RELATIONSHIP BETWEEN LONGITUDINAL WEIGHT PATTERNS OF MEN DURING MIDDLE AGE AND SUCCESSFUL AGING IN LATER LIFE: THE MANITOBA FOLLOW-UP STUDY

BY

DENNIS J. BAYOMI

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfilment of the Requirements
for the Degree of

MASTER OF SCIENCE

Department of Community Health Sciences
University of Manitoba
Winnipeg, Manitoba, Canada

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

*****

COPYRIGHT PERMISSION

RELATIONSHIP BETWEEN LONGITUDINAL WEIGHT PATTERNS OF MEN DURING MIDDLE AGE AND SUCCESSFUL AGING IN LATER LIFE: THE MANITOBA FOLLOW-UP STUDY

BY

DENNIS J. BAYOMI

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

OF

MASTER OF SCIENCE

TABLE OF CONTENTS

CHAPTER FOUR RESULTS

ABSTRACT

Introduction: Overweight and obesity are serious health conditions associated with the development of chronic diseases like cardiovascular disease, Type 2 diabetes, hypertension, and certain forms of cancer. Numerous studies have related overweight and obesity at different points in time with specific health conditions later in life. Little research however has been reported characterizing longitudinal weight patterns throughout middle age and linking those patterns with a comprehensive set of indicators of successful aging.

Methods: The longitudinal dataset of the Manitoba Follow-up Study, launched in 1948, was used to develop regression models relating summary measures of weight patterns during middle age (35-60 years) with the following outcomes of successful aging: survival to an advanced age (75 years), self-rated health, physical and mental functioning, limitations in daily activities, life satisfaction and self-report of aging successfully. Using a minimum of seven weight measurements over a 35-60 year age window, weight patterns were characterized for each subject (n=2,298 men, 31,274 weight measurements). Simple weight summary measures commonly used by other researchers including the first, last, maximum, minimum, and mean Body Mass Index (BMI) over the period were used. A classification method was also developed combining the longitudinal characteristics of duration and trend, using least squares fourth-order polynomial curve fitting and extrema finding. Clinical and mortality data collected since 1948 and responses to the 1996 Successful Aging Questionnaire (n=1,438, mean age=76 years) were used to define successful aging outcomes. Logistic regression and multiple linear regression were performed for categorical and continuous outcomes respectively, adjusted for age, smoking and occupation history.

Results: Approximately 25% of the men were predominantly normal weight ($18.5 \leq$ BMI < 25.0 kg/m^2) while maintaining steady weights (average BMI change < 0.1 kg/m^2 per year) during middle age. These men showed more favorable successful aging outcomes in later life than men predominantly overweight ($25 \leq$ BMI < 30 kg/m^2) with varying weight. Specifically, men with steady, normal weights during middle age had almost twice the adjusted odds of reporting excellent health [OR 1.90, 95% CI (1.39, 2.61)] or feeling they had aged successfully [OR 1.74, 95% CI (1.13, 2.69)], and were more likely to report excellent satisfaction with life [OR 1.40, 95% CI (1.04, 1.89)]. In addition, these men in later life had roughly half the odds of reporting limitations in daily activities, to have difficulty walking several blocks, or to have difficulty climbing several flights of stairs compared to men mainly overweight with appreciably changing weight during most of middle age. No evidence for significant differences between overweight patterns during middle age and premature mortality or mental functioning in later life were observed.

Conclusion: Being predominantly overweight with variable weight throughout middle age may bring reduced odds of aging successfully, notably with increased impediments to physical functioning in later life. In light of these findings, current health promotion efforts targeting youth might also be extended to encourage healthy weight patterns among the middle-aged.

ACKNOWLEDGEMENT

First and foremost, I would like to salute Dr. Francis Mathewson who founded the Manitoba Follow-up Study, and all of the men and their families who have participated to the present day. Your individual dedication and collective devotion to this study have been truly awe-inspiring.

Thanks to the Canadian Institutes of Health Research for its ongoing funding of MFUS, to the University of Manitoba's Centre on Aging for its support through a Faculty-Graduate Student Collaborative Grant which helped plant the seeds for my research and to the university's administration for a Graduate Student Travel Award, allowing me to present preliminary results of my work at an international conference.

A big "tap of the hockey stick" to Dr. Bob Tate, my thesis advisor, MFUS Director and long-time friend. Bob, I will be forever grateful for your bringing me aboard MFUS, encouraging me to become a student again and providing the best balance between mentorship and friendship one could imagine.

To Drs. Verena Menec and Elizabeth Ready, thank you so much for your invaluable insight and guidance as members of my thesis committee. Your involvement has made my thesis that much better.

A big hug to my MFUS family: first to Madge Biddell, Brenda Loewen and Barb Masterman, the three ladies who make our unit as much a home as an office; to my good friends and MFUS colleagues, Drs. Ted Cuddy, Leon Michaels and Christina Lengyel, your clever wit, sage advice and inspiring camaraderie have made research both fun and intellectually stimulating; and to our MFUS students, past and present – Lisa, Priyanka, Laura and Aynslie – for keeping us all young at heart in MFUS.

A big thanks to my Community Health Sciences family, including all of my professors, support staff colleagues, and fellow students, especially all the students I have met through the CHS Student Council. A warm thanks to my long-time friend Mary Cheang, for your encouragement and biostatistical expertise. Thank you Dr. Tom Hassard, as previous chair of the CHS Graduate Program, for providing much appreciated encouragement and support. Theresa Kennedy, I have recommended that you be made a Saint, for your extraordinary help in the CHS Graduate Program office, both to me and indeed to just about every CHS student. Thank you so much TK!

To my Bannatyne campus family, another round of thanks. Thanks to Ada Ducas and her hard-working staff in the Neil John Maclean Health Sciences Library, especially Carol Cooke, Michael Tennenhouse, Anne Thornton-Trump, Jovy Beltran and Ruth Holmberg for providing such outstanding services and resources, both within the library walls and e-beyond. To Dr. Ed Kroeger, assistant dean of graduate studies in the Faculty of Medicine and coordinator of the near-legendary Canadian Health Student Research Forum, thank you very much for providing me with numerous opportunities to present my work among our peers. To Mary "mx" Hill, my long-time friend in the Dean's Office, thank you so much for your endless encouragement and enthusiasm. And of course, thanks to the staff at the Joe Doupe gym, for providing the facilities, especially the basketball court, so that I could work on my own middle-age weight pattern!

To my biological family – my parents and brother – thank you for your support and patience, and for not asking too often if I was still going to school!

And finally to Heidi, my inspiration and biggest fan, for cheering me on and seeing me through to the end. For that, my dear, you will always be in my heart.

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADL	Activities of Daily Living
BMI	Body Mass Index
BMI_{35}	Body Mass Index at age 35 years
BMI_{60}	Body Mass Index at age 60 years
BMI_{AVG}	Average BMI over age 35 to 60 years
BMI_{MIN}	Minimum BMI over age 35 to 60 years
BMI_{MAX}	Maximum BMI over age 35 to 60 years
CI	confidence interval
EKG	electrocardiogram
HRQOL	Health-Related Quality of Life
HSQ-12	Health Status Questionnaire-12
IADL	Instrumental Activities of Daily Living
kg	kilogram
kg/m^2	kilograms per meter squared
lb	pound
m	meter
MCS	Mental Component Score
MFUS	Manitoba Follow-up Study
OR	odds ratio
PCS	Physical Component Score
SAQ	Successful Aging Questionnaire
SAQ-1996	Successful Aging Questionnaire 1996
SD	standard deviation
SF-36	Short Form-36
SRH	Self-Rated Health
WHO	World Health Organization

Chapter One
INTRODUCTION

1.1 The Research Problem

Overweight and obesity are serious health conditions characterized by excess adiposity and are associated with the development of chronic diseases like cardiovascular disease, Type 2 diabetes, hypertension, certain forms of cancer, arthritis, and gall bladder disease [WHO 1998]. Body Mass Index (BMI), defined as the weight of an individual in kilograms (kg) divided by the height in meters squared (m^2), is a commonly accepted measure of overweight and obesity. The World Health Organization (WHO) classifies individuals with a BMI of between 25.0 and 29.9 kg/m^2 as overweight and those with a BMI of 30.0 kg/m^2 or greater as obese [WHO 1998].

The magnitude of the problem of overweight and obesity is overwhelming as the WHO reports that a billion people worldwide are overweight or obese, with 300 million obese, 100 million of these in the developing world [WHO 2002]. National estimates claim that between 40% and 50% of Canadian adults are overweight, and approximately 15% are obese, with high prevalence occurring among middle-aged Canadians, with middle-aged men experiencing the highest rates [Katzmarzyk 2002]. Beyond the costs in human pain and suffering, Katzmarzyk and Janssen [Katzmarzyk 2004] recently estimated the annual costs associated with obesity in Canada in excess of $4 billion ($1.6 billion direct costs), representing 2.2% of total Canadian health care costs.

Numerous studies have related body weight at different points in life with specific health conditions in later life. Little research however has been reported relating longitudinal weight patterns throughout middle age (eg. from 35 to 60 years) with a broad range of measures of successful aging including survival to an advanced age, self-rated health, physical and mental functioning, limitations in daily activities, life satisfaction and self-assessments of successful aging. Given that over a third of the Canadian population is middle-aged [Statistics Canada 2006a] and that our population is steadily aging, with estimates that over 20% of Canadians will be at least 65 years old by 2026, up from 13% today [Statistics Canada 2005a], insights into how weight patterns during middle age might impact successful aging in later life could be valuable.

