.2%)	78 (2.2%)	
Education level						
Post-secondary completed	1395	499 (35.8%)	712 (51.0%)	159 (11.4%)	25 (1.8%)	47.9, 6df
High school completed	2980	844 (28.3%)	1585 (53.2%)	481 (16.1%)	70 (2.4%)	p<0.0001
Less than high school	372	92 (24.7%)	191 (51.3%)	78 (21.0%)	11 (3.0%)	
Rank						
Junior NCM	2124	667 (31.4%)	1062 (50.0%)	340 (16.0%)	55 (2.6%)	66.1, 9df
Senior NCM	1322	324 (24.5%)	732 (55.4%)	236 (17.9%)	30 (2.3%)	p<0.0001
Junior officer	775	292 (37.7%)	385 (49.7%)	85 (11.0%)	13 (1.7%)	
Senior officer	527	152 (28.8%)	310 (58.8%)	57 (10.8%)	8 (1.5%)	
Element						
Air	1829	573 (31.3%)	942 (51.5%)	276 (15.1%)	38 (2.1%)	19.3, 6df
Land	2042	644 (31.5%)	1066 (52.2%)	292 (14.3%)	40 (2.0%)	p<0.01
Sea	878	218 (24.8%)	482 (54.9%)	150 (17.1%)	28 (3.2%)	
Work Activity						
Sedentary	1874	538 (28.7%)	991 (52.9%)	298 (15.9%)	47 (2.5%)	10.8, 9df
Light	1978	601 (30.4%)	1038 (52.5%)	290 (14.7%)	49 (2.5%)	ns
Moderate	678	216 (31.9%)	354 (52.2%)	101 (14.9%)	7 (1.0%)	
Heavy	124	43 (34.7%)	65 (52.4%)	14 (11.3%)	2 (1.6%)	
Medical condition limiting employment						
Yes	454	105 (23.1%)	237 (52.2%)	96 (21.2%)	16 (3.5%)	24.2, 3df
No	4295	1330 (31.0%)	2253 (52.5%)	622 (14.5%)	90 (2.1%)	p<0.0001
Medical condition limiting deployment						
Yes	455	117 (25.7%)	234 (51.4%)	89 (19.6%)	15 (3.3%)	12.7, 3df
No	4287	1317 (30.7%)	2252 (52.5%)	627 (14.6%)	91 (2.1%)	p<0.01
Mental Distress						
Yes	733	228 (31.1%)	364 (49.7%)	117 (16.0%)	24 (3.3%)	5.9, 3df
No	3983	1196 (30.0%)	2107 (52.9%)	598 (15.0%)	82 (2.1%)	ns
Depression						
Yes	404	131 (32.4%)	194 (48.0%)	63 (15.6%)	16 (4.0%)	8.2, 3df
No	4313	1294 (30.0%)	2280 (52.9%)	649 (15.1%)	90 (2.1%)	p=0.04

Abbreviations: BMI = body mass index; NCM = non-commissioned member; ns = not significant.
* Row percentages sum to 100% except for rounding errors

Table 4. 5 Comparison of final analytical sample by BMI group – continuous variables.

Characteristic	BMI 18.5 to 24.9 n = 1435 mean (range)	BMI 25 to 29.9 n = 2490 mean (range)	BMI 30 to 34.9 n = 718 mean (range)	BMI 35 to 50 n = 106 mean (range)	ANOVA p-value
Age	37.0 (19, 57)	39.1 (19, 58)	39.9 (20, 57)	39.6 (22, 56)	<0.0001
Number of chronic health conditions	0.6 (0, 6)	0.7 (0, 9)	0.9 (0, 6)	1.1 (0, 5)	<0.0001
Recreational Energy Expenditure (kcal/kg/day)	3.0 (0, 29.1)	2.9 (0, 25.6)	2.4 (0, 18.7)	2.3 (1, 11.5)	<0.0001
Sedentary Activity (hours/week)	22.1 (0, 78)	24.5 (0, 77)	28.0 (0, 76)	25.8 (0, 66)	<0.0001

Abbreviations: BMI = body mass index

classified as obese class I. With regard to service element, while the BMI differences were statistically significant, the groups had a generally similar distribution of BMI. A smaller proportion of members in the sea element reported a BMI in the normal category and there were proportionately more overweight and obese members in the sea element. The BMI distribution was fairly similar for all categories of work activity.

Four summary variables were used to describe the health status of military members: two related to physical health and two related to mental health. For individuals without a medical condition which limited their work participation or deployment status, the proportion with a normal BMI was larger and the proportion of obese class I was smaller. For the two variables related to mental health, the BMI distribution was similar for individuals classified as having or not having mental distress or depression. Lastly, the mean number of chronic health conditions reported increased with higher BMI levels. While the results are statistically significant, the difference in number of chronic health conditions is small.

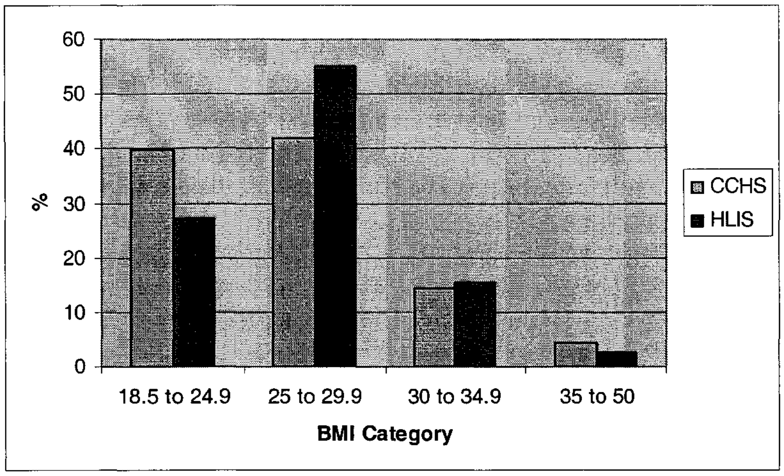
Mean recreational energy expenditure was lower for subjects in the two highest BMI categories. Subjects in the highest two BMI categories reported significantly higher mean levels of sedentary activity.

4.1.3 Comparison to Canadian Community Health Survey

Only limited information (BMI and activity levels) was available to compare the CF members to the Canadian population. This is included to provide a context for interpreting the CF results. In Figures 4.3 and 4.4 BMI of the HLIS sample was compared to results from the 2000-2001 Canadian Community Health Survey (CCHS)(77). The CCHS results were limited to subjects aged 20 – 59. The prevalence of being overweight was higher in the military male population (55% versus 42%) and the prevalence of normal BMI weight classification was lower (31% versus 48%). Prevalence of the two highest classes of obesity was similar in the two populations. There were no striking differences between the two female populations of the two surveys.

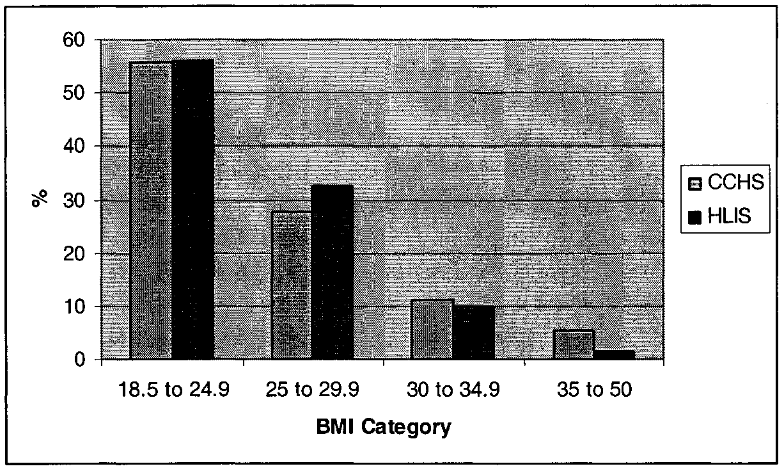
A comparison was also made between the 2000 HLIS and the 2000-2001 CCHS of recreational energy expenditure in Table 4.6. Overall, the Canadian Armed Forces members report higher levels of recreational energy expenditure. Roughly 10% of CCHS respondents report doing no recreational physical activity versus 2% of the respondents to the HLIS. These results were further explored by classifying recreational energy expenditure into three levels of activity: active (recreational energy expenditure greater or equal to 3 kcal/kg/day), moderate (recreational energy expenditure greater or equal to 1.5 kcal/kg/day but less than 3 kcal/kg/day), and inactive (recreational energy expenditure less than 1.5 kcal/kg/day). The proportion of subjects classified as 'inactive' (doing less than what is equivalent to walking 30 minutes per day) was higher in the CCHS (53%) than in the HLIS (38%). The results (not shown) were similar when the analysis was stratified by sex.

Figure 4. 3 Prevalence of BMI in the Canadian adult male population[1]



[1]Comparison made between the 2000 Canadian Forces Health and Lifestyle Information Survey and the 2000-2001 Canadian Community Health Survey (CCHS)(77). CCHS sample limited to BMI ≥ 18.5 and age 20 to 59 to reflect analysis of this study.

Figure 4. 4 Prevalence of BMI in the Canadian adult female population[1]



[1]Comparison made between the 2000 Canadian Forces Health and Lifestyle Information Survey and the 2000-2001 Canadian Community Health Survey (CCHS)(77). CCHS sample limited to BMI ≥ 18.5 and age 20 to 59 to reflect analysis of this study.

Table 4. 6 Comparison of recreational energy expenditure (kcal/kg/day) and categorized activity level between the 2000-2001 Canadian Community Health Survey (CCHS)(77) and 2000 Canadian Forces Health and Lifestyle Information Survey (HLIS).

	HLIS	CCHS
Recreational energy expenditure (kcal/kg/day)		
Mean	2.84 (± 2.71)	1.91 (± 2.05)
Minimum	0.00	0.00
5%	0.17	0.00
25%	0.99	0.50
50%	2.10	1.30
75%	3.88	2.70
95%	7.95	5.90
Maximum	29.06	26.50
Recreational energy expenditure – categorized[1]		
Active	35%	22%
Moderate	27%	25%
Inactive	38%	53%

[1]Active – recreational energy expenditure (EE) ≥ 3 kcal/kg/day
Moderate – 1.5 kcal/kg/day ≤ EE < 3 kcal/kg/day
Inactive – 0 kcal/kg/day ≤ EE < 1.5 kcal/kg/day

4.1.4 Linearity Assessment

The regression models assume that continuous variables demonstrate a linear relationship with the logit of the outcome variable(234). Prior to modelling, this assumption needs to be confirmed. If there is non-linearity, then a more complex model is required. As noted in the Methods, linearity was examined using a combination of linear trend testing based on Likelihood Ratio tests comparing a model with the predictor entered as a continuous variable compared to one where it is entered after categorization into quartiles and graphical methods (LOESS smoothing of the logit). These methods were applied to the continuous predictor variables: *recreational energy expenditure*, *age*, *number of chronic health conditions*, and *sedentary activity*. Since the outcome (BMI) has four categories, linearity was examined separately for the comparison of each of the three highest levels to the 'normal' BMI group.

Table 4.7 demonstrates that the likelihood ratio tests in each of the three models for *recreational energy expenditure* were non-significant ($p < 0.05$ level), indicating that there was no violation of the linearity assumption. This was further confirmed with LOESS smoothing on the logit scale (Figures 4.5 – 4.7). Although there was some non-linear effects noted in the LOESS smooth curve for the BMI ≥ 35 cut-point, this was likely the result of the small sample size. None of the other BMI cut-points demonstrated a violation of the assumption of linearity. Therefore, *recreational energy expenditure* was maintained as a continuous variable for analysis.