1.2 Brief Overview of the Manitoba Follow-up Study

The Manitoba Follow-up Study (MFUS) is a prospective, longitudinal study begun in 1948 that has investigated cardiovascular disease by documenting weights, blood pressures, adverse health events and electrocardiograms of 3,983 male aircrew recruits since their entry into the study. Since 1996, with the steady aging of its cohort, MFUS has shifted its research focus to successful aging. A series of Successful Aging Questionnaires (SAQ) have asked the surviving members of the original cohort for self-assessments of their health, limitations in daily living, physical, and mental functioning, life satisfaction and successful aging. At July 2005, 1,148 members were alive at a mean age of 84 years.

Little has appeared in the literature linking longitudinal weight patterns during middle age with broader measures of successful aging; only very recently have the first few papers appeared in print [Daviglus 2003] [Strandberg 2003]. One could speculate that this might be due to the absence of any true relationship between excessive weight during middle age and successful aging. On the other hand, one might argue that datasets permitting this kind of investigation are quite rare, and only with a long-term longitudinal dataset like that of MFUS could such an investigation ever be undertaken.

1.3 The Research Question and Objectives

This thesis addresses the following research question:

> **What relationship exists between longitudinal weight patterns of men during middle age (35-60 years) and measures of successful aging in later life (after age 75 years) ?**

Using the longitudinal dataset of the Manitoba Follow-up Study containing weight, clinical and successful aging questionnaire data for a subset of its male subjects, the research question will be addressed through the following three objectives:

<u>OBJECTIVE 1</u>: Determine weight patterns throughout middle age for each subject. Characterize the patterns using both simple summary measures such as BMI at age 35 and mean BMI over time, and also by developing a more complex summary measure that classifies individual longitudinal patterns according to duration and trend;

<u>OBJECTIVE 2</u>: Operationalize successful aging using the following measures:

- Survival to an advanced age (75y)
- Self-rated health
- Physical and mental functioning
- Limitations in activities of daily living
- Life satisfaction
- Self-report of "Aged Successfully"

OBJECTIVE 3: Develop regression models to relate middle-age weight patterns with outcome measures of successful aging, adjusting for possible confounders such as smoking status and occupation history.

A rationale for the choice of weight pattern summary measures and measures of successful aging is presented in Chapter Two, Literature Review and Conceptual Framework, while details about the measures and model development are described in Chapter Three, Methodology.

1.4 Hypotheses and Potential Implications

One would expect, based on current knowledge of the deleterious effects of overweight and obesity, that patterns of excessive weight during middle age would have a negative influence on successful aging. Furthermore, one might anticipate that weight patterns that vary considerably may have less favorable effects on outcomes in later life than do more steady weight patterns. Factors such as smoking and occupation history are reasonably inferred to be related both to weight patterns and successful aging. After controlling for these potentially confounding effects, if negative associations can be demonstrated between these suspected detrimental weight patterns in middle age and later outcomes, health professionals will have additional evidence for encouraging healthy weight patterns among middle-aged individuals, and not just among the young. On the other hand, if the opposite is shown, then health promotion efforts may require new approaches for encouraging the maintenance of healthy weight levels, perhaps not only among the middle-aged but more broadly among the general population.

1.5 Ethics Review

The Health Research Ethics Board of the University of Manitoba has granted the Manitoba Follow-up Study approval for ongoing data collection. Application to the ethics board for approval to conduct the current research project was made in November 2004 and approval was received on December 6, 2004. At all times during the current project, confidentiality was maintained as names, addresses and any other information that might identify study subjects were not used.

1.6 Role of the Author

The current project was undertaken by the author as an analysis of already collected data. No surveys were designed, administered or data-entered during this project; all clinical and questionnaire data had been collected and entered either before the project began or incidental to it. All data manipulation was performed by the author, done almost entirely by writing computer programs in SAS 8.2 and SPSS 11.0.

1.7 Summary

Overweight and obesity are serious health issues, with prevalences dramatically increasing not only in Canada but worldwide. Little research has related weight patterns during middle age with broader measures of successful aging in later life. Using the longitudinal dataset of the Manitoba Follow-up Study, this thesis will attempt to address that gap by 1) characterizing individual longitudinal weight patterns during middle age using simple measures commonly used by other researchers and a measure that incorporates duration and trend; 2) operationalizing successful aging through a variety of outcomes in later life and 3) relating those weight patterns and measures of successful aging through regression modeling.

Chapter Two, Literature Review and Conceptual Framework, describes work reported by other researchers, identifies gaps in the current literature, and proposes a conceptual framework around which the methodology outlined in Chapter Three, Methodology, is based.

Chapter Two
LITERATURE REVIEW
AND
CONCEPTUAL FRAMEWORK

2.1 Overview

Numerous longitudinal studies have examined the relationship of weight with mortality and disease. Many of these studies have used simple methods for summarizing weight patterns of their subjects using isolated weight values. Perhaps due to the limited nature of their datasets, few studies have had the data necessary for assessing long-term weight patterns in their analyses. As well, little has been reported linking weight with broader, non-clinical measures of successful aging, such as physical and mental functioning, limitations in daily activities, life satisfaction, or self-assessments of successful aging. The purpose of the present study is to bridge this gap, relating summary measures of weight patterns over time with broader measures of successful aging.

This chapter consists of a literature review divided into three main parts, roughly corresponding to the present study's predictor variables (summary measures of weight patterns), outcome variables (measures of successful aging) and relationships between the two. In the first part, the use of summary measures of weight patterns from other studies is reviewed, beginning with simple summary measures and progressing to more complex ones. The second part reviews how gerontologists and other researchers have defined and operationalized the concept of successful aging. In the third section, the very few papers to date that have related summary measures of weight patterns over time with broader measures of successful aging are reviewed.

2.2 Summary Measures of Weight Patterns

Matthews *et al* [Matthews 1990] assert that although not widely known in medical research until the late 1980s, the use of summary measures in general is not new, dating back to the late 1930s. Summary measures treat the individual as the basic unit of analysis and derive a measure summarizing a particular aspect of the series of observations over time for each individual. These summary measures can be derived using as few as one observation, such as the first or last value, or as many as all of the observations in a series for a given individual. In the latter case, these might be used to determine the minimum or maximum value, to calculate one or more differences or rates of change between selected values, or to compute the mean, median, or weighted mean (area under the curve) of the entire series of values. Particularly appealing is the use of summary measures where measurements are taken at differing points in time for individuals, over a common time period. Such irregularly-spaced data preclude the use of other techniques for analyzing serial data such as repeated measures methods which depend on more regular spacing of data.

Studies examining the relationship between weight and health outcomes have employed a variety of methods for describing the weight patterns of their subjects. Some have used only single weight measurements due to the limited availability of data while other studies have derived more complex summary measures from a finite number of weight measurements taken at various points in time. The following sections review some of these, beginning with simpler approaches and progressing to more complex ones.

2.2.1 Simple Summary Measures

Wilson *et al* [Wilson 2002], using data from the Framingham study, assessed the relationship of weight with cardiovascular risk factors and outcomes among the 5,209 male and female members of the original Framingham cohort, aged 30 to 62 years. Using pooled repeated measures, BMI categories (normal weight, overweight and obese) were determined using the most recent BMI values collected for any given individual. The authors found increased risks for hypertension, diabetes and cardiovascular disease for overweight and obese men relative to their normal-weight peers.

Roberts *et al* [Roberts 2002] used single recalled weights from the 1994 wave of the Alameda Study to examine possible relationships between weight and subsequent declines in mental health among 1,739 male and female participants, aged 50 years and older. Eight indicators of mental health – perceived mental health, happiness, life satisfaction, positive affect, negative affect, optimism, feeling loved and cared for, and depression – were derived from a self-administered questionnaire during the 1999 wave of the study. Logistic regression models adjusted for age, sex, education, marital status, chronic medical conditions, limitations in activities of daily living, financial strain, social isolation and support and recent life events. The authors found that obese individuals were at greater risk only of incident depression, no evidence was found for increased risk of the other mental health outcomes.

Roberts *et al* [Roberts 2003], in a follow-up analysis to the one mentioned above, used single recalled weights from 1,886 men and women in two waves of the Alameda Study to examine possible temporal effects between obesity and depression. Suggesting their analysis was the first to look prospectively at possible reciprocal effects between depression and obesity, the authors administered written questionnaires in 1996 and again in 1999 to participants of the Alameda Study fifty years of age or older in 1994. In addition to self-reported weight and height, the authors collected at both times demographic and socioeconomic data. Responses to questions about social isolation, social support, financial strain, chronic medical conditions and limitations in daily living were collected at both times. Obesity was defined where BMI ≥ 30 kg/m^2 while depression was assessed using a set of 12 items describing a major depressive episode as defined by the Fourth Edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV). Logistic regression models were developed using obesity in 1999 as an outcome with depression in 1994 as a predictor, as well as depression in 1999 as an outcome with obesity in 1994 as a predictor, adjusting for the covariates described earlier. The adjusted odds for subsequent depression was 1.69 times greater for individuals who were obese five years previously compared to those who were not obese. No evidence was found to suggest depression predicted subsequent obesity. The authors noted two important limitations of their study: the use of self-reported weights, heights and other measures, and the relatively short time frame between assessments.

2.2.2 Simple Summary Measures Involving Weight Change

Harris *et al* [Harris 1997] used data from the National Health and Nutrition Examination Survey I (NHANES I) to assess the relationship between weight change and coronary heart disease among 1,581 elderly white men and women. Weight change was calculated as the percentage change between initial weight measurements in 1971-75 and weights measured in 1982-84 (aged 70 to 86 years). These changes were categorized into three groups: weight gain of 10% or more, loss of 10% or more, and gain or loss of less than 10%, with this relatively stable group used as the reference group. These three groups were combined with three groupings of BMI in 1982-84 ("current BMI") to assess whether current BMI modified the effect of weight change on risk for heart disease. It was found that historic weight (baseline weight) and not current weight, was associated with increased risk of heart disease for both men and women. In addition those currently heavy individuals who experienced weight gain also faced increased risk of heart disease while weight gainers with lower levels of current weight did not.

Recently Lahmann *et al* [Lahmann 2005] in the European Prospective Investigation into Cancer and Nutrition Study (EPIC) examined the relationship between weight change and breast cancer incidence among 98,352 women. The investigators used the difference in weights of study participants between their enrollment into the study and at age 20 years, with stable weight defined as a weight difference of less than 2 kg over that time period. Weight gain was positively associated with breast cancer risk among post-menopausal women not concurrently undergoing hormone replacement therapy.

Galanis *et al* [Galanis 1998] in the Honolulu Heart Study examined the effect of weight change on cardiovascular disease risk among 6,176 Japanese-American men. They used recalled weights at 25 years and two weight measurements spaced roughly six years apart when the participants were in late middle age (mean age at first examination was 54 years). Differences between consecutive weight values were computed and grouped according to six weight change categories in the "early weight change" (age 25 years to first examination) with cut-points of -5, -2.5, 2.5, 5 and 10 kg. Five weight change categories were defined in the "late weight change" (first examination to second examination) with cut-points of -2.5, -1.0, 1.0, and 2.5 kg. Results of survival analyses suggested increased risk for heart disease among subjects with larger weight gains during the early weight change and increased risk for those with larger weight losses during the late weight change.

In the British Regional Heart Study, Wannamethee *et al* [Wannamethee 2002] examined the effect of weight change and weight cycling during a 12- to 14-year period on subsequent mortality of 5,608 men aged 40-59 years in two dozen British towns. They divided weight change between three examinations (Q1 initial screening, Q5 five years after screening, and Q92 examination in 1992, 12- to 14-years after initial screening) into five groups: "stable" (less than 4% change from Q1 to Q5 to Q92), "sustained gain" (stable-gain, gain-stable, or gain-gain, with gains of at least 4% between examinations), "sustained loss" (stable-loss, loss-stable or loss-loss, with losses of at least 4% between examinations), "loss-gain" and "gain-loss". Initial BMI at screening, smoking history to Q92, longest-term occupation (proxy for social class), physical activity at Q92, and self-reported pre-existing disease and self-reported health at Q92 were adjusted for in Cox survival models examining the effect of weight change on eight-year all-cause and cardiovascular mortality after examination Q92. Once factors such as pre-existing disease were accounted for, no evidence was found to suggest men experiencing weight loss or weight cycling (loss-gain or gain-loss) were at any greater risk of all-cause or cardiovascular mortality than men with a history of stable weight.

Lazarus *et al* [Lazarus 1998] in the Normative Aging Study investigated the temporal relationship between obesity and fasting insulin blood levels among 376 male subjects, mean age 62 years. Differences in weight measurements between four successive examinations (times T1 to T4), were used to compute rates of change in weight or "weight slopes" over time (ΔWt1, ΔWt2, and ΔWt3). Change in insulin levels, between times T2 and T3, were related to the weight slopes through adjusted regression models, initially as an outcome and subsequently as a predictor, in an attempt to determine the temporal direction of possible relationships. The authors found that temporality could not be deduced since weight gain (ΔWt2) appeared to predict increasing insulin levels during that period but also rising insulin levels appeared to predict weight gain in the subsequent period (ΔWt3).

2.2.3 Summary Measures Using Means and Variability

In the Johns Hopkins Precursors Study, a longitudinal investigation of cardiovascular disease among 1,337 former medical students during 1948-64 at Johns Hopkins, Brancati *et al* [Brancati 1999] assessed the risk of incident type 2 diabetes as well as the relative predictive abilities of seven weight measures. Characterizing weight patterns of the cohort over the thirty years from age 20 to 50 years, the seven measures included BMI at ages 25, 35, and 45 years, BMI change between age 25 and 45 years, maximum BMI over the entire thirty year period, BMI variability defined as the mean sum of squared differences between reported weights and predicted weights using the entire cohort's weights at those ages, and an "average BMI" measuring the duration and magnitude of BMI for each individual (modified sum of BMIs divided by 30 years). BMI measures were each divided into four groups, in the case of BMI at 25, 35, and 45 years, cut-offs were used based on the distribution of BMI at 35 years, while true quartiles were used for the other weight measures. The authors found that BMI at age 25, BMI at age 45 and average BMI to age 50 years were highly predictive of incident diabetes. Overweight men (BMI of at least 25.0), as determined by any of those three measures, had a three-fold greater adjusted risk of diabetes than their normal weight counterparts. In models adjusted for the other weight measures, BMI at age 45 and average BMI appeared to be the most predictive of the seven weight measures for incident diabetes.

Blair *et al* [Blair 1993], in the Multiple Risk Factor Intervention Trial, examined the effect of weight change on all-cause and cardiovascular mortality among 10,529 men aged 35 to 57 years at baseline from 22 centers in the U.S. with mean follow-up of 3.8 years. These men, at high risk for but without clinical evidence of cardiovascular disease, were divided into two groups: "usual care" (UC) and "special intervention" (SI). Over a 6- to 7-year period, weight was measured at annual examinations for the UC group, while weight measurements were taken every 4 months for the SI group. The investigators used two methods for measuring weight variability: the standard deviations of weight measurements for each study participant (referred to as the ISD or "intrapersonal standard deviation of weight") divided into quartiles and the use of five weight-change categories - no change (gains or losses less than 5% of body weight), steady loss (at least 5% loss), steady gain (at least 5% gain), cycle-loss (gain followed by loss) and cycle-gain (loss followed by gain). Through Cox proportional hazards modeling using the ISD method for characterizing weight change, it was found for those in the lowest tertiles of baseline BMI, men whose weight remained stable had the lowest risk for all-cause and cardiovascular mortality than their counterparts whose weight changed. Models were adjusted for a variety of factors including age, race, intervention group, smoking history, diastolic blood pressure, alcohol consumption, activity level, serum cholesterol, and BMI.

Men in the highest ISD quartile faced an almost two-fold relative risk of death compared to those in the lowest, weight-stable quartile. Even with participants diagnosed with disease during the examinations period excluded from analyses, using the weight change categorization method, men with sustained weight loss or whose weight cycled were at 1.5 to 1.89 times greater risk of death than men with stable weight change.

Lissner *et al* [Lissner 1991] investigated the relationship of variability in weight with subsequent all-cause and cardiovascular mortality, and cardiovascular and cancer morbidity among 1,351 men and 1,779 women of the original cohort of the Framingham Study, mean baseline ages 42.8 and 43.8 years respectively. The authors derived a weight coefficient of variation for each subject using weight measurements at the first eight biennial examinations and a recalled weight at age 25 years, taking the ratio of the standard deviation of the subject's nine BMI values by his or her mean BMI value. In addition, to account for the overall magnitude of each subject's BMI values and magnitude and direction of linear trend in those BMI values, the authors included variables for "level" (mean BMI) and "slope" (change in BMI per year) in their proportional hazards models. In so doing, it was possible for the authors to control the effect of higher weight levels on the likelihood of weight cycling and separating systematic weight change from the random or periodic weight fluctuation that was of particular interest in this study. Separate analyses were performed for men and women, adjusting for age, baseline smoking, systolic blood pressure, cholesterol, glucose tolerance and physical activity level. To prevent possible influence of pre-existing disease on weight, the investigators allotted a four-year window, and in a re-run of their analyses using a six-year window, between the last weight measurements and the beginning of the twelve- to fourteen-year follow-up period. Weight variability was found to be a strong predictor of mortality and non-cancer morbidity, especially among the youngest sub-cohort, 30-44 year old men and women, with relative risks ranging between 1.27 and 1.93 relative to weight-stable individuals. The authors noted the relative risks of weight variation on mortality and morbidity were similar to those due to obesity as reported by other researchers, and hence recommended that overweight individuals be counseled not just on losing weight but also on maintaining weight loss and preventing weight loss relapse.

Yatsuya *et al* [Yatsuya 2003] investigated the relationship between weight fluctuation and fasting serum insulin levels among 1,932 male Japanese workers aged 40-59 years who participated in annual work-site health examinations since 1997. The authors defined a weight fluctuation index by taking the root mean square errors of regression lines using five or six weight measurements for each individual and placing the individuals into quartiles using study-specific cut-points. BMI at baseline and at age 20 years were used as covariates in analysis of variance models along with smoking, alcohol consumption and physical activity. Weight fluctuation was shown to increase the risk of developing hyperinsulinemia, with differences in risk greater among those with baseline BMI of at least 25.0 compared to their lower weight counterparts.