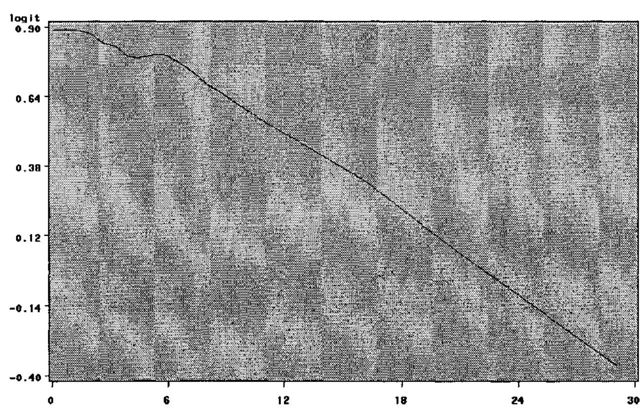
Conversely, the likelihood ratio tests comparing the three separate models treating *age* as a continuous variable and categorical variable were are all significant, indicating a departure from linearity (Table 4.8). The LOESS smoothed plots suggested a non-linear pattern with risk changing around age 37 (Figures 4.8 – 4.10). The above analyses were repeated using a cut-point of age 37 as well as separate analyses for male versus female (results not shown). Each of these methods demonstrated a departure from linearity for at least one of the BMI cut-points, therefore *age* was reclassified as a categorical variable: 19–29, 30–34, 35–39, 40–44, 45–58. These age categories were based on sample size and biological considerations.

These same methods were applied to the *number of chronic health conditions* variable and the *sedentary activity* variable. The analyses (not shown) supported retaining these factors as continuous variables.

Table 4. 7 -2LogLikelihood, likelihood ratio test statistic, and the p-value for change for the models treating recreational energy expenditure (kcal/kg/day) as a continuous variable versus categorical variable.

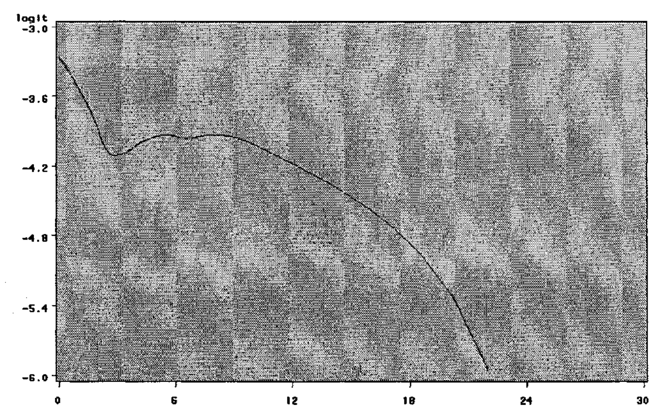
Model	Variable	-2LogL	G	p
BMI ≥ 25 vs. normal	EE - continuous	5991.767		
	EE - quartiles	5991.515	0.252(2df)	p=0.88
BMI ≥ 30 vs. normal	EE - continuous	4501.177		
	EE - quartiles	4499.294	1.883(2df)	p=0.39
BMI ≥ 35 vs. normal	EE - continuous	1055.385		
	EE - quartiles	1049.831	5.554(2df)	p=0.06

Figure 4. 5 Recreational energy expenditure and risk of BMI greater or equal to 25 (LOESS smoothing on logit scale)



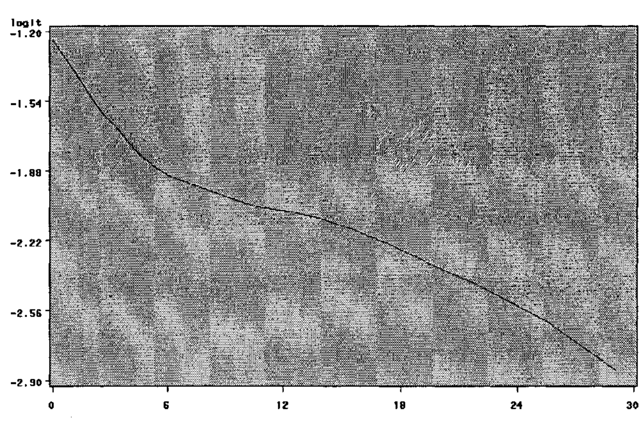
smooth = 0.8

Figure 4. 7 Recreational energy expenditure and risk of BMI greater or equal to 35 (LOESS smoothing on logit scale)



smooth = 0.8

Figure 4. 6 Recreational energy expenditure and risk of BMI greater than or equal to 30 (LOESS smoothing on logit scale)

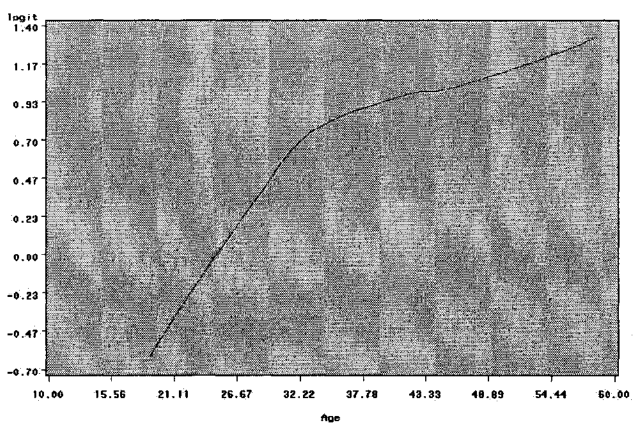


smooth = 0.8

Table 4. 8 –2LogLikelihood, likelihood ratio test statistic, and the p-value for the change for models containing age as a continuous versus categorical variable.

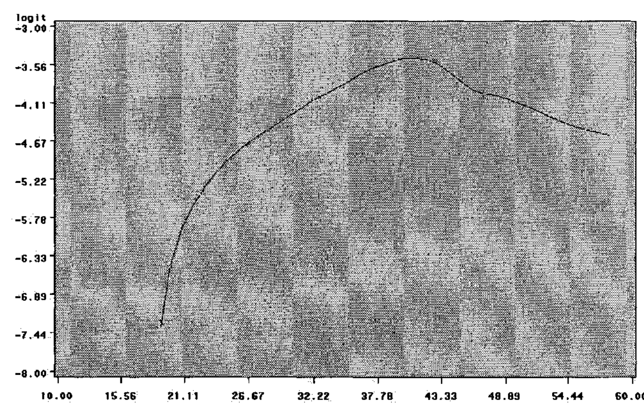
Model	Variable	-2LogL	G	p
BMI ≥ 25 vs. normal	Age - continuous	8210.409		
	Age - quartiles	8195.671	14.738(2df)	p=0.0006
BMI ≥30 vs. normal	Age - continuous	6069.637		
	Age - quartiles	6047.194	22.443(2df)	p<0.0001
BMI ≥ 35 vs. normal	Age - continuous	1395.140		
	Age - quartiles	1375.806	19.334(2df)	p=0.0001

Figure 4. 8 Age and risk of BMI greater or equal to 25 (LOESS smoothing on logit scale)



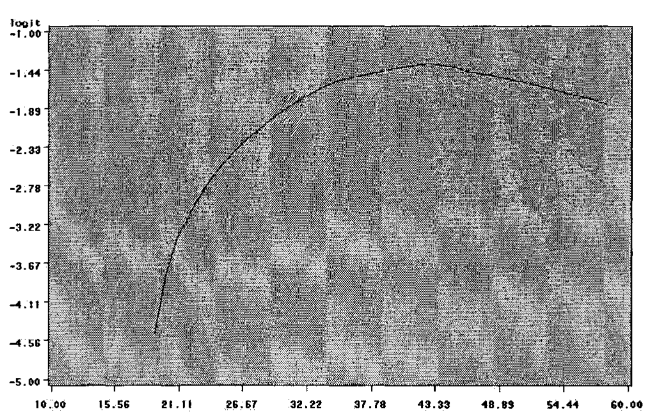
smooth =0.6

Figure 4. 10 Age and risk of BMI greater or equal to 35 (LOESS smoothing on logit scale)



smooth =0.6

Figure 4. 9 Age and risk of BMI greater or equal to 30 (LOESS smoothing on logit scale)



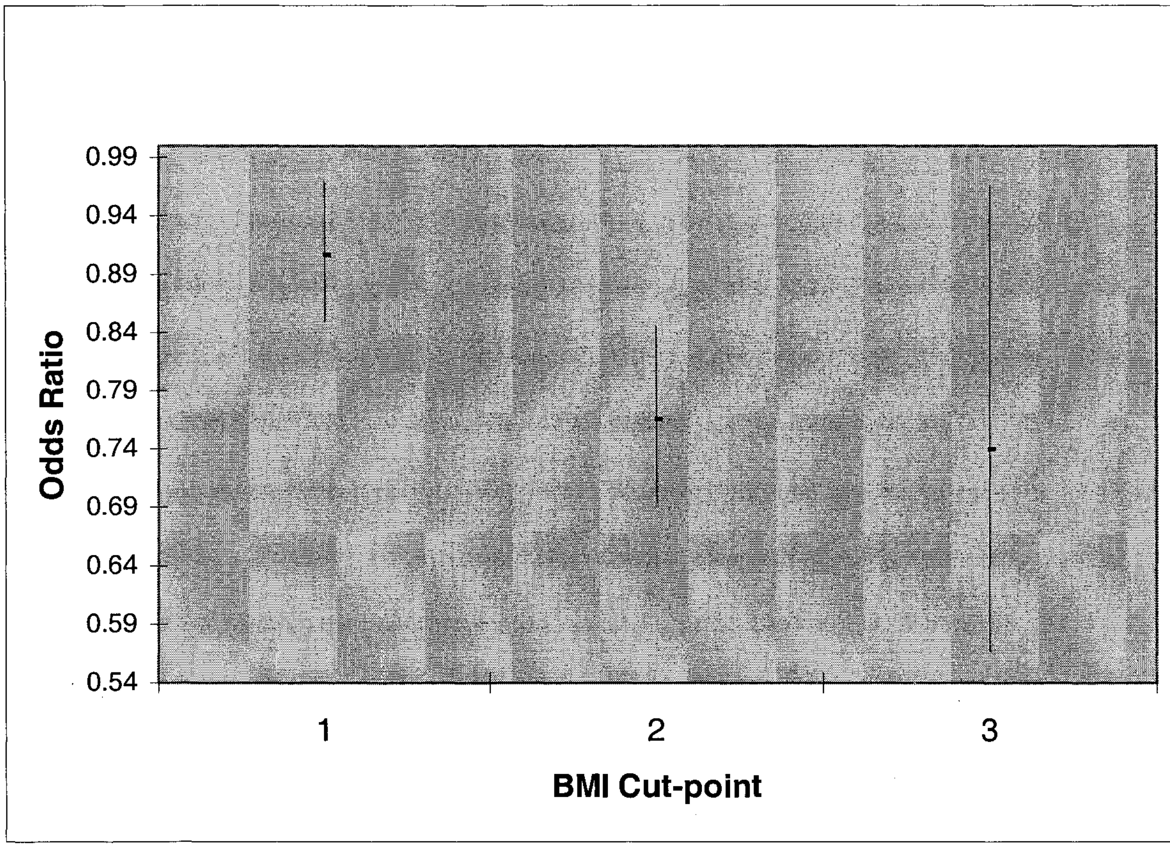
smooth =0.6

4.2 Regression Analysis

4.2.1 Alternate ordinal regression models considered

The initial regression analyses focused on determining the appropriate polytomous model to use. The validity of the proportional odds assumption was examined using formal statistical testing as well as graphical methods. Analysis of the 2000 HLIS data using the proportional odds model revealed a violation of the proportional odds assumption using the Score test ($X^2 = 10.98$, 2 df, $p = 0.004$). The Score test, a global test of non-proportionality, cannot distinguish heterogeneity associated with the 'exposure' variable from that associated with other covariates. To minimize this difficulty, the test was performed with both crude and adjusted models; the Score test remained strongly statistically significant in all models. For the graphical analysis, binary logistic odds ratios for each cut-point were estimated (1: normal BMI versus overweight and above; 2: normal/overweight BMI versus obese class I and above; and 3: normal/overweight/obese class I versus obese class II /class III). These cut-point-specific odds ratios along with their 95% confidence limits were plotted against the BMI cut points. This graph (Figure 4.11) provided a visual aid to support the Score test results refuting the validity of imposing a common odds ratio across all cut-points.

Figure 4.11 Plot of BMI cut-point specific odds ratios (for 3 units of recreational energy expenditure) to assess validity of imposing one common odds ratio.