Similarly, Tamakoshi *et al* [Tamakoshi 2003], in another study with colleagues from and using the original cohort as the Yatsuya study mentioned earlier, investigated the relationship between weight variability and levels of C-reactive protein (CRP), a key inflammatory marker associated with heart disease. Weights of 637 of the men at the Japanese manufacturing plant, aged 40-49 years at study completion, were measured at five different times (age 20, 25, and 30 years, and later at study completion and five years previous). The authors derived measures of weight variability by fitting regression lines to the five weight measurements for each participant, obtaining weight trend ("weight-slope") and weight fluctuation ("weight-RMSE", root mean square error about the slope) values for each subject. Suggesting this to be the first population-based study of long-term weight variability and serum CRP levels, the authors observed that upper normal-weight, overweight or obese participants had higher prevalences of elevated CRP levels compared to lower weight participants, even after controlling for pre-existing health conditions associated with elevated CRP levels. Participants in the highest quartiles for weight-slope had higher risk of elevated CRP levels than those in the lowest (referent) quartile, especially for men with BMI of 25.0 or greater. Only among those men with BMI below 25.0 did higher weight fluctuation, given by weight-RMSE, confer higher risk for elevated CRP levels relative to those with least weight fluctuation.

Dyer *et al* [Dyer 2000], in the Chicago Western Electric Company Study, examined the relationship between weight change and weight variability among 1,281 male participants aged 40 to 55 years at the beginning of an 8-year observation period. They assessed all-cause and cardiovascular mortality during a 15-year follow-up period and repeated their analysis for the subsequent 10-year follow-up period. Individuals from the original study were included if they had a minimum of five weight measurements during the observation period, did not change smoking status and did not experience incident coronary heart disease or cancer during that time. The authors fit individual regression lines to the BMI values of the participants, calculating slope or trend variables characterizing weight gain or weight loss, as well as variation variables derived from the standard deviations of BMI values and the standard deviations about the regression lines. From the analysis using a 15-year follow-up period, men with BMI gains or losses of at least 0.12 kg/m^2 per year had an increased risk of all-cause mortality relative to men with stable weights over the observation period. In addition men with that size weight loss had a 25% greater risk of cardiovascular death. However in the analysis of the subsequent 10-year follow-up period, neither weight gain nor weight loss conferred a statistically significant increased risk of all-cause or cardiovascular mortality, suggesting the effects of weight loss and weight gain on mortality likely did not persist far into the future. Weight variability, independent of weight gain or loss, showed no difference in relative risk for all-cause or cardiovascular mortality using either the 15-year or subsequent 10-year follow-up analysis.

2.2.4 Summary Measures Estimating Durations

Janssen *et al* [Janssen 2004] used data from the Third National Health and Nutrition Examination Survey (NHANES III) to assess the relationship between duration of overweight with metabolic health risk. Using a single measured weight and single recalled weight from 10 years previous for each of 2,285 male and 2,589 female participants, the authors calculated BMIs, categorizing them into overweight (BMI $\geq$ 25) and normal weight categories (18.5 $\leq$ BMI < 25). If a participant's BMI remained in the overweight category at both time points, the overweight duration was "$\geq$ 10 years", if overweight at the first time point but normal weight at the second the duration was deemed "< 10 years", otherwise the duration was considered normal weight throughout. Logistic regression models were developed with abdominal obesity, hypertension, hypertriglyceridemia, low HDL-cholesterol, metabolic syndrome, insulin resistance and Type 2 diabetes as outcomes, stratifying on sex and adjusting for age, race, socioeconomic status, physical activity, smoking and alcohol consumption. Men overweight for at least 10 years faced a two-fold risk of hypertriglyceridemia and metabolic syndrome compared to their normal weight counterparts, while women overweight for at least 10 years faced a two- to seven-fold increase in risk in all of the metabolic disorders except for abdominal obesity compared to normal weight women.

Sakurai *et al* [Sakurai 1999] in the Sotetsu Study reported on an investigation of 1,598 male railway employees aged 30 years and older, relating duration of obesity with incident non-insulin dependent diabetes. Weights were measured at 5-year examinations starting at age 20 for a period of between twenty and thirty years. Using the person-years method of calculating duration of obesity, for each subject durations at each weight measurement were set to five years and summed to yield total durations in the "ordinary obese" (BMI at least 25 but less than 27.8) and "extreme obese" (BMI at least 27.8) categories. Logistic regression models controlled for age, current obesity, physical activity, smoking status, alcohol use, family history of diabetes and observation period. The authors observed the risk for diabetes increased with greater duration of obesity, with those experiencing up to ten years of "ordinary obesity" at a risk almost three times higher, and those up to twenty years in that obesity category at an almost ten-fold risk, compared to their never-obese counterparts.

2.3 Measures of Successful Aging

Although the term "successful aging" has been used increasingly in the gerontological literature over the past four decades, it is far from universally defined. Phelan and Larson [Phelan 2002], in a review of published literature presenting definitions and predictors of successful aging, observed that "no single, uniform, operational definition of 'success' has been adopted". Citing the work of Havighurst and Albrecht [Havighurst 1953], Ryff [Ryff 1982], Rowe and Kahn [Rowe 1987][Rowe 1997], Baltes and Baltes [Baltes 1990], Schulz and Heckhausen [Schulz 1996], Strawbridge *et al* [Strawbridge 1996], and Roos and Havens [Roos 1991], they described "successful aging" as a multidimensional concept that, depending on the researcher, embodies one or more of the following elements:

- life satisfaction
- longevity
- freedom from disability
- mastery/growth
- active engagement with life
- high/independent functioning (including high physical, cognitive, and social functioning or lack of dependency or need of assistance), and
- adaptation

Phelan and Larson further noted that while some researchers consider elements like physical activity, social engagement, and freedom from chronic illness as part of their definitions of successful aging, others view these as predictors of successful aging.

Despite efforts for more encompassing definitions of successful aging, recent epidemiologic studies continue to view the aging process in the context of the presence (or absence) of disease and disability. Newman *et al* [Newman 2003] in the Cardiovascular Health Study which recently found a negative relationship between subclinical cardiovascular disease and likelihood of maintaining successful aging, defined successful aging for the purposes of its investigation as "remaining free of major, life-threatening chronic disease and having normal physical and cognitive functioning". Not surprisingly, the introduction to that report began with the quotation "a man is as old as his arteries". Others like Vita *et al* [Vita 1998], have examined cumulative disability, testing the compression-of-morbidity hypothesis put forward by Fries [Fries 1980] [Fries 2002] almost twenty-five years ago. They concluded that smoking, body mass index and exercise patterns in midlife and late adulthood predict onset and duration of disability in later life.

At the other end of the spectrum, there has been growing interest in examining the elderly's views and perceptions of successful aging. Tate *et al* [Tate 2003b] asked the elderly cohort of the Manitoba Follow-up Study the open-ended question "What is your definition of successful aging?" A content analysis identified twenty themes, with 30% of responses relating to health and disease and 28% involving a "happy life or satisfying lifestyle".

Knight and Ricciardelli [Knight 2003] surveyed a small cohort of 60 elderly Australians aged 70-101 years using a semi-structured interview and concluded that, when asked for an open-ended definition, most participants provided only one or two criteria but when prompted with themes, most participants ranked as highly important almost all criteria previously reported in the literature. Health and activity were the two major themes emerging from this study each given by at least 50% of participants, while personal growth, happiness/contentment, close personal relationships, and independence were each reported by at least 20% of participants. Almost 70% of respondents felt that "old" is more an attitude than an indication of one's chronological age.

Phelan *et al* [Phelan 2004] used a cross-sectional survey of two relatively well-educated and health-conscious elderly cohorts from Washington state, including one consisting of Japanese Americans, asking participants to rate the importance of twenty attributes extracted from a review of the successful aging literature. In all, thirteen attributes spanning four dimensions of health (physical, functional, psychological and social) were rated as important to successful aging; "being able to take care of myself until close to the time of my death", "remaining in good health until close to death" and "remaining free of chronic disease" were each recognized as important by over 90% of both cohorts.

2.4 Linking Weight Patterns to Successful Aging

There is a broad gap in the literature linking weight patterns and successful aging. As mentioned earlier, numerous studies have demonstrated strong associations between summary measures of weight patterns and mortality and chronic disease but few have looked at linking summary measures of weight patterns during middle age to broader measures of successful aging.

Some investigations have examined the relationship between weight and "health-related quality of life" (HRQOL), following the WHO's definition of "health" as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" [WHO 1946]. HRQOL refers to the "physical, psychological, and social domains of health, seen as distinct areas that are influenced by a person's experiences, beliefs, expectations, and perceptions", and "reflects an individual's subjective evaluation and reaction to health or illness" [Kolotkin 2001]. Using survey instruments measuring physical and mental functioning, such as the Medical Outcomes Trust Short Form-36 (SF-36) [Ware 1992] or weight-related quality of life instruments, numerous studies have focused on clinical settings, often involving surgical interventions and treatments.

From reviews of studies on HRQOL and obesity [Fontaine 2001][Kolotkin 2001][Kushner 2000], there appears to be a positive association between increasing BMI and HRQOL impairment. Physical domains of functioning, rather than mental health domains, are most influenced by increasing weight levels. The reviews cited the work of Doll *et al* [Doll 2000] and Han *et al* [Han 1998] who each examined the relationship between a single BMI and SF-36 scores of the participants in their respective studies.

Doll *et al* received questionnaires from 8,889 men and women surveyed within the old Oxford Regional Health Authority in 1997, 18 to 64 years, and found that physical, but not emotional, well-being declined with increasing level of overweight, even when accounting for age, sex and self-reported co-morbid conditions. The authors also found a linear increase in the proportion of subjects who reported longstanding illness from those who were underweight to those morbidly obese.

Han *et al* collected single BMI and waist circumference measurements and responses to SF-36 questionnaires from 1,885 men and 2,156 women, 20 to 59 years, in the 1995 cohort of the Monitoring Risk Factors and Health in the Netherlands study. Categorizing the SF-36 scores into binary variables ("good" vs "poor"), their logistic regression models adjusted for age, lifestyle factors (smoking, alcohol, physical activity) and demographic factors (education, employment, marital status, household composition, social contacts). Physical functioning declines were associated strongly with increased BMI, declines in mental functioning much less so.

Three papers of particular interest looking at quality of life measures relating to weight patterns over time, outside of interventional settings are Fine *et al* [Fine 1999], Daviglus *et al* [Daviglus 2003] and Strandberg *et al* [Strandberg 2003], the latter two involving weight patterns of middle-aged men and quality of life in later life. Table 2.1 provides a brief methodological overview of their work.

TABLE 2.1: Literature review matrix of articles of interest relating weight patterns with outcomes in later life.

Authors	Sample	Weight Measures	Covariates	Outcome Measures
Fine et al (1999) Nurses' Health Study	45,375 women	1972 baseline, self-reported in 1992, 1994, 1996	Baseline BMI Age Physical activity Smoking Alcohol Diagnosis in 1992 of obesity-related conditions: diabetes, hypertension, hypercholesterolemia, arthritis Diagnosis between 1992 and 1996 of obesity-related conditions listed above	1992, 1996: SF-36 Seven of eight SF-36 domains (not General Health due to omission of items in 1992 questionnaire)
Daviglus et al (2003) Chicago Heart Association Detection Project in Industry Study	3,830 men 2,936 women	1967-1973: Single baseline BMI value	Baseline: Smoking Education EKG abnorms. SBP Serum cholesterol Race 1996: Age	1996: HSQ-12 (eight domain scores and prevalences of twelve individual items)
Strandberg et al (2003)	1,657 men born 1919-1934, healthy and employed in 1974 (mostly business executives), socioeconomically homogeneous 1,147 responded in 2000	1974: Measured weight, recalled weight at 25y 1986: Measured weight * Analyses used weight difference between 1974 (avg age 47y) and at 25y	1974: Smoking Alcohol Self-rated health Self-rated physical fitness 2000: Age Self-reported weight	1974-2000: Total mortality (national registry) 2000: SF-36 (eight domain scores)

2.4.1 Fine *et al*

Fine *et al* [Fine 1999], using data from 45,375 female participants in the Nurses' Health Study, related weight change over a 4-year period with quality of life based on the SF-36 survey instrument. Weights were self-reported in 1992, 1994, and 1996 and questionnaires incorporating the SF-36 instrument were administered in 1992 and 1996.

Stratifying on baseline age (< 65 and ≥ 65 years) and BMI (< 25.0, 25.0-29.9, 30.0-34.9 and ≥ 35.0), the authors looked at weight at baseline and weight change over the 4-year period in relation to seven of the eight domains of the SF-36. They found that across all domains, scores declined steadily with increasing baseline weight, regardless of baseline age.

The investigators then categorized weight change from 1992 to 1996 into three groups: "weight losers", having a net loss of at least 5 lbs over the four-year period and no gain of at least 5 lbs during either of the two-year periods (1992-1994, 1994-1996); "weight gainers", with a net gain of at least 5 lbs over the four-year period and no loss of at least 5 lbs during either of the two-year periods; and "weight maintainers", having weight in 1996 within 5 lbs of weight in 1992 and a net loss/gain of no more than 5 lbs. Potential weight-cyclers were excluded from the analysis, as were participants who developed cancer or cardiovascular disease during the observation period, thereby controlling for underlying disease as a possible cause of weight loss and function decline. Covariates included smoking status in 1992, physical activity, alcohol consumption, age, and obesity-related comorbid conditions – diabetes, hypertension, hypercholesterolemia, and arthritis – existing prior to 1992 and developing between 1992 and 1996.

The authors found that regardless of age, weight gain was consistently associated with declines in several physical domains, including physical functioning, vitality and pain while weight loss was associated with improved physical functioning and decreased bodily pain. Weight change was less strongly associated with domains related to mental health.

2.4.2 Daviglus *et al*

Daviglus *et al* [Daviglus 2003] reported on an analysis from the Chicago Heart Association Detection Project in Industry Study, linking single baseline BMI values of men and women with their self-assessed quality-of-life responses obtained during follow-up twenty-six years later. The quality-of-life responses encompassed dimensions of physical and mental functioning. The authors stated that "to our knowledge, the relation of body mass index earlier in life to future quality of life, particularly in older age, has not been examined".

Baseline measurements, which also included demographic and clinical data, were collected between 1967 and 1973 from 39,522 adult men and women. The follow-up quality-of-life responses were obtained using the 12-item Health Status Questionnaire (HSQ-12) mailed in 1996 to surviving participants 65 years and older. The HSQ-12 addressed eight domains, similar to the SF-12 and SF-36 instruments. Sample size for the analysis consisted of 6,766 individuals – 3,830 male and 2,936 female.

Chi-square and F tests were performed, confirming significant differences between all baseline variables and BMI level, categorized using normal weight ($18.5 \leq \text{BMI} < 25$), overweight ($25 \leq \text{BMI} < 30$) and obese ($\text{BMI} \geq 30$). General linear models were developed for each of the eight group mean HSQ-12 domain scores and prevalences of favorable/adverse outcomes for the twelve HSQ-12 individual items with BMI category as a class variable. Models were adjusted for age in 1996, race, and baseline smoking status, electrocardiographic major/minor abnormalities, education level attained, systolic blood pressure and serum cholesterol level. Multivariate linear and logistic regression were used, with BMI as a continuous variable, to detect trends in the group mean HSQ-12 domain scores and prevalence of favorable/adverse item scores respectively.

Across all eight of the HSQ domains and the twelve individual quality-of-life items, significant trends were found, with less favorable domain scores and higher prevalence of adverse item outcomes with increasing BMI. The investigators acknowledged that study limitations included using single baseline BMI values and large but understandable loss of follow-up between participant contacts.

2.4.3 Strandberg *et al*

Strandberg *et al* [Strandberg 2003] investigated the long-term relationship between body weight and weight gain during midlife with mortality and quality of life among 1,147 Finnish men having similar baseline socioeconomic status, born between 1919-1934. The study used baseline weights at age 25 years recalled in 1974 when the average age of participants was 47 years, two measured weights in 1974 and 1986, and a self-reported weight in 2000. Weight gain from age 25 years to 1974 was divided into four quartiles: gain of 4.0 kg or less, 4.1-9.0 kg, 9.1-14.9 kg and 15.0 kg or greater. To consider potential weight loss and associated subclinical disease, the first quartile was further subdivided into two subgroups: loss or no gain, and gain of 0.1-4.0 kg.

Quality of life was assessed using a Finnish version of the RAND-36, a variation of the SF-36 instrument, administered by mail in 2000. Each of the eight domain scores was related to the weight differences between age 25 years and in 1974, as described earlier. Note that BMI was only mentioned in the baseline characteristics of the sample, and was not used in any of the analyses.

With the exception of Mental Health, the remaining seven of the eight SF-36 domain scores were significantly different between groups defined according to weight change, with more favorable scores obtained by those with the least weight change. Total mortality was not predicted by baseline weight but was by weight difference, with prevalence highest among those with greatest mid-life weight difference.

2.5 Conceptual Framework

A conceptual framework for this thesis is proposed in Figure 2.1. Based on the preceding literature review, the underlying premise is that overweight and obesity during middle age might have deleterious direct effects on elements of successful aging (eg. survival to an advanced age, physical and mental functioning, self-assessment of successful aging). Causal pathways are complex as excessive weight during middle age may have indirect effects on successful aging via mediating factors such as the development of chronic disease (eg. cardiovascular disease, hypertension, diabetes, cancer). The relationship of overweight and obesity with these factors may be bi-directional since weight during middle age may be affected by these factors earlier in life.