We next considered the constrained continuation-ratio model, which compares the target group to higher outcomes. Again the Score test was used to assess the model's assumption, in this case, parallel slopes. Unlike the Score test used for the proportional odds model, which is global, this test is specific to the exposure-outcome relationship(260). The Score test was significant, meaning that the data differed from the main model assumption. Therefore, the model was not an appropriate choice for this analysis.

The **baseline logit model**(234), also called polytomous logistic model(261), is the most flexible model to analyse multinomial responses and can be used for both ordinal and nominal outcome groups. It does not utilize any information about the ordering of the response categories instead allowing each outcome to be compared to a reference group. Due to inappropriateness of the other methods considered here to analyze ordinal data, this model was adopted for the thesis. Normal BMI was used as the referent category.

4.2.2 Crude Odds Ratio for Recreational Energy Expenditure.

Prior to model building, a scatter plot of BMI (treated as a continuous variable) by recreational energy expenditure was produced (Figure 4.12). The scatter plot suggested a weak negative relationship with considerable scatter. The Pearson's correlation coefficient was -0.07. This suggests a weak but negative association with higher recreational energy expenditure being associated with lower BMI. This observation was supported by computation of crude odds ratios relating recreational energy expenditure with the four BMI categories (Table 4.9). The crude odds ratios indicated that increased recreational energy expenditure was associated with a decreased odds of having an obese class I or class II/III versus a normal BMI. And, while not statistically significant, an inverse relationship was also noted for the odds of being overweight versus having a normal weight.

Figure 4. 12 Scatter plot of BMI by recreational energy expenditure (kcal/kg/day)

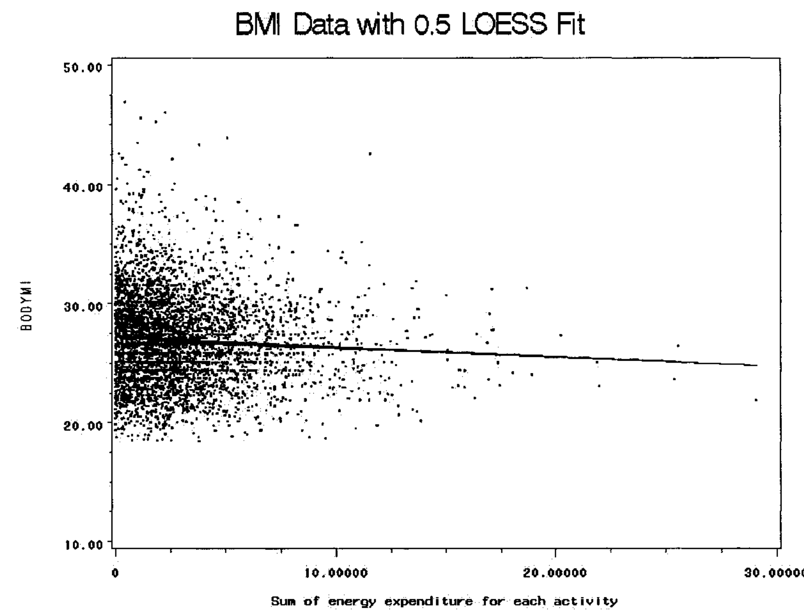


Table 4. 9 Baseline logit model estimates of crude odds ratios for a 'normal' versus a higher BMI based on recreational energy expenditure.

	Odds ratio and 95% confidence interval		
	BMI 18.5 to 24.9 versus 25 to 29.9	BMI 18.5 to 24.9 versus 30 to 34.9	BMI 18.5 to 24.9 versus 35 to 50
Recreational energy expenditure (kcal/kg/day)	0.984 (0.962, 1.007)	0.903 (0.869, 0.938)	0.892 (0.814, 0.977)

4.2.3 Identification of potential confounders by bivariate analysis

Table 4.10 provides the odds ratios for recreational energy expenditure of the three highest BMI categories using normal weight members as the referent group, adjusted for different potential confounders separately. Among the 13 covariates considered, five categorical variables were identified as potential confounders: *age*, *marital status*, *rank*, *service element*, and *sex*. The Beta value for recreational energy expenditure for at least one of the levels of BMI changed more than 10% from the crude Beta value when each of these variables were entered separately into the model.

Table 4.10 Variables found to confound the relationship between recreational energy expenditure and BMI for the baseline logit model, in bivariate analysis

Potential confounder added to the model	BMI comparison 18.5 to 24.9 versus	Unadjusted odds ratio for recreational energy expenditure	Adjusted odds ratio for recreational energy expenditure	% Change in Beta value for recreational energy expenditure
Age (categorical)	35 to 50	0.892	0.915	**22.6%**
	30 to 34.9	0.903	0.927	**25.4%**
	25 to 29.9	0.984	1.001	**108.8%**
Sex (categorical)	35 to 50	0.892	0.894	1.7%
	30 to 34.9	0.903	0.905	2.0%
	25 to 29.9	0.984	0.986	**16.0%**
Marital status (categorical)	35 to 50	0.895	0.902	6.8%
	30 to 34.9	0.905	0.912	7.4%
	25 to 29.9	0.984	0.991	**40.7%**
Education level (categorical)	35 to 50	0.892	0.893	1.5%
	30 to 34.9	0.903	0.905	1.9%
	25 to 29.9	0.984	0.984	1.9%
Rank (categorical)	35 to 50	0.892	0.893	0.9%
	30 to 34.9	0.903	0.906	3.3%
	25 to 29.9	0.984	0.989	**28.8%**
Service element (categorical)	35 to 50	0.892	0.901	8.5%
	30 to 34.9	0.903	0.907	3.9%
	25 to 29.9	0.984	0.987	**18.5%**
Work activity (categorical)	35 to 50	0.878	0.888	8.7%
	30 to 34.9	0.904	0.907	3.1%
	25 to 29.9	0.982	0.984	9.4%
Medical condition limiting employment (categorical)	35 to 50	0.892	0.898	5.9%
	30 to 34.9	0.903	0.907	4.8%
	25 to 29.9	0.984	0.985	9.3%
Medical condition limiting deployment (categorical)	35 to 50	0.892	0.898	6.0%
	30 to 34.9	0.902	0.906	4.4%
	25 to 29.9	0.984	0.986	7.0%
Mental distress (categorical)	35 to 50	0.890	0.894	3.5%
	30 to 34.9	0.902	0.903	0.1%
	25 to 29.9	0.983	0.983	2.9%
Depression (categorical)	35 to 50	0.892	0.892	0.2%
	30 to 34.9	0.906	0.906	0%
	25 to 29.9	0.984	0.985	0.6%
Number of chronic health conditions (continuous)	35 to 50	0.892	0.898	5.6%
	30 to 34.9	0.903	0.906	3.6%
	25 to 29.9	0.984	0.985	8.0%
Sedentary activity (continuous)	35 to 50	0.892	0.892	0.4%
	30 to 34.9	0.903	0.904	1.5%
	25 to 29.9	0.984	0.984	2.5%

Table 4.10 shows meaningful confounding of the *recreational energy expenditure* effect by *age*. The adjusted estimates show a reduced association of *recreational energy expenditure* at all levels of BMI. There is only marginal confounding by the other variables (*marital status*, *rank*, *service element*, and *sex*) with the adjusted estimates showing a reduced association for *recreational energy expenditure* when compared to the crude estimates in the overweight BMI category, however, the absolute change in the odds ratios is quite small.

In order to assess effect modification, all biologically meaningful pair wise interaction terms were entered into the model. The Likelihood ratio test revealed that none of the interaction terms (*recreational energy expenditure* with *age, sex, condition limiting employment, condition limiting deployment, mental distress, depression*, and *number of chronic health conditions*) were significant at the p=0.05 level (results not shown). Therefore, no interaction terms were retained in the final model. Rather, the final model was a main effects model.

4.2.3 Preliminary univariate analysis

Table 4.11 presents the results of univariate analyses linking each covariate to the BMI categories, using 'normal weight' as the reference category. *Age, sex, education, service element, condition limiting employment, condition limiting deployment, sedentary activity* and *number of chronic health conditions* were significant for all levels of BMI comparison and, in the case of categorical variables, all levels of the variable (p-value ≤ 0.10). The variables *rank, mental distress* and *depression* also showed overall significance at the p=0.10 level but, some of the individual levels were not significant (e.g. senior officers for the comparison of 'obese class II/III' to 'normal weight'). *Work activity* was the only variable not significant at any level of comparison in univariate analysis.

Table 4.11 Baseline logit model univariate analysis of potential covariates.

Variable [p-value for overall likelihood ratio test statistic]	BMI 25 to 29.9 versus BMI 18.5 to 24.9		BMI 30 to 34.9 versus BMI 18.5 to 24.9		BMI 35 to 50 versus BMI 18.5 to 24.9	
	Odds ratio	p-value	Odds ratio	p-value	Odds ratio	p-value
Age [<0.0001]						
20-29 (ref)						
30-34	1.73	<0.0001	3.06	<0.0001	1.98	<0.0001
35-39	1.95	<0.0001	3.86	<0.0001	4.28	<0.0001
40-44	2.20	<0.0001	4.45	<0.0001	6.29	<0.0001
45-58	2.40	<0.0001	4.43	<0.0001	2.74	0.01
Sex [<0.0001]						
Female (ref)						
Male	3.46	<0.0001	3.18	<0.0001	3.01	0.0002
Marital Status [<0.0001]						
Single, never married (ref)						
Divorced/separated	1.22	0.07	1.30	0.12	2.42	0.01
Married/common-law	1.94	<0.0001	2.62	<0.0001	2.81	0.0002
Education level [<0.0001]						
Post-secondary completed (ref)						
High school completed	1.29	<0.0001	1.78	<0.0001	1.66	0.01
Less than high school	1.40	0.003	2.42	<0.0001	2.11	0.02
Rank [<0.0001]						
Junior NCM (ref)						
Senior NCM	1.45	<0.0001	1.46	<0.0001	1.13	0.55
Junior officer	0.83	0.02	0.55	<0.0001	0.45	0.01
Senior officer	1.26	0.02	0.68	0.01	0.54	0.08
Element [<0.001]						
Sea						
Air	0.72	<0.0001	0.67	0.0003	0.63	0.04
Land	0.75	0.0004	0.66	0.0001	0.57	0.01
Work Activity [0.33]						
Sedentary (ref)						
Light	0.93	0.23	0.82	0.20	0.93	0.71
Moderate	0.90	0.22	0.90	0.38	0.57	0.51
Heavy	0.82	0.24	0.84	0.44	0.94	0.91
Medical condition limiting employment [<0.0001]						
No (ref)						
Yes	1.35	0.003	2.08	<0.0001	2.82	<0.0001
Medical condition limiting deployment [<0.0001]						
No (ref)						
Yes	1.21	0.06	1.79	<0.0001	2.90	<0.0001
Mental Distress [0.001]						
Yes (ref)						
No	1.20	0.09	1.03	0.90	0.61	0.04
Depression [0.02]						
Yes (ref)						
No	1.18	0.02	1.02	0.80	0.60	0.01
Sedentary activity [<0.0001]	1.02	<0.0001	1.03	<0.0001	1.03	<0.0001
Number of chronic conditions [<0.0001]	1.10	0.0008	1.26	<0.0001	1.59	<0.0001

Abbreviations: BMI = body mass index; NCM = non-commissioned member.

4.2.4 Preliminary multivariate model

Twelve covariates were entered into the preliminary multivariate model along with *recreational energy expenditure. Age*, *sex*, *marital status*, *rank*, and *service element* were significant variables (p=0.10) in univariate analysis and found to be potential confounders of recreational energy expenditure in bivariate analysis. *Education*, *medical condition limiting employment*, *medical condition limiting deployment*, *mental distress*, *depression*, *number of chronic conditions*, and *sedentary activity* were all significant ($p \leq 0.10$) in univariate analysis but did not show evidence of confounding. *Work activity* was the only covariate not to be entered into the preliminary multivariate model since it was neither found to be a confounder in bivariate analysis nor was it a significant variable ($p > 0.10$) in univariate analysis. Table 4.12 presents the results of the preliminary multivariate model.