One would expect demographic factors such as sex and age and social/lifestyle factors such as smoking and occupation to also have adverse effects on successful aging

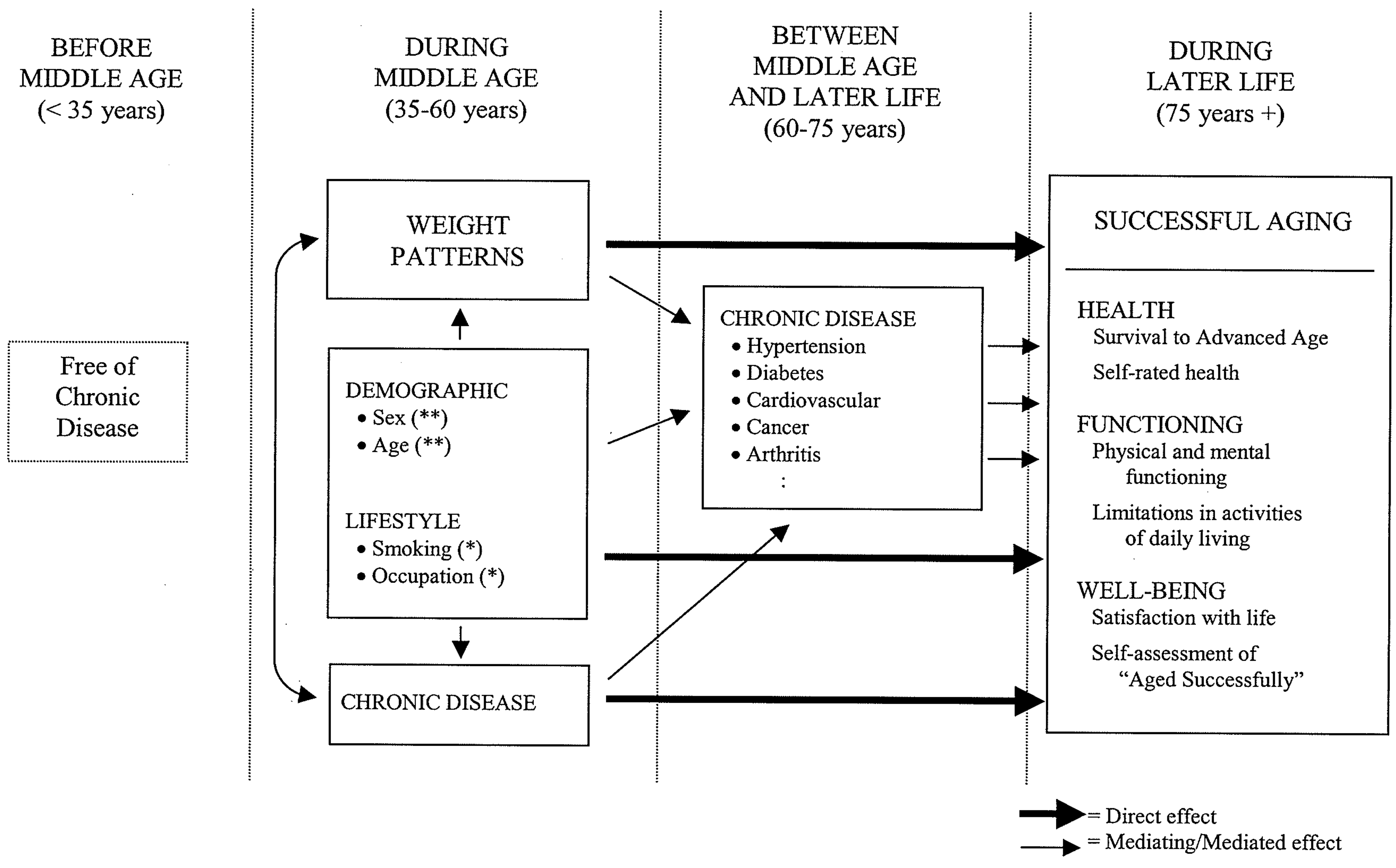


Figure 2.1: Proposed Conceptual Framework.

independent of weight patterns. These factors may also directly influence the development of excessive weight and mediating factors. Klesges [Klesges 1989] in a review of 70 cross-sectional and longitudinal studies concluded that smokers weigh less than non-smokers, those who quit smoking gain weight and non-smokers who start smoking lose weight. Indeed Manson *et al* [Manson 1987] in a review of twenty-five major prospective studies on the relationship between weight and mortality found that many of them failed to control for smoking. Sobal [Sobal 1991] makes the case that socioeconomic factors such as education, income, occupation, sex and ethnicity, through caloric intake and energy expenditure, as well as indirectly through smoking may influence weight gain or loss.

There are arguably many pathways linking weight patterns during middle age and successful aging. This thesis examines the direct effect of weight on successful aging, while controlling for some possible direct effects (demographics and lifestyle) and some mediating factors (chronic disease). Smoking and occupation are controlled through regression modeling. Age and sex are controlled by virtue of the study design, constraining weight data to a common age window for all subjects in an all-male cohort.

Consistent with the literature reviewed in this chapter, weight patterns in the current project are characterized using the following simple summary measures as well as a novel measure assessing weight patterns by incorporating duration and trend:

- BMI at age 35 years
- BMI at age 60 years
- Minimum BMI
- Maximum BMI
- Mean BMI

Following the review by Phelan and Larson [Phelan 2002], these measures of successful aging are used in the current project:

- Survival to an advanced age
- Self-rated health
- Physical and mental functioning
- Limitations in activities of daily living
- Life satisfaction
- Self-report of "Aged Successfully"

Survival to an advanced age corresponds with "longevity", self-rated health and limitations in activities of daily living with "freedom from disability", measures of physical and mental functioning with "high/independent functioning (including high physical, cognitive and social functioning)", and life satisfaction with "life satisfaction".

2.6 Summary

Although considerable work has been reported in the literature relating individual weight measurements with mortality and disease morbidity and some relating weight patterns with chronic disease and mortality, very little has been reported relating weight patterns with a broader range of measures of successful aging. Chapter Three, Methodology, describes the approach taken in the current research project to investigate some of those possibilities.

Chapter Three
METHODOLOGY

3.1 Overview

The current research project investigated the relationship between longitudinal weight patterns in men during middle age with measures of successful aging in later life. This was accomplished through an analysis of prospectively collected data from the Manitoba Follow-up Study. Weight measurements recorded between the ages of 35 and 60 years were used to characterize weight patterns for each subject through simple summary measures commonly used by other researchers. A novel method was also developed combining the concepts of duration and trend for subject-specific patterns. Successful aging was assessed using several outcome measures reported in the literature, including survival to an advanced age, self-rated health, physical and mental functioning, limitations in daily activities, life satisfaction and self-assessed successful aging.

Summary weight measures were used as the independent variables in regression models for predicting successful aging outcomes, adjusted for smoking status, occupation history, and age. As outcome variables included both categorical and continuous variables, multiple logistic regression and multiple linear regression were used.

This chapter continues with a description of the data source used, including a brief background of the Manitoba Follow-up Study and a step-by-step explanation of the sample selection process for both subjects and weight measurements. A detailed description of the algorithm devised to classify longitudinal weight patterns, an outline of the existing variables used and new variables created, and details about the regression analyses that were performed are then given.

3.2 Data Source: The Manitoba Follow-up Study

Data for the current research project came from the longitudinal dataset of the Manitoba Follow-up Study (MFUS). This dataset was used as MFUS is one of the longest running studies to prospectively follow a cohort of men, collecting body build and clinical data from the same cohort for over fifty years, spanning a sizable part of the adult lives of these individuals. In addition, MFUS has provided a view into the aging process by administering a series of questionnaires over the past decade examining issues of successful aging among the cohort.

The Manitoba Follow-up Study was founded in 1948 by Dr. Francis A. L. Mathewson, a Winnipeg physician and graduate of the University of Manitoba medical college. During World War II, Dr. Mathewson served as deputy director of medical services for the Royal Canadian Air Force and was responsible for overseeing the examination of about 7,000 aircrew recruits. Shortly after the war Dr. Mathewson invited many of these men to participate in a long-term study initially designed to investigate the prognostic significance of the electrocardiogram to predict subsequent cardiovascular disease.

On July 1, 1948 the cohort of the Manitoba Follow-up Study was sealed, consisting of 3,983 apparently healthy male aircrew recruits. The mean and median age at baseline was 31 years, with 90% of the cohort between 20 and 39 years of age. Since its inception, the Manitoba Follow-up Study has been housed in the Faculty of Medicine at the University of Manitoba [Mathewson 1987].

A key component of the Manitoba Follow-up Study has been the collection of routine medical examinations and documentation of clinical events. Routine examinations were initially conducted every five years until 1963 and every three years thereafter. Since the beginning of the study, routine examinations have been performed by the study members' own physicians. These examinations recorded weight, systolic and diastolic blood pressure and adverse health conditions, as well as the results of general cardiovascular assessments and the recording of electrocardiograms.

Weight and blood pressure measurements at these examinations, as well as MFUS physician-coded clinical conditions and electrocardiograms, have been stored in the MFUS database. Heights were measured at each examination but only baseline heights were recorded in the database.

An equally integral component of the Manitoba Follow-up Study has been the ongoing contact made with study members by MFUS personnel, thereby confirming the vital status of the cohort and monitoring intervening health conditions requiring further follow-up and documentation. For the first 30 years to 1978, return postcards were mailed to all the men, with mailings staggered so that half the cohort would receive a postcard one year, the other half the following year. Since 1978, a one-page questionnaire has been mailed annually to study members. In 1996, with the cohort's average age approaching 75 years, contact was increased to twice a year.