Based on the criteria outlined in section 3.7.2, six variables were dropped from the model: marital status, education, rank, condition limiting deployment, mental distress, and depression. In each case, removal of the variable from the model did not change the recreational energy expenditure Beta by more than 10% and the likelihood ratio test statistic comparing the models was not significant (Table 4.13). The main effects model thus contained seven variables: recreational energy expenditure, number of chronic conditions, sedentary activity, condition limiting employment, service element, sex and age.

Table 4.12 Baseline logit model full model multivariate analysis.

Variable [p-value for overall likelihood ratio test statistic]	BMI 25 to 29.9 versus BMI 18.5 to 24.9		BMI 30 to 34.9 versus BMI 18.5 to 24.9		BMI 35 to 50 versus BMI 18.5 to 24.9	
	Odds ratio	p-value	Odds ratio	p-value	Odds ratio	p-value
Age [<0.0001]						
20-29 (ref)						
30-34	1.43	0.007	2.15	0.0005	1.42	0.50
35-39	1.57	0.0005	3.02	<0.0001	2.82	0.03
40-44	1.80	<0.0001	3.23	<0.0001	4.20	0.003
45-58	1.80	0.0002	3.43	<0.0001	2.28	0.13
Sex [<0.0001]						
Female (ref)						
Male	2.85	<0.0001	2.34	<0.0001	2.72	0.005
Marital Status [0.34]						
Single, never married (ref)						
Divorced/separated	0.81	0.26	0.70	0.21	1.45	0.40
Married/common-law	1.27	0.03	1.29	0.11	1.28	0.49
Education level [0.26]						
Post-secondary completed (ref)						
High school completed	1.26	0.20	1.34	0.40	1.21	0.54
Less than high school	1.20	0.28	1.47	0.07	1.31	0.55
Rank [0.14]						
Junior NCM (ref)						
Senior NCM	1.06	0.59	0.94	0.50	0.67	0.14
Junior officer	1.06	0.63	0.82	0.25	0.74	0.42
Senior officer	1.09	0.58	0.58	0.12	0.51	0.16
Element [0.005]						
Sea (ref)						
Air	0.72	0.002	0.66	0.003	0.42	0.002
Land	0.76	0.008	0.72	0.02	0.49	0.008
Medical condition limiting employment [0.03]						
No (ref)						
Yes	1.49	0.04	2.02	0.005	1.91	0.17
Medical condition limiting deployment [0.80]						
No (ref)						
Yes	0.88	0.52	0.78	0.33	0.84	0.71
Mental Distress [0.88]						
Yes (ref)						
No	1.04	0.74	1.03	0.87	0.83	0.51
Depression [0.76]						
Yes (ref)						
No	1.08	0.59	1.12	0.55	0.79	0.51
Sedentary activity [<0.0001]	1.01	0.0001	1.03	<0.0001	1.01	0.07
Number of chronic conditions [<0.0001]	1.12	0.003	1.22	<0.001	1.40	0.0001
Recreational energy expenditure [0.002]	1.01	0.49	0.94	0.003	0.94	0.16

Abbreviations: BMI = body mass index; NCM = non-commissioned member.

Table 4.13 Variables excluded from final baseline logit model based on results of multivariate analysis.

Potential confounder removed from the model	BMI comparison 18.5 to 24.9 versus	New adjusted odds ratio for recreational energy expenditure	% Change in Beta value for recreational energy expenditure	Likelihood ratio test statistic
Marital status (categorical)	35 to 50	0.937	0.7%	2.9, 6df, ns
	30 to 34.9	0.940	1.1%	
	25 to 29.9	1.008	8.4%	
Education level (categorical)	35 to 50	0.936	1.4%	7.7, 6df, ns
	30 to 34.9	0.940	1.6%	
	25 to 29.9	1.008	5.4%	
Rank (categorical)	35 to 50	0.936	1.4%	13.8, 9df, ns
	30 to 34.9	0.941	0%	
	25 to 29.9	1.009	0.3%	
Medical condition limiting deployment (categorical)	35 to 50	0.938	1.1%	1, 3df, ns
	30 to 34.9	0.942	2.1%	
	25 to 29.9	1.009	4.2%	
Mental distress (categorical)	35 to 50	0.936	2.3%	0.7, 3df, ns
	30 to 34.9	0.941	0.3%	
	25 to 29.9	1.009	2.6%	
Depression (categorical)	35 to 50	0.938	1.7%	1.2, 3df, ns
	30 to 34.9	0.941	0.5%	
	25 to 29.9	1.009	2.4%	

Abbreviations: df = degrees of freedom; ns = not significant.

4.3 Final Model

The results of fitting the baseline logit model to the four level outcome variable, BMI, are shown in Table 4.14. Recreational energy expenditure was significantly associated with the odds of being classified in obese class I BMI compared to normal weight classification (OR 0.94, 95% CI 0.90-0.97), but was not significantly associated with the odds of having a normal BMI versus either an overweight or obese class II/III BMI (OR 1.01, 95% CI 0.98-1.03; OR 0.93, 95% CI 0.85-1.02). However, the odds ratio for the obese class II/III was similar to the odds ratio for obese class I. It is likely that the small sample size for the former group contributed to the lack of statistical significance.

Increased age was significantly associated with the odds of having a higher than normal BMI for all categories, with the exception of age 30-34 and 45-58. For both of these age categories, the results were not statistically significant for the comparison of normal versus obese class II/III although this likely reflects the small sample size in these groups (n=11 and n=16).

CF males were two to three times more likely than CF females to be in either the overweight, obese class I, or obese class II/III categories compared to the normal BMI category (OR 3.07, 95% CI 2.50-3.76; OR 2.44, 95% CI 1.81-3.29; OR 2.75, 95% CI 1.38-5.48 respectively).

Table 4.14 Results of fitting the baseline logit model for BMI18.5 to 24.9 versus a higher BMI category

Variable [p-value for overall likelihood ratio test statistic]	Odds ratio and 95% confidence limits		
	BMI 25 to 29.9	BMI 30 to 34.9	BMI 35 to 50
EE (kcal/kg/day) [0.0006]	1.01 (0.98, 1.03)	0.94 (0.90, 0.97)	0.93 (0.85, 1.02)
Age [<0.0001]			
19-29 (ref)			
30-34	1.56 (1.23, 1.98)	2.37 (1.59, 3.54)	1.59 (0.60, 4.18)
35-39	1.74 (1.40, 2.17)	3.16 (2.18, 4.57)	3.17 (1.36, 7.36)
40-44	2.01 (1.60, 2.52)	3.23 (2.22, 4.71)	3.98 (1.72, 9.18)
45-58	2.06 (1.62, 2.61)	3.18 (2.15, 4.69)	1.75 (0.69, 4.44)
Sex [<0.0001]			
Female (ref)			
Male	3.07 (2.50, 3.76)	2.44 (1.81, 3.29)	2.75 (1.38, 5.48)
Element [0.01]			
Sea (ref)			
Air	0.73 (0.60, 0.89)	0.67 (0.51, 0.87)	0.47 (0.28, 0.80)
Land	0.78 (0.64, 0.95)	0.74 (0.57, 0.96)	0.52 (0.31, 0.88)
Condition Limiting Employment [0.005]			
No (ref)			
Yes	1.33 (1.03, 1.71)	1.71 (1.25, 2.34)	1.82 (1.00, 3.31)
Number of chronic conditions [<0.0001]	1.12 (1.04, 1.21)	1.23 (1.12, 1.35)	1.44 (1.21, 1.71)
Sedentary Activity (hours/week) [<0.0001]	1.01 (1.01, 1.02)	1.03 (1.02, 1.04)	1.02 (1.00, 1.03)
OR for 24 hours/week	1.30 (1.14, 1.47)	1.99 (1.69, 2.35)	1.53 (1.07, 2.18)

Members of the Air element were roughly half as likely as members of the Sea element to be in obese class II/III versus normal BMI (OR 0.47, 95% CI 0.28-0.80); roughly two thirds as likely to be in obese class I versus normal BMI (OR 0.67; 95% CI 0.51-0.87); and roughly three quarters as likely to be overweight versus normal BMI (OR 0.73, 95% CI 0.60-0.89). The findings were similar for the comparison of members of the Land element to members of the Sea element (obese class II/III - OR 0.52, 95% CI 0.31-0.88; obese class I – OR 0.74, 95% CI 0.57-0.96; overweight – OR 0.78, 95% CI 0.64-0.95).

Having a condition that limited a member's employment was significantly associated with increased odds of having a higher than normal BMI. The odds ratio for being overweight versus normal BMI was 1.33 (95% CI 1.03-1.71) for members who had a limiting condition; the odds ratio was higher for each successive BMI comparison (obese class I versus normal BMI, obese class II/III versus normal BMI). A similar result was found for the other physical health variable - number of chronic health conditions. The odds ratio for being overweight versus normal BMI was 1.12 (95% CI 1.04–1.71) and the odds ratio for each successive BMI comparison was higher.

Lastly, increased sedentary activity was significantly associated with increased odds of having a higher than normal BMI. When sedentary activity was scaled to roughly represent the mean number of hours of sedentary activity per week reported by study subjects (24 hours/week), the odds ratios were as follows: the OR for being overweight was 1.24 (95% CI 1.10, 1.38); the OR for being obese class I was 1.76 (95% CI 1.53, 2.02); and the OR for being obese class II/III was 1.39 (95% CI 1.04, 1.88).

4.4 Variables related to health promotion

The following section provides descriptive results for some variables which pertain to the final section of the thesis – development of an intervention to deal with overweight and obesity in the Canadian Armed Forces.

With regard to self-perceived health status, there was a tendency for members with higher BMI to rate their health lower (Table 4.15). 73% of the members with a BMI in the normal range rated their health as 'very good' or 'excellent' versus 33% of members in the obese class II/III category. Similarly, only 5% of members with a BMI in the normal range rated their health as 'poor' compared to 25% of members in the obese class II/III category. For members with a BMI in the overweight category, the corresponding figures were 63% (very good, excellent) and 6% (poor) and for obese class I the figures were 44% (very good, excellent) and 13% (poor).

Table 4.15 BMI related to self-perceived health status for the 2000 Canadian Forces Health and Lifestyle Information Survey

BMI	Excellent	Very Good	Good	Fair/Poor
18.5 to 24.9	397 (27.7%)	644 (45.0%)	323 (22.6%)	68 (4.8%)
25 to 29.9	449 (18.1%)	1112 (44.8%)	774 (31.2%)	145 (5.9%)
30 to 34.9	53 (7.4%)	265 (36.9%)	305 (42.5%)	95 (13.2%)
35 to 50	8 (7.6%)	27 (25.5%)	45 (42.5%)	26 (24.5%)

Table 4.16 demonstrates that CF members recognized the personal health benefits from getting more exercise (74%), improving their diet (62%), and losing weight (51%). CF members who indicated that a specific action would help improve their physical health were also asked to indicate if they intended to take action. In every case, over 80% of respondents said they did intend to make this type of change in the next year. Intention to

change behaviour was somewhat more common among those who identified losing weight as a potential health benefit (88%) or to engage in higher levels of exercise (86%) than in people indicating a potential benefit from dietary change (80%).

Table 4.16 Perceived benefits of health promotion actions targeted at overweight and obesity for the 2000 Canadian Forces Health and Lifestyle Information Survey

Physical Health Promotion Action	Say it would improve own health	Say they intend to make change[1]
Lose weight	2392 (51.0%)	2108 (88.1%)
Exercise more or start to exercise	3440 (73.5%)	2940 (85.7%)
Improve diet	2925 (62.3%)	2331 (79.7%)

[1] Among those who express awareness of the action as potentially beneficial to them

Awareness of the potential benefits of health promotion actions varied somewhat across the survey population within categories of BMI. Table 4.17 demonstrates that obese respondents were more likely to recognize that they might benefit from losing weight (class I 88%; class II/III 88%) than were members in the 'normal' and 'overweight' groups (57% and 17% respectively). A similar, but less strong, pattern was observed for recognition of the benefits of exercising more and improving their diet. Recognition of the potential benefit from increasing recreational physical activity was high in all groups, although the two highest obesity groups had the highest levels (around 84%). While 72% of the overweight respondents recognized the need for more exercise and 62% recognized the need for improved diet, only 57% of them felt there was a need to lose weight. This may be reflective of members in this group having a higher muscle mass versus a high fat mass. The intention to act on the health promotion actions was consistently over 80% in all groups with the exception of normal weight members' intentions to improve their diet (76%).

Table 4.17 Perceived benefits of health promotion actions for the 2000 Canadian Forces Health and Lifestyle Information Survey stratified by BMI Category

	Lose weight		Exercise more		Improve diet	
	Yes[1]	Intent to change[2]	Yes[1]	Intent to change[2]	Yes[1]	Intent to change[2]
BMI 18.5 to 24.9	248 (17.3%)	212 (85.5%)	918 (64.0%)	751 (81.8%)	732 (51.0%)	556 (76.0%)
BMI 25 to 29.9	1423 (57.2%)	1244 (87.4%)	1835 (73.7%)	1577 (85.9%)	1562 (62.7%)	1249 (80.0%)
BMI 30 to 34.9	628 (87.5%)	568 (90.4%)	597 (83.2%)	531 (88.9%)	544 (75.8%)	455 (83.6%)
BMI 35 to 50	93 (87.7%)	84 (90.3%)	90 (84.9%)	81 (90.0%)	87 (82.1%)	71 (81.6%)

[1] Those who express awareness of the action as potentially beneficial to them
[2] Of those who feel that the health promotion action would improve their health, those intending to change within the next year

Barriers to the implementation of health promotion intentions are important factors associated with the low adherence to behaviour change. Survey respondents were presented with a list of possible reasons or barriers which might stop them from making changes to improve their own health. Respondents were asked to identify as many reasons as applied to their situation. Although these barriers were not linked specifically to health promotion actions targeted at overweight and obesity, they do provide a general indication of the barriers to the implementation of health promotion actions. Table 4.18 shows that there were a wide range of barriers reported. The most commonly identified barriers included not having enough time to take action (33%), having too many other demands (31%), or considering the problem or risk not serious enough to make change a priority (30%). It is interesting to note that very few respondents listed lack of knowledge of how to proceed or where to go to get help as a barrier to taking action.

Table 4.18 Obstacles to health promotion actions for the 2000 Canadian Forces Health and Lifestyle Information Survey

Reason for not making changes	n
Not enough time	1567 (33.0%)
Too many other demands	1454 (30.6%)
The problem isn't serious enough; there's no rush	1441 (30.3%)
Not motivated	1200 (25.3%)
Not enough money	862 (18.2%)
No support from employer	692 (14.6%)
Not enough energy	578 (12.2%)
Other reasons	480 (10.1%)
Too much stress	466 (9.8%)
I don't know how to get started	338 (7.1%)
Not sure that I can do it	301 (6.3%)
I don't know	176 (3.7%)
I don't know where to go for help	148 (3.1%)
No support from family or friends	132 (2.8%)
It's too hard	115 (2.4%)

The majority of CF members have few external barriers to performing exercise at work. More than 80% of CF members have access to an exercise program, class, and/or facility while they are at work. Nearly nine in 10 (87%) have access to shower and locker facilities at work. And, roughly three-quarters (73%) of members are given time to exercise during work hours. The positive effect of these resources on physical activity is shown by examining the mean recreational energy expenditure in people with and without such access. In all cases, those with access reported significantly higher recreational energy expenditure.

Table 4.19 Potential external barriers to exercise

		Proportion	Mean EE (95% confidence interval)
Access to an exercise program/class/facility at work	Yes	3909 (83.0%)	2.9 (2.9, 3.0)
	No	801 (17.0%)	2.5 (2.3, 2.7)
Access to shower and locker facilities at work	Yes	4102 (87.1%)	2.9 (2.8, 3.0)
	No	609 (12.9%)	2.5 (2.3, 2.7)
Given time to exercise during normal working hours	Yes	3440 (73.4%)	3.0 (3.0, 3.1)
	No	1248 (26.6%)	2.4 (2.3, 2.6)

Abbreviations: EE = recreational energy expenditure (kcal/kg/day).

Chapter 5 Discussion

5.1 Summary of Key Findings

This cross sectional study of Canadian Armed Forces personnel found that recreational energy expenditure was inversely associated with body mass index. However, after adjusting for age, sex, service element, conditions limiting employment, number of chronic health conditions and sedentary activity, recreational energy expenditure was significantly and inversely associated with only the prevalence of class I obesity. There was evidence to suggest an inverse relationship between recreational energy expenditure and class II/III obesity although the findings were not statistically significant (likely due to small sample size). In contrast, there was no association between recreational energy expenditure and the prevalence of being overweight.

5.2 Descriptive Results

A striking finding of the study was the very high prevalence of overweight and obesity among CF members. The data show that the majority of those surveyed were either overweight (52%) or obese (17%) when classified by Health Canada guidelines. This high prevalence mirrors, to a certain extent, the Canadian population. While differences in methodology limit the comparability of findings from the Canadian Community Health Survey and the Health and Lifestyle Information Survey (the CCHS was a telephone/face-to-face interview survey, while the HLIS was a mail-out, mail-back survey), Figures 4.3 and 4.4 show that the prevalence of being overweight or obese in CF women was similar to that found in the 2000-2001 CCHS(77) while the prevalence of being overweight was strikingly higher among CF men.

One possible explanation for the difference in the prevalence of overweight BMI concerns the classification of members with a high muscle mass as a result of the high levels of physical activity required for job performance. Based on the BMI criteria, they would be classified as 'overweight' although their 'excess' weight was not related to fat. BMI is not a direct measure of percent body fat. Some individuals are overweight but not 'overfat' (e.g., body builders) while others can have a BMI within normal range and yet have a high percentage of their body weight as fat. Although misclassification of people using BMI standards is uncommon in the general population(262), there is a possibility of higher levels of misclassification in physically active groups such as members of the Canadian Forces.

Overall, CF members report higher levels of recreational energy expenditure than those reported by Canadians in the 2000-2001 CCHS (Table 4.5). The higher levels of recreational energy expenditure reported by CF members may in part be due to the widespread access to exercise facilities at work and provision of work time to exercise (Table 4.19). However, despite the limited external barriers to exercise, 38% of survey respondents reported a recreational expenditure of under 1.5 kcal/kg/day. This amount is roughly equivalent to 30 minutes of walking or 13 minutes of stationary bicycling or 11 minutes of stair climbing per day.

5.3 Interpretation of the findings

The prevalence of overweight and obesity showed a positive association with older *age*, male *sex*, a *condition limiting employment*, *number of chronic health conditions*, *sedentary activity* and with being a member of the sea element versus being a member of the air or land element. No clear association was observed with *work activity*, *rank*, *education, and marital status, condition limiting deployment, mental distress, depression.* While the crude model showed a negative association between recreational energy expenditure and the prevalence of overweight and obesity, once the model adjusted for significant confounders, there was evidence to support recreational energy expenditure being inversely associated only with the prevalence of obesity (class I and classII/III) but not with the prevalence of being overweight.

It is important to note that these results are based on cross-sectional data and therefore lack the temporal order that is required for implying causation. Indeed, it could be argued that BMI is a determinant of recreational energy expenditure rather than an outcome of it. This discussion attempts to describe the contribution of the variables controlled for in the analysis without inferring a causal relationship. Further discussion about the limitations of this study will follow later.

These results agree with those of several studies on the link between BMI and age(102, 263-277). The results suggest that increased age is associated with increased BMI. These results are consistent for the comparison of overweight and class I obesity to normal weight. The lack of statistical significance noted for the comparison of class II/III obesity to normal weight is likely the result of the sample size in the highest obesity group.

Service element was related to all levels of BMI. Members of the air and land elements had a lower prevalence of overweight/obesity than members of the sea element. A possible explanation for these results is that the finding is due to an extraneous yet unmeasured variable, such as diet.

This study demonstrated a strong positive association between being male and having an increased BMI when compared to females. This finding is reflected in the Canadian population(77). There is some debate regarding the appropriateness of applying the same BMI standards to both males and females. While the World Health Organization(1) and Health Canada(16) do not believe there should be different BMI thresholds for men and women, there is evidence to suggest that for the same BMI, body fat percentages are higher for women than men(278-280). Additionally, there is evidence to suggest that the upper limit of BMI associated with reduced mortality rates is higher for men than women(281).

The *number of chronic health conditions* was associated with the prevalence of obesity and being overweight. One of the more difficult relationships to explain was the observation that having a *condition limiting employment* was positively associated with increased BMI yet a related variable (*condition limiting deployment*) failed to demonstrate a clear association. It is possible that conditions which affect a person's ability to be deployed are less debilitating than those which affect a person's employability and consequently have less impact on a person's body weight.

Recently, there has been more emphasis placed on the role of lifestyle habits, such as television viewing and the use of computers, as a factor contributing to the development of overweight and obesity(282-285). This study supports the results of previous studies in finding a positive association between time spent in sedentary activity and increased BMI. The association was statistically significant across all levels of the outcome variable (Table 4.14).

Recreational energy expenditure was significantly associated with the prevalence of class I obesity. For the comparison to normal BMI, a one unit increase in recreational energy expenditure was associated with a 6% decrease in the prevalence of class I obesity. One unit of recreational energy expenditure is roughly equivalent to walking 20 minutes per day or jogging/running for 6 minutes per day. An increase of 3 kcal/kg/day (equivalent to walking for one hour per day or jogging/running for 19 minutes per day) is associated with an odds ratio of 0.82 (95% CI 0.73, 0.92). Thus, a meaningful reduction in the risk of class I obesity is associated with higher levels of recreational activity.

This study failed to find that recreational energy expenditure was an independent risk factor for being overweight or Class II/III obesity. Once the model adjusted for the other variables, recreational energy expenditure failed to have a statistically significant association for both the comparison of class II/III obesity to the normal weight class and the comparison of being overweight to the normal weight class. In fact, the latter association, while not statistically significant, was a positive association. That is, each unit increase in recreational energy expenditure was associated with a 1% increase in the prevalence of being overweight. Similarily, a one unit increase in recreational energy expenditure was associated with a 7% decrease in the prevalence of class II/III obesity although this was not statistically significant.

There are several possible explanations for the failure to find a statistically significant association between recreational energy expenditure and all levels of BMI. First, the study may have failed to control for a confounding variable which varied across levels of BMI, the most obvious being diet. Second, BMI may be a determinant of recreational energy expenditure. Respondents who are overweight may have increased their level of recreational energy expenditure in an effort to lose weight. Thirdly, the possibility exists that active military members may be classified as overweight due to high muscle mass, that was gained as a result of recreational activity. With respect to the highest obesity category, the failure to find a statistically significant association is likely the result of the small sample size.

Many variables that have previously been reported as important determinants of BMI were not significant in this analysis. Educational level has been found to be a significant determinant of increased body mass in several studies(286-293) as has marital status(294-296). Other studies have found socioeconomic status to be an important determinant(297, 298). In this study, rank (a measure of socioeconomic status), marital status, and educational level failed to be significant predictors in the multivariate analysis. There is likely less variability in the socioeconomic status of members of the Canadian Forces than in the general population. This may have contributed to the failure to support the results of previous research showing a relationship between social variables and body mass.

Work activity has previously been found to be a significant predictor of body mass(299, 300). This study failed to find work activity significantly related to body mass index in the military. Work activity was assessed by response to a four category question, which may have been insufficiently sensitive to measure the impact of this variable on BMI status.

5.4 Methodological Issues

Strengths

Body mass index is a widely accepted standard for assessing weight related health risk. The BMI scale adopted by Health Canada that was used for this thesis defines four levels of overweight and obesity. And, although the two highest levels of obesity were combined due to small sample size, the remainder of the categories along with the normal weight category were maintained for this analysis.

Baseline logit modeling was used for the logistic regression analysis. Commonly, ordinal response scales are collapsed into a dichotomous outcome for estimation of effect (odds ratio or risk ratio). This approach causes loss of information and potential loss of power in detecting the effect of explanatory variables(301). The use of baseline logit modeling in this analysis allowed for the calculation of odds ratios without an arbitrary decision about how to dichotomize BMI. An alternative approach could have been to dichotomize the outcome variable at several cut-points (i.e. normal weight versus overweight and above; normal and overweight versus obese class I, II, and III; and normal, overweight and obese class I versus obese class II and III) and use separate binary logistic regression models for each dichotomized response. While this method eliminates the arbitrary nature of a single dichotomization, it can lead to final models with different sets of covariates for each BMI comparison. This approach does not allow the broader interpretation of the simultaneous effect of a covariate across multiple dichotomizations of the outcome.