Thanks in great part to the persistent efforts of MFUS staff and volunteers, at present the vital status of all but 2% of the original cohort is known. At July 2005, 1,148 men were alive at a mean age of 84 years. Over 90% of the men live in Canada, dispersed throughout the country with a geographic distribution comparable to the general Canadian population. The MFUS database is substantial, with 173,580 person-years of follow-up, including 79,552 weight measurements and 86,622 clinical entries after 57 years of follow-up. The MFUS database up to July 1, 2005 was used for the current project.

Over the course of the study, a number of surveys have been administered, inquiring about a variety of characteristics of the cohort. In 1974, a survey was mailed asking about smoking status, family history of disease, and work history, while another survey mailed in 1982/1984 asked again about those issues as well as physical activity and stress experienced during the war. In the mid-1990s, with the aging of the MFUS cohort, interest within the Manitoba Follow-up Study was expanded to examine issues about aging. To that end, MFUS developed a nine page Successful Aging Questionnaire (SAQ) and administered it for the first time by mail in 1996 (SAQ-1996). This survey appears as Appendix I. The SAQ, essentially in its original form with different add-in questions was mailed again in 2000, 2002, 2004, 2005 and 2006.

In addition to questions about living arrangements and leisure time activities, the SAQs have included core questions about:

- Physical and mental functioning
- Limitations in activities of daily living
- Self-rated health
- Life satisfaction
- Definition and self-assessment of successful aging

Physical and mental functioning were evaluated by embedding the suite of thirty-six questions of the SF-36 in the SAQ [Ware 1992]. Limitations in activities of daily living were assessed by including questions from the Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) series [Katz 1963]. Self-rated health and life satisfaction were single questions with Likert scale responses, while a subjective measure of successful aging was derived using two questions, one a yes/no question asking whether subjects felt they had aged successfully and the other an open-ended question asking respondents to define what successful aging meant to them.

Height at baseline, weight measurements over time, smoking status and previous work history reported in 1982/1984, clinical and mortality data from the MFUS database (up to July 1, 2005) and responses to the aforementioned core questions from the SAQ-1996 were used for the current research project.

3.3 Use of Body Mass Index

The current research project utilized Body Mass Index (BMI) in assessing weight patterns, computed as the weight in kilograms of an individual divided by his height in meters squared. Although some researchers maintain that other anthropometric measures such as skinfold thickness, waist circumference, waist-to-hip ratio, or percentage of visceral adipose tissue are better measures in assessing body composition, BMI is a widely used measure of weight status in population studies [Janssen 2002] and is "the most useful indicator, to date, of weight-related health risk" [Health Canada 2003]. Due to the availability of only weight and height measurements in the MFUS dataset and the generally accepted utility of BMI in population studies, BMI was the sole anthropometric measure used in the current research project.

For all analyses, BMI values were categorized using the World Health Organization's classification system [WHO 1998]:

BMI (kg/m^2)	**Category**
Under 18.5	Under weight
18.5 – 24.9	Normal weight
25.0 – 29.9	Overweight
30.0 and over	Obese

The WHO classification system also includes several sub-categories of obesity such as Obesity I (BMI 30.0 – 34.9) but as there were very few obese individuals in MFUS, only one obesity category was used for the current project.

3.4 Sample Selection

Subjects and their weight data for the current project were selected from the MFUS database in such a way as to take weight measurements during an "age window" common to all men spanning middle age and maximizing the number of weight measurements available for analysis. The age window that fulfilled these requirements was from age 35 to 60 years, hereafter referred to as the "35-60 year age window".

This window closely approximated middle age, that relatively stable period generally between early adulthood and retirement. For many men in the MFUS cohort, this period would have marked their return from the war, "settling down" with marital and family responsibilities, the establishment of post-war careers and possible adoption of relatively stable dietary, physical activity and other lifestyle patterns.

Restricting analysis to this age window ensured that all men contributed weight measurements over the same age range, hence age was controlled as a possible confounder through the study design. Since approximately half of the men were 31 years or younger at entry to the study, this age window also provided the greatest number of weight measurements available for analysis.

Additional selection criteria included the following conditions:

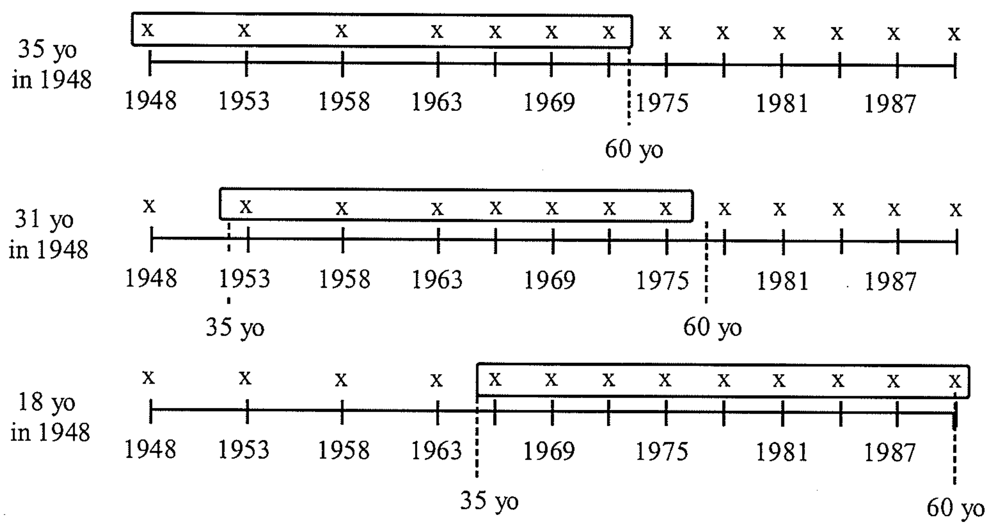
- Men had to be alive and enrolled in the study during the entire 35-60 year age window;

- Men had to be free of disease at age 35, including cardiovascular disease, diabetes and cancer;
- Each man selected needed to have had a sufficient number of weight measurements to characterize his weight pattern. A minimum of seven weight measurements in the 35-60 year age window were required, thereby assuring, on average, one weight measurement for every three years during that period;
- Weight measurements recorded during the 35-60 year age window had to have been distributed relatively uniformly throughout the period, avoiding large gaps between consecutive weight measurements during the twenty-five year period;
- Occupation data had to be available for each man during the age window.

The criterion for selecting only men who were disease-free at age 35 years was a commonly used selection criterion in studies described in Chapter Two, Literature Review and Conceptual Framework.

The criterion of selecting only individuals with at least seven weight measurements recorded in the 35-60 year age window was considered reasonable as the MFUS study protocol specified that examinations were requested every five years during the first fifteen years of the study (1948-1963), and thereafter every three years. As Figure 3.1 illustrates, at one end of the spectrum, men 35 years old at entry to the study in 1948 (who would have been 60 years old in 1973) would have had at least seven weight measurements in the 35-60 year age window: a baseline measurement, at least three measurements in the fifteen years from 1948-1963, and at least three more measurements

Figure 3.1: Three scenarios illustrating selection of weight measurements.



during 1963-1973. At the other extreme, most men 18 years of age at entry (and consequently 35 years old in 1965 and 60 years old in 1990) would have had at least seven weight measurements during the twenty-five year period 1965-1990 if they adhered to the MFUS protocol of routine examinations every three years after 1963. More typically, men who had baseline ages somewhere between 18 and 35 years would also have had at least seven weight measurements in the 35-60 year age window.

To ensure that all men had weight measurements spanning the entire 35-60 year age window, all available weight measurements during that period were used for each man. Two additional weights were estimated on each man's 35th and 60th birthdays, unless he happened to have had measurements taken on either of those days. Estimation was done by linear interpolation using the two closest weight measurements on either side of those birthdays, providing those measurements were within five years of the birthday in question. If only one close measurement was available, then the value of that measurement was assigned as the weight at the birthday. Height data, necessary to calculate BMI values, were taken from baseline measurements.

Table 3.1 lists the inclusion criteria used in the step-by-step selection process and the numbers of men and weight measurements available after each step. By applying these selection criteria, 2,298 men contributing 31,274 weight measurements were selected for weight pattern characterizations and regression analysis. Of these, 1,438 responded to the SAQ-1996 and were used for analysis of outcomes from the SAQ-1996.

Table 3.1: Data selection process.

Step #. Inclusion Criteria	Number of Men	Number of Weight Measurements
0. All possible data in database	3,983	79,552
1. Lived to age 60 during 1948-1996	3,432	72,824
2. 35th birthday occurred in 1948-1996	2,797	59,262
3. Free of disease at age 35	2,767	58,713
4. Weights within 1948-1996	2,767	49,518
5. Weights in 35-60 year age window	2,767	29,794
6. At least 7 weights in age window	2,416	27,824
7. Gaps between all adjacent weights < 7 years	2,337	27,110
8. Weights near age 35 and 60 years for interpolation	2,322	26,971
9. After interpolation at age 35 and 60 years	2,322	31,609
10. Employment data in 35-60 year age window	2,298	31,274
11. Responded to SAQ-1996	1,438	19,627

Just over half of the men in the sample had at least ten measurements during the 35-60 year age window, providing on average a weight measurement every two years (Table 3.2). Some of these men maintained pilot licences, which required yearly physical examinations. The two samples had virtually identical distributions of numbers of weight measurements.

Table 3.2: Distribution of numbers of weight measurements.