The study is based on a large representative sample of members of the Canadian Armed Forces and allowed for control of many potential predictor variables. While the cross-sectional nature of this study limits interpretation of results, use of a study population with high levels of recreational energy expenditure contributes to the body of knowledge on the relationship between activity level and body mass index. Previous longitudinal population studies which have examined this relationship and failed to find a strong association have pointed to the low levels of participation in leisure-time physical activity as a possible contributing factor. 62% of the subjects in our study were categorized as at least moderately active while only 2% reported doing no recreational physical activity.

The calculation of recreational energy expenditure took into account the frequency, duration, and intensity of a number of activities over a relatively long time-frame thereby generating a more complete estimate of energy expenditure than questionnaires which use single-item questions or fail to estimate to total amount of energy expended.

Limitations

The main limitations of this study were the cross-sectional study design, reliance on self-reported variables, use of BMI as a proxy for body fat, and the failure to control for some potentially important confounders.

There are substantial advantages to a longitudinal study design when exploring the effect of energy expenditure on body weight. For instance, physical activity may not only be a determinant of weight but also a consequence of weight. Being overweight may lead to an individual increasing their level of exercise in order to lose weight. Conversely, increased weight may lead to a decrease in activity level due to difficulty in participating or decreased self-esteem. Therefore, this study was able to show an association between recreational energy expenditure and BMI but could not confirm a causal association.

Additionally, weight gain is a chronic process that is based on a long term imbalance of the energy equation - excess intake of calories over calories expended. Cross-sectional studies only measure recreational expenditure and diet at one point in time which may not reflect the average levels of the previous10-15 years (the etiological relevant window).

Longitudinal studies permit an integrative estimate of physical activity and diet and body weight.

Another limitation of this study is the reliance on self-reported variables. It is known that people tend to bias self-reported height upwards while under-estimating their weight, leading to an under-estimate of the actual BMI(302-305). However, there is evidence to suggest that misestimation of weight does not differ according to BMI status(306) resulting in non-differential misclassification which would bias the study towards the null value. Estimation of recreational energy expenditure is also subject to self-reporting bias and measurement error. Our questionnaire took into account several aspects of activity but could not capture all areas of recreational activity, did not contain measures of activity intensity and obtained only coarse estimates of 'time on task'. The questionnaire asked about activity in the past three months and therefore may introduce a seasonal bias. In addition, no attempt was made to estimate work related energy expenditure. Hence, it is possible that our inability to find a strong inverse relationship between physical activity and obesity is due to measurement error.

Body mass index by itself does not distinguish between muscles and fat. While it has been recognized that BMI is a predictor of obesity-related health risk in the general population, it is not a direct measure of body composition. In this study, subjects who had high muscle mass due to participation in physical exercise would have been classified in a higher BMI category (since muscles have a higher density than fat) and would tend to lead to an underestimation of recreational physical activity as a factor regulating weight.

The fourth potential limitation of this analysis of BMI is that it was confined to variables that were included in the HLIS. Some factors that have been shown to be related to BMI were not available from this survey. The most obvious of these are diet and smoking status. It is well recognized that body weight is a function of energy balance – energy intake and energy expenditure. Without knowledge of diet, this important aspect of the energy balance equation could not be statistically controlled for. Failure to control for potential confounders may have attenuated the relationship between recreational physical activity and BMI.

5.5 Implications for future public health activities

The results from the analysis of the HLIS provide a comprehensive look at BMI and recreational energy expenditure in the Canadian Armed Forces. Analysis of the HLIS revealed that recreational physical activity had a modest association with BMI. This study suggests efforts to prevent excess weight and obesity in the military could profitably address physical activity habits, but need to consider the multi-factorial nature of the problem. Ideally, any health promotion approach would involve multi-component interventions aimed at diet, physical activity, and cognitive change. Appendix D outlines an intervention strategy, aimed at promoting healthy weight in the Canadian Armed Forces, using the PRECEDE-PROCEED model as a framework for the development of recommendations.

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Appendices

Appendix A Characteristics of Excluded Studies

Study ID	Reason for exclusion
Aires 2003(108)	No study of the longitudinal relationship between physical activity and body mass.
Alsaif 2002(307)	No study of the longitudinal relationship between physical activity and body mass.
Artalejo 2002(308)	No study of the longitudinal relationship between physical activity and body mass.
Bild 1996(309)	Earlier follow-up of included study (Schmitz 2000(310)).
Ching 1996(311)	Earlier follow-up of included study (Koh-Banerjee 2003(312)).
Coakley 1998(313)	Earlier follow-up of included study (Koh-Banerjee 2003(314)).
DiPietro 1998(315)	Not a population–based or occupational cohort study.
Fogelholm 2000(316)	Not a population–based or occupational cohort study.
Galuska 1996(317)	No study of the longitudinal relationship between physical activity and body mass.
Garry 2002(318)	No study of the longitudinal relationship between physical activity and body mass.
Goulding 1996(319)	No study of the longitudinal relationship between physical activity and body mass.
Grundy 1999(320)	Not a population–based or occupational cohort study.
Hu, Li 2003(321)	No study of the longitudinal relationship between physical activity and body mass.
Hu 2003(322)	Narrative of previously published research.
Kahn 1997(323)	Not a population–based or occupational cohort study.
Kannel 1967(324)	No study of the longitudinal relationship between physical activity and body mass.
Klesges 1992(325)	Not a population–based or occupational cohort study.
Klesges, Klesges 1992(326)	Not a population–based or occupational cohort study.
Lahti-Koski 2002(327)	No study of the longitudinal relationship between physical activity and body mass.
Lewis 1997(328)	Earlier follow-up of included study (Schmitz 2000(329)).

Appendix A *continued*

Study ID	Reason for exclusion
Lindquist 2001(330)	No study of the longitudinal relationship between physical activity and body mass.
Macdonald 2003(331)	Not a population–based or occupational cohort study.
Mensink 1999(332)	No study of the longitudinal relationship between physical activity and body mass.
Moller 1991(333)	No study of the longitudinal relationship between physical activity and body mass.
Peel 2001(334)	No study of the longitudinal relationship between physical activity and body mass.
Rainwater 2000(335)	No study of the longitudinal relationship between physical activity and body mass.
Rissanen 1991(336)	No study of the longitudinal relationship between physical activity and body mass.
Sanchez-Villegas 2000(337)	Language – Spanish (not retrieved for full-text review)
Shah 1991(338)	No study of the longitudinal relationship between physical activity and body mass.
Simmons 1996(339)	No study of the longitudinal relationship between physical activity and body mass.
Smith 1998(133)	No study of the longitudinal relationship between physical activity and body mass.
Sowers 1996(340)	Not a population–based or occupational cohort study.
Trichopoulou 2000(341)	No study of the longitudinal relationship between physical activity and body mass.
Trichopoulou 2001(342)	No study of the longitudinal relationship between physical activity and body mass.
Wietlisbach 1997(343)	No study of the longitudinal relationship between physical activity and body mass.
Wilhelmsen 1997(344)	No study of the longitudinal relationship between physical activity and body mass.
Wolk 1995(345)	No study of the longitudinal relationship between physical activity and body mass.
Young 1993(346)	Earlier follow-up of included study (Taylor 1994(347)).
Young 1995(348)	Not a population–based or occupational cohort study.
Zablotsky 2004(142)	No study of the longitudinal relationship between physical activity and body mass.

Appendix B

Recreational energy expenditure (EE) values for all activities in a day were calculated as follows:

EE (kcal/kg/day) = Sum of ((N_i * D_i * MET value) / 365)

N_i = the number of times a subject participated in an activity over a twelve month period

D_i = the average duration in hours of the activity

MET = the energy cost of the activity expressed as kilocalories expended per kilogram of body weight per hour of activity / 365 (to convert yearly data into daily data)

Example:

Activity	Number of times per three months	Minutes per session	MET value
Bicycling	36	60	4.0
Walking	16	45	3.8

Calculations:

Activity specific energy expenditure = [(number of sessions per 3 months * 4) X (average assigned duration in hours) X (MET level)] / 365

Bicycling = (36 * 4) (1.0) (4.0) / 365

= 1.578

Walking = (16 * 4) (0.75) (3.0) / 365

= 0.395

EE = 1.97 kcal/kg/day

Appendix C

Rank Classification	Included Ranks
Junior non-commissioned members	Private / Ordinary Seaman Able Seaman Corporal / Leading Seaman Master Corporal / Master Seaman
Senior non-commissioned members	Sergeant / Petty Officer 2nd Class Warrant Officer / Petty Officer 1st Class Master Warrant Officer / Chief Petty Officer 2nd Class Chief Warrant Officer / Chief Petty Officer 1st Class
Junior officers	Officer Cadet 2nd Lieutenant / Acting Sub-Lieutenant Lieutenant / Sub-Lieutenant Captain / Lieutenant (Navy)
Senior officers	Major / Lieutenant-Commander Lieutenant Colonel / Commander Colonel / Captain (Navy) Brigadier General / Commodore Major General / Rear Admiral Lieutenant General / Vice Admiral General / Admiral

Appendix D

Health Promotion Program – Weight Control in the Canadian Armed Forces

6.1 Introduction

The results from the analysis of the HLIS provided a comprehensive look at BMI and recreational energy expenditure in the Canadian Armed Forces. Despite some methodological limitations, the study has implications for strategies to promote healthy body weight in the Canadian military. It is clear from the weak association between recreational energy expenditure and BMI that any health promotion strategy must address both sides of the energy equation, namely diet and exercise. What follows is an intervention strategy based on the PRECEDE-PROCEED model of health promotion.

6.2 Overview of PRECEDE-PROCEED

PRECEDE-PROCEED is a planning model that was developed for health education and health promotion programs. PRECEDE, an acronym which stands for predisposing, reinforcing, and enabling constructs in educational/ecological diagnosis and evaluation, was based on the premise that determinants of health must be diagnosed before an intervention is designed(349). The later addition of PROCEED (policy, regulatory, and organizational constructs in educational and environmental development) to the framework was done in recognition of the need for health promotion interventions to go beyond traditional educational approaches to change unhealthy behaviours.

The PRECEDE-PROCEED model begins at the end, focusing on the desired outcome, and works backward to determine the best way to achieve that outcome. After identifying factors that precede the desired outcome, programs are targeted at these factors. The model recognizes that health behaviours are complex, multidimensional and influenced by multiple factors. While many determinants of health could be considered individual behaviours (i.e. patterns of diet and exercise) they are not wholly volitional behaviours. That is, they are in many ways influenced by forces outside of the individual (e.g. industry, media, politics, and social inequities). Through a systematic approach, the PRECEDE-PROCEED planning model facilitates consideration of both individual and environmental factors that influence health and health behaviours.

The PRECEDE-PROCEED model has nine phases. The first five phases form the assessment part of the model; the four remaining phases comprise implementation and evaluation. Figure 6.1, a generic representation of the PRECEDE-PROCEED model, shows the main lines of causation by the direction of the arrows and the order of analysis in planning and evaluation in phases. The phases are briefly described in the following summary(349, 350):

Phase 1 – Social Assessment and Situational Analysis: Health problems, as perceived by the target population, that affect individual quality of life are identified as well as any barriers that exist.

Phase 2 – Epidemiological Assessment: Data and statistical information, pertaining to the health problems identified in Phase 1, are gathered during this phase of the assessment.

Phase 3 – Behavioural and Environmental Assessment: This phase defines specific behaviours and environmental factors contributing to the health problem. These become targets of the intervention program.

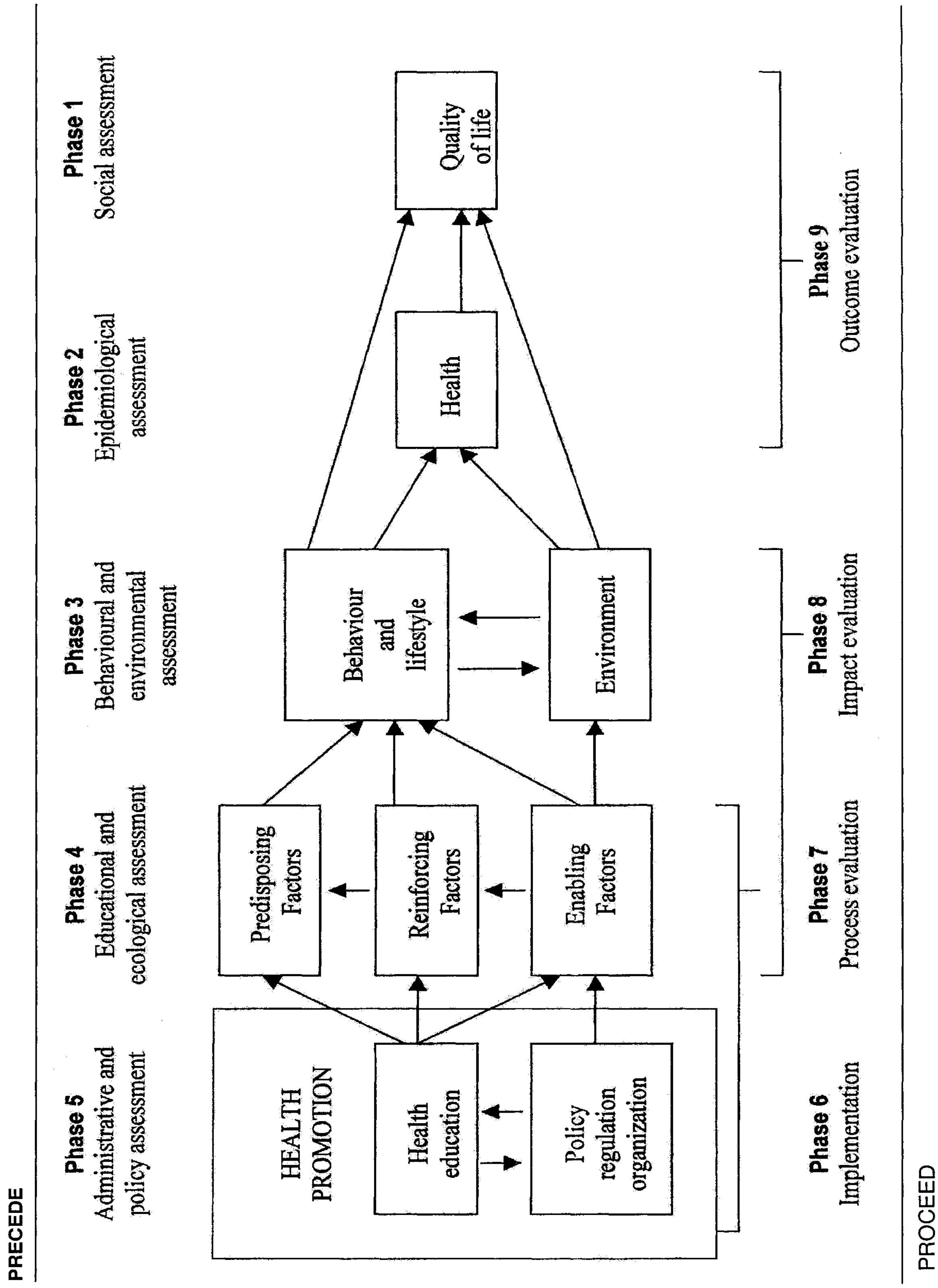
Phase 4 – Educational and Ecological Assessment: After identifying the behavioural and environmental factors for intervention, Phase 4 identifies the predisposing, reinforcing and enabling factors that affect behaviour.

Phase 5 – Administrative and Policy Assessment: This phase describes the resources that are needed for program implementation, the resources that are available, and any barriers to implementation.

Phases 6 to 9 – Implementation and Evaluation: At Phase 6, the health promotion program is ready for implementation. The measurable objectives that have been defined during the assessment phase form the benchmarks for evaluation of the process, impact, and outcome of the program (Phases 7, 8, and 9). Process evaluation determines how well the program was implemented according to protocol. Change in predisposing, reinforcing, enabling, behavioural and environmental factors is assessed during impact evaluation. Lastly, outcome evaluation determines program effect on health and quality of life indicators.

Source: Maryland Department of Health and Mental Hygiene, 2002(350).

Figure 6.1 PRECEDE-PROCEED model for health promotion planning and evaluation



From: Green LW, Kreuter MW. Health Promotion Planning: An Educational and Ecological Approach. Mayfield Publishing Company, 1999.
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Assessments during the PRECEDE phase help to answer what, who, and why questions. What are the quality of life, health, behavioural, and environmental problems or goals? Who has those problems or goals? Why do they have them? What assets can be built on? Answering these questions enables program planners to identify the best ways to influence behaviour and build effective programs. PROCEED asks what resources, barriers, policies, regulations, and organizational factors require adjustment in order to make a program work and allow one to set up an implementation and evaluation design(349).

6.3 Application of the PRECEDE-PROCEED planning model

Analysis of the 2000 HLIS revealed that recreational physical activity had modest association with body mass index. Therefore, any efforts to prevent overweight and obesity in the military population could consider factors related to physical activity habits. However, food consumption habits need to be addressed as well since the amount of recreational energy expenditure required for weight loss is high in the absence of diet control(351).

The PRECEDE-PROCEED model was used as a framework for the development of recommendations in this thesis. Based on the analysis of the HLIS 2000 and a review of the literature on overweight and obesity the model in Figure 6.2 was developed as a starting point. This model, although incomplete, illustrates the complexity of overweight/obesity prevention planning due to the multi-factorial nature of the problem.

Figure 6.2 PRECEDE-PROCEED model developed for weight control in the Canadian Armed Forces

PRECEDE

Phase 5 Administrative and policy assessment	**Phase 4** Educational and ecological assessment	**Phase 3** Behavioural and environmental assessment	**Phase 2** Epidemiological assessment	**Phase 1** Social assessment
HEALTH PROMOTION Health Education	Predisposing factors • Genetic predisposition • Attitudes about health, food, eating, and exercise • Knowledge of recommended amount of exercise • Perceived risk • Knowledge of food guide choices • Food preparation and cooking skills • Belief in self-efficacy for weight loss • Previous weight loss attempts: experience with weight loss	Health Behaviour and Lifestyle • Lack of exercise • Consuming excess calories • Excessive sedentary activity • Fatty food consumption/fast food • Time management	Health Problem • Obesity • Overweight • At risk for overweight	Quality of Life Individual • Social stigmatization • Discrimination • Economic loss • Unfulfilled potential Employer • CF image • Lost productivity • Increased health care costs
Policy Regulation Organization	Reinforcing factors • Social encouragement to lose weight or maintain a healthy weight Co-worker/Supervisor Family Physician • Lack of role models • Material incentives Rewards for passing fitness test Rewards for weight loss • Restrictive policy violations	Environmental factors • Work load • Access to healthy food choices • Media influence • Physical layout of work environment		
	Enabling factors • Access to foods (unhealthy > healthy) • Lack of access to exercise facilities • Restrictive weight policy • Restrictive fitness policy			
Phase 6 Implementation	**Phase 7** Process evaluation	**Phase 8** Impact evaluation	**Phase 9** Outcome evaluation	

PROCEED

Although the PRECEDE-PROCEED planning model was followed, the complete planning process was not adhered to because the CF has a number of programs in place, or new programs that have recently been implemented, that deal with nutrition and physical activity. Therefore, the initial phases of the model were followed with the intent to build on programs that were in place and recommendations developed to focus on gaps or limitations of the current programs.

Social Assessment (Phase 1)

The health problem (overweight/obesity) and its associated impact on quality of life were defined at the outset based on the prevalence of overweight/obesity among the target audience, potential for change, and growing public/professional concern. Additionally, using self-perceived health status as a broad measure of quality of life, increased BMI is linked to lower ratings of health status (Table 4.15). As is often the case when the starting point for implementing health promotion activities is based on epidemiological assessment, there is no direct information on the quality of life issues that are of concern to the target audience. However, it would be important to capture this information.

Although there is no information on the quality of life issues that are of concern, there is broad awareness among those surveyed in the HLIS 2000 about what they can do to improve their own health and well being (Tables 4.14 and 4.15). They identify the benefits of losing weight, getting more exercise, and improving their diet. A majority of those identifying each health promotion action also state their intention to make the change in the coming year. However, there is no information on the relative priority of these proposed health promotion actions.

Even though health promotion has an influential role in reducing risks for morbidity and mortality, its essential value lies in its contribution to quality of life(349). An individual is less likely to engage in a health related behaviour because they feel it will make them live longer than if they believe it will make them feel, perform, or look better(352, 353). At the community (corporate) level, an employer is more likely to support a health promotion initiative if they can see how it will contribute to actual corporate concerns (i.e. absenteeism, employee performance, or health care costs). From an occupational health perspective, there is a need to identify the priority of values from both the employee and employer viewpoints in order to more effectively define the content and method of delivery of any proposed program(349). It is recommended that focus groups, as a means of obtaining target-group perceptions, be conducted. The focus groups will also serve as a means to engage the active participation of target population (CF members at risk for overweight as well as overweight/obese members).

Epidemiological Assessment (Phase 2)

The epidemiological assessment, based on a review of the literature and analysis of 2000 HLIS data covered in previous sections of this thesis, will not be further elaborated on but formed the basis for development of program goals and objectives.

Program Goal:

The overall health of the Canadian Armed Forces will be improved by reducing the prevalence of overweight and obesity.

Specific program objectives:

1. The prevalence of obesity in the Canadian Armed Forces will be decreased by 10% within the first two years of the program.
2. The prevalence of being classified as overweight in the Canadian Armed Forces will be decreased by 10% within the first two years of the program.

Behavioural and Environmental Assessment (Phase 3)

Behavioural theory and background literature were used to identify the behavioural and environmental determinants of overweight/obesity listed in Figure 6.2. Obtaining complete community input (i.e. through the planning committee and interviews) was not feasible for this thesis. Therefore, identification of the most important behavioural and environmental factors associated with weight management was primarily based on a review of the literature. This inventory should be further substantiated through two methods. First, the insight of a planning committee should be sought. The planning committee should include members of Force Health Protection (design and evaluate health promotion programs), CF Personnel Support Agency (deliver health promotion programs), the Directorate of Logistics Business Management/Food Services (provide food services), and the Primary Care Renewal Initiative (in place to modernize the CF primary care delivery system). Second, interviews using a representative sample of the target population should be conducted in order to elicit perceptions on weight management as well as current diet/nutrition and physical fitness/exercise practices.

As a starting point, Health Behaviour and Lifestyle factors which need to be considered include:

- Lack of exercise
- Consuming excess calories
- Excessive sedentary activity
- Consumption of high fat food (often in the form of "fast food")
- Time management (lack of time to engage in recreational activity)

Environmental factors of relevance would include:

- Work load
- Access to healthy food choices
- Physical layout of the work environment
- Media influence

Ideally, once the list of factors is completed, each factor should be rated in terms of its importance to the health problem and changeability before intervention targets are chosen.

In this way, the proposed intervention(s) can be more efficiently directed to those factors that are deemed to be most important.

The following measurable objectives illustrate the desired behavioural impact and environmental change expected of the health promotion program.

Behavioural objectives:

1. Decrease by 50% the proportion of individuals undertaking fewer than 3 kcal/kg/day of recreational energy expenditure by the first year of program implementation.

The current recommendation of 30 minutes of moderate-intensity activity undertaken five or more times per week is important for inducing improvement in cardiovascular health(354, 355). However, recent evidence indicates that higher levels of physical activity levels are required to prevent weight gain in the general population(356-358). It has been suggested that a physical activity level ≥ 3 kcal/kg/day (roughly equivalent to 60 minutes of brisk walking per day) is required to limit the transition of adults to overweight or obesity(359, 360). Based on analysis of the 2000 HLIS, 65% of the population is currently exercising below the recommended amount of physical activity required for weight stability.