Numbers of Weight Measurements During 35-60 Age Window/Man (excludes interpolated values)	Men Selected for Analysis (n=2,298) Number (%)	Men Selected Responding to SAQ-1996 (n=1,438) Number (%)
7 – 9	1,033 (45.0)	645 (44.9)
10 – 14	681 (29.6)	413 (28.7)
15 – 19	454 (19.8)	295 (20.5)
20 – 24	96 (4.2)	66 (4.6)
25 or more	34 (1.5)	19 (1.3)

3.5 Characterization of Weight Patterns (Objective 1)

Weight patterns were characterized for each of the 2,298 men (Step 10 of Table 3.1) through the use of simple summary measures commonly used in other studies. A method was also developed within the current project combining elements of duration and trend to describe each man's weight pattern.

3.5.1 Simple Summary Measures – BMI_{35}, BMI_{60}, BMI_{MIN}, BMI_{MAX}, BMI_{AVG}

Using all BMI values available during the age window, BMI at age 35 (BMI_{35}) and 60 years (BMI_{60}), as well as the minimum (BMI_{MIN}), maximum (BMI_{MAX}) and mean BMI (BMI_{AVG}) were identified for each subject and used separately as five simple summary measures for BMI patterns. Each simple summary measure was categorized as underweight, normal weight, overweight or obese using the WHO classification system described earlier.

3.5.2 Classifying Longitudinal Weight Patterns Using Duration and Trend

Intuitively, classifying longitudinal weight patterns should in some way incorporate a sense of magnitude and direction. For example a weight pattern between age 35 and 60 years could be described as "mostly normal weight and steady", or "overweight and increasing", or "predominantly obese with no discernible pattern". A classification system should be meaningful with relevant and easily interpreted categories, while being practical with a relatively small number of non-overlapping categories suitable for outcomes modeling. Such a system was developed as part of the current project by incorporating the concepts of duration and trend in classifying individual weight patterns.

The classification system involved the following series of steps that determined for each man the predominant duration weight category and overall trend of his weight pattern:

1. Determine the predominant weight category during the 35-60 year age window, based on durations in each WHO weight category: underweight, normal weight, overweight or obese
2. Assess the curvilinear nature of the weight pattern: quartic, cubic, quadratic, linear, constant or no best fit determined by least squares regression
3. Deduce the general trend of the weight pattern: steady, increasing, decreasing, cycling, or no discernible trend

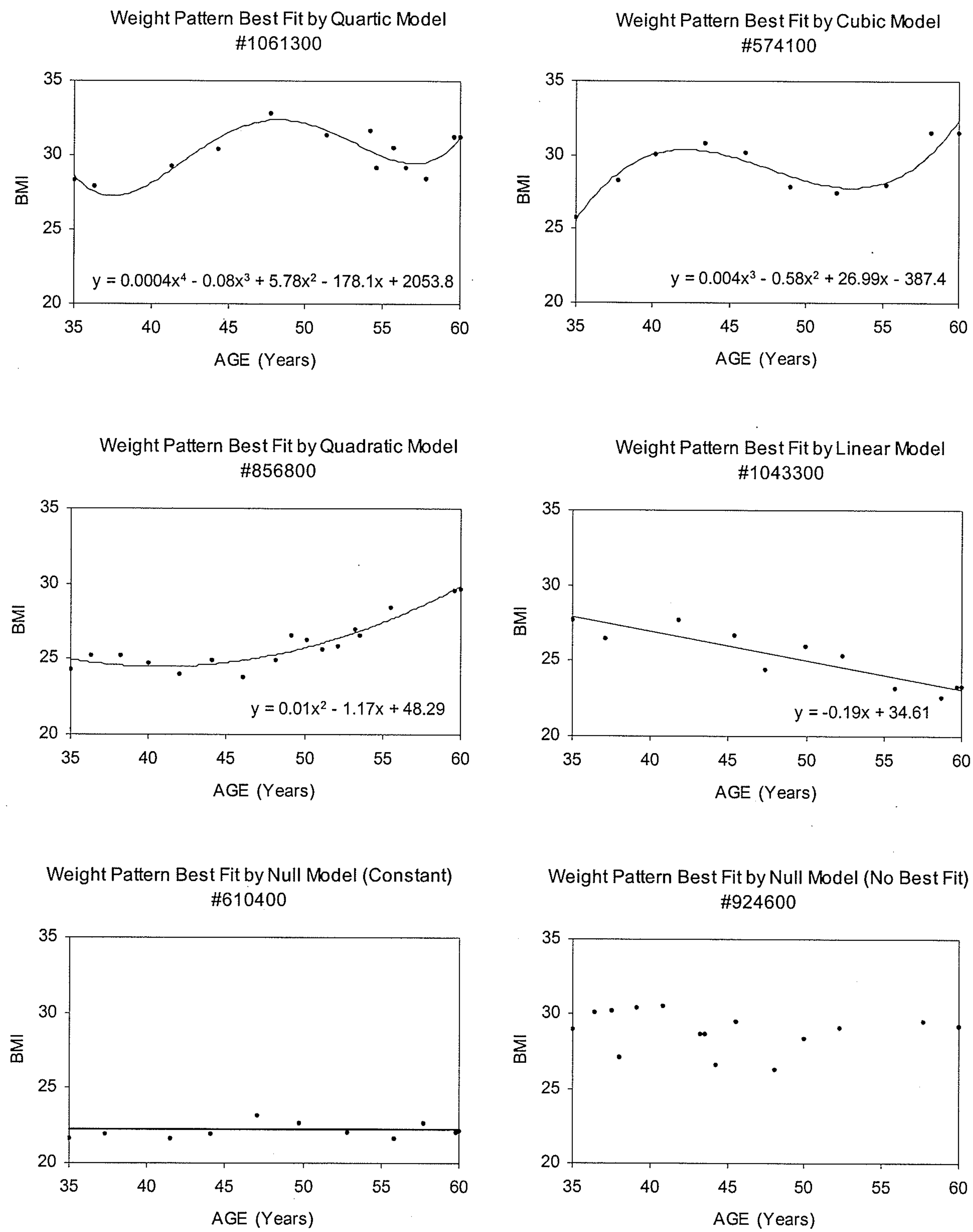
In Step One, durations or cumulative times that a subject was in each WHO weight category were calculated, with the category having the greatest time selected as the predominant weight category. Durations in BMI categories were estimated by stepping through each pair of adjacent BMI values, beginning at age 35 years, and computing the amount of time during that interval a given individual was in each weight category. This was calculated by assuming a linear fit between adjacent BMI values and computing where that straight line intersected each weight category and equating that with a duration. These times were summed over all adjacent BMI pairs resulting in total durations in each weight category. Relative durations were calculated by dividing the total durations by 25 years, the total time of the 35-60 year age window. Finally, the predominant duration weight category for that subject was determined as that WHO weight category having the longest duration.

For example, if a man had BMI measurements of less than 25.0 kg/m^2 (normal weight) over the first five years from age 35 – 40 years and 25.0 or greater (overweight) for the next fifteen years from age 40 – 55 years, and 30.0 or greater (obese) for the last five years until age 60 years, that man would have been classified as "predominantly overweight" during the 35-60 year age window, with fifteen out of twenty-five years in the overweight category.

The second step assessed the curvilinear nature of each weight pattern by fitting quartic, cubic, quadratic, and linear curves to the BMI values over time for each man. The best fit was determined by least squares regression with a SAS program written by the author using PROC REG to derive polynomial coefficients for each of the four curve fits and a series of calls to PROC GLM comparing the statistical significance of improvements between all pair-combinations of the quartic, cubic, quadratic, linear and null models. Each model's sum of squares and degrees of freedom were used to compute F-values and hence level of significance for difference in model fits, determining the best fitting model.

In the event none of the four polynomials fit the data, the null model was selected as the best fitting model. In such a case, a further test was performed to determine if the pattern was truly an indiscernible ("no fit") pattern or a minimally changing, horizontal ("constant") one; if the standard deviation of the BMI values about the regression line was less than or equal to 1.0 kg/m^2 the pattern was classified as "constant", otherwise it was classified as "no fit". Figure 3.2 illustrates examples of the six possible curve fits using actual BMI data from six study subjects.

Figure 3.2: Examples of the six possible least-squares curve fits of weight patterns, from actual data.



The third step consisted of determining the general trend of each weight pattern, ultimately assigning each pattern to one of five trend categories: "steady", "increasing", "decreasing", "cycling", or "no discernible trend". This was done by a SAS program written by the author that first classified each best-fit curve from Step Two into one of twenty-four curve families that described all possible curve orientations. To accomplish this, the program systematically identified all global and local maximum and minimum BMI values during the 35-60 year age window, in essence all the "peaks and valleys" in the pattern, and with the initial best-fit curve determination from Step Two, assigned the pattern to one of the curve families. Examples of the curve families included "quadratic, concave-up, with full decline, full incline", "cubic, with incline, decline, incline" and "quartic, w-shaped". Finally, depending on the family selected and location of global extrema, each pattern was placed into one of the five trend categories: "steady", "increasing", "decreasing", "cycling", or "no discernible trend".

3.6 Measures of Successful Aging (Objective 2)

Successful aging was operationalized using the following outcomes:

1. Survival to an advanced age
2. Self-rated health
3. Physical and mental functioning (SF-36)
4. Limitations in activities