2. Decrease mean sedentary activity by five hours per week by the first year of program implementation.

Epidemiological studies have pointed to the association between sedentary activity and increased risk of overweight/obesity(361, 362). Analysis of the 2000 HLIS also demonstrated that sedentary activity is significantly associated with the prevalence of overweight and obesity. The Task Force on Community Prevention Services identified studies that evaluated the effectiveness of interventions to decrease the amount of time spent in television viewing and other sedentary behaviours(363). Although the study failed to find consistent evidence for increased physical activity as a result of the interventions, there was some evidence of reduced adiposity(364).

3. Decrease by 25% the proportion of individuals reporting the need to improve their diet by the first year of program implementation.

Dietary factors that have been implicated as a cause of overweight/obesity include: excess dietary fat, the energy density of consumed food, sugar intake, large portion sizes, frequency of eating(365). This objective is kept deliberately broad in an effort to encompass both food consumption patterns (e.g. fruits, vegetables) and intake of nutrients and food components.

Environmental objectives:

1. All cafeterias will offer "healthy choice" menus by the sixth month of program implementation.
2. A flexible exercise policy, developed with participation of key stakeholders, will be adopted by the sixth month of the program.

Educational and Ecological Assessment (Phase 4)

Phase 4 identifies the antecedent and reinforcing factors that exert an influence on the change process. Predisposing factors are the antecedents that provide the rationales or motivation for behaviour (i.e. individuals' knowledge, attitudes, beliefs, values, existing skills, and self-efficacy beliefs). Reinforcing factors are those factors that appear subsequent to a behaviour that provided continuing reward or incentive for the behaviour to continue(349). Enabling factors are antecedents that enable motivation to be realized(349). They include programs, services, and resources necessary for behavioural and environmental outcomes to be realised.

The predisposing, reinforcing, and enabling factors for healthy weight status that influence the behavioural and environmental factors in Phase 3 have been listed in Table 6.1. These components have been analyzed, rated in terms of importance and changeability, and priority targets for intervention have been selected. Normally this would have been done in consultation with the target community and service providers but, this was not possible within the scope of this thesis.

Table 6.1 Educational and organizational assessment of predisposing, reinforcing, and enabling factors related to weight control

- Predisposing Factors
    - Genetic predisposition
    - Attitudes, beliefs, and values concerning health, food, eating, exercise
    - Self-esteem
    - Perception of the threat of health problems
    - Knowledge of recommended amount of exercise
    - Knowledge of food guide choices
    - Food preparation and cooking skills
    - Belief in self-efficacy for weight loss
    - Previous weight loss attempts: experience with weight loss
- Reinforcing Factors
    - Social encouragement to lose weight or maintain a healthy weight
        - Co-worker/Supervisor
        - Family
        - Physician
    - Lack of role models
    - External and Internal incentives
        - Rewards for passing CF Exercise Prescription Test
        - Rewards for weight loss
    - Restrictive policy violations
- Enabling Factors
    - Access to foods (unhealthy > healthy)
    - Access to exercise facilities
    - Restrictive weight policy
    - Restrictive fitness policy

Measurable objectives, in the form of learning and resource objectives were developed at this phase in the assessment. Learning objectives define the predisposing factors and skills that are the targets of intervention at the end of the program (i.e. How many will know, believe, or be able to do what by when?)(349). Resource objectives define environmental enabling factors that should be in place at the end of the program(349). Table 6.2 lists learning and resource objectives for this phase of the assessment.

Table 6.2 Learning and resource objectives based on predisposing, reinforcing, and enabling factors of weight control

Knowledge	By the end of the program, 90% of CF members will be able to: (a) Identify normal weight, overweight, and obesity based on the BMI classification system (b) Identify recreational activity as necessary to combat weight gain (c) Identify the recommended amount of daily activity in order to attenuate weight gain (d) Identify the four food groups (e) Identify the number of recommended daily servings within each of the four food groups and appropriate portion sizes
Beliefs	By the end of the program, 80% of CF members will believe: (a) The consequences of overweight/obesity can be serious (b) They can take a leading action in the prevention of overweight/obesity (c) Preventive measures will reduce the potential for associated illnesses
Skills	By the end of the program, 70% of CF members will be exercising at the recommended amount of daily activity. By the end of the program, 60% of CF members will be eating the recommended number of fruit and vegetable servings per day.
Resource objectives for environmental enabling factors	By the end of the program, 100% of the time the following will be made available: (a) Time (1 hour) to exercise during normal working hours (b) Access to "healthy choice" meals and snacks at the work place

Administrative and Policy Assessment and Implementation (Phases 5 and 6)

The purpose of the administrative and policy diagnosis is to identify the resources needed as well the barriers and supports present within an organization that could facilitate or hinder program implementation. At this stage, intervention strategies based on the previous diagnostic steps are enumerated.

The administrative and policy diagnosis identified four distinct population based interventions designed to positively influence individuals' weight control practices: an individually-adapted health behaviour change program, two informational approaches, and an environmental/policy approach. Some interventions, as noted earlier, are currently in place. Therefore, only new programs designed to fill gaps or limitations of the present programs were addressed.

1. Individually-Adapted Health Behaviour Change Program

Individually-adapted health behaviour change programs are tailored to an individual's specific interests, preferences, and readiness for change. In an effort to address body weight concerns in the military, the Force Health Protection team have developed a "Weight Wellness" program. The program focuses on achieving a healthy weight while developing healthy physical activity and eating habits. The program takes a self-management approach to behaviour change and incorporates group meetings along with self-assessment. Participants receive a workbook in which they log eating and activity patterns in order to analyse problem areas and attend twelve group meetings over a fifteen-week period. Staff, hired through the Canadian Forces Personal Support Agency, deliver the program at military bases across Canada. Data is collected pre/post-course on behavioural variables and self-reported biomedical variable information (BMI, pounds lost, waist circumference) is collected post-course and one year after course completion. Subject matter experts at Force Health Protection then evaluate this data.

Individually-adapted health behaviour change programs require careful planning and coordination, well-trained staff members, and resources sufficient to carry out the planned program. Inadequate resources or lack of professionally trained staff members can affect how completely and correctly interventions are implemented and evaluated. Indeed, this program was originally implemented in the late 1980's and early 1990's with some success. However, lack of health promotion staff to implement the program led to its demise. The recent re-introduction of this program has been facilitated by the hiring and training of staff to deliver the program. Appropriate process and impact evaluation will be essential to ensure continued success of this program.

2. Informational Approach to Increase Physical Activity and Improve Diet/Nutrition – Media Campaign

Informational approaches focus on increasing physical activity and improving diet/nutrition by providing information that will motivate and enable people to change behaviour and to maintain that change over time. Information is intended to change knowledge about the benefits of physical activity / healthy diet, increase awareness of opportunities for increasing physical activity / following a healthy diet, explain methods for overcoming barriers and negative attitudes about physical activity / diet/nutrition, and increase physical activity behaviours / healthy eating practices among community members.

A media campaign will be implemented as one informational approach. The media campaign will deliver messages that promote physical activity and healthy eating and increase knowledge about recommended levels of exercise and guidelines for healthy eating. These messages will be transmitted through the military website and military publications.

3. Informational Approach to Increase Physical Activity and Improve Diet/Nutrition – Point-of Decision Prompts

The second informational approach will involve point-of decision prompts. Point-of-decision prompts in the form of motivational signs will be employed. Motivational signs will b placed by elevators and escalators to encourage people to use nearby stairs, and motivational signs will be placed in cafeterias to encourage people to choose a healthy meal.

A potential barrier to intervention implementation is that stairways in buildings are frequently difficult to find, poorly lit, maintained, or secured. As a result they may appear to be, or may actually be, unsafe. In addition, some stairwells are locked, preventing access. With regard to the point-of-decision prompt for health eating, access to healthy food choices may not always be available. However, this concern has recently been addressed by implementation of "Choice and Quantity" standards for food services.

The "Choice and Quantity" standards in CF food services were developed by a working group of twelve senior members of the cook occupation and implemented in April 2004. The standards were developed to reflect the nutritional requirements of an active and healthy military population. In an effort to support healthy eating practices, the standards require that "healthy choices" be available at each meal and that each meal incorporates the four food groups as expressed in "Canada's Good Guide to Healthy Eating". The standard also designates how much of each food item is required for a portion. The standard was set to meet or exceed Canadian healthy eating guidelines in order to reflect the energy and nutritional requirements of an active military population while at the same time recognizing that an excessive standard would send the wrong health promotion message by encouraging over consumption.

4. Environmental and Policy Approach to Increase Physical Activity

It is necessary for Canadian Force members to be physically fit in order to meet military operational requirements. This requirement has been formally recognized by policy in the form of a Canadian Forces Administrative Order (CFAO). The CFAO states that CF members must participate in the Canadian Forces Exercise Prescription (CF EXPRES) program. The order further states that the physical fitness training prescribed under the program should take place during normal working hours when circumstances permit. The chain of command has the primary responsibility for ensuring that all members actively participate in regular exercise programs and meet the CF minimum physical fitness standards through annual testing. Under the policy, members failing to meet the standard are to be placed under a supervised exercise program while those exceeding the standard are exempted from testing for one year. It is the responsibility of a commanding officer to assess members who fail the meet the minimum standard and, once the reason for failure has been determined, direct appropriate remedial action. This policy, while longstanding (issued in 1994), has not been strictly adhered to. Part of the problem has been lack of adequate means to track the number of individuals participating in annual testing. This problem has recently been addressed through the implementation of a software program which tracks CF EXPRES results allowing commanding officers to keep current on CF members' participation and fitness. However, lack of commitment to the policy can only be addressed by concentrated efforts to promote physical fitness as a key CF priority.

Process Evaluation (Phase 7)

The first level is in the evaluation phase of the model is designated process evaluation because observations on the process of the program are the first to be available. In process evaluation, the potential objects of interest include program inputs, implementation activities, and stakeholder reactions. Process evaluation enables researchers to detect problems and make adjustments early on. The essential product of process evaluation is a clear, descriptive picture of the quality of the program elements being put in place(349).

The quality of the process will be determined by various methods:

- post-program ("Weight Wellness") satisfaction surveys
- counts of the number of "Weight Wellness" programs delivered
- tracking number of educational messages published
- employee surveys regarding: satisfaction with fitness policy, whether employees abide by the policy, level of reinforcement of the policy at their worksite
- employee surveys regarding: satisfaction with food standards, knowledge of food standards
- surveillance of CF EXPRES database use

Impact Evaluation (Phase 8)

Impact evaluation assesses the immediate effect the program has on target behaviours, influential environmental factors, and predisposing, enabling, and reinforcing antecedents. The importance of generating clear, specific, and plausible behavioural and educational objectives in phases three and four of the Precede planning process can not be underestimated as they provide the foundation for evaluating program impact.

At the level of impact evaluation, pre- and post-program "Weight Wellness" participant survey results will be used to assess changes in knowledge, attitudes, beliefs, skills, and social influences. Comparison of baseline and follow-up biomedical variables will indicate whether participants lost weight. An abbreviated version of the HLIS version A will be administered to track sedentary activity levels, recreational activity levels, and self-reported satisfaction with diet. Site visits to CF food service operations will be used to assess whether "Choice and Quantity" standards are being adhered to. The CF EXPRES database will be used to track changes in the frequency and distribution of members participating in the annual evaluation.

Outcome Evaluation (Phase 9)

The foci of outcome evaluation are the health status and quality-of-life indicators that were outlined in the earliest stages of the planning process. In this case, only health status indicators were defined. With full application of the planning model, social indicators could also be evaluated if defined at the outset. Follow-up HLIS surveys will be used to identify overall trends in BMI status in the military. To augment this analysis, comparisons to trends in the CCHS will be made.

6.4 Summary

The PRECEDE-PROCEED planning model offers a structured yet flexible approach to health promotion program planning. The methodical diagnostic approach is intended to make planners think critically about where and how to intervene(349). The process broadens the approach to health promotion planning beyond that typically included in a single theory or framework by incorporating different levels of analysis of the problem (individual, behavioural, and social environmental) and by linking determinants to intervention strategies(349). The PRECEDE-PROCEED framework is an appropriate method for addressing the complex issue of weight control within the Canadian Armed Forces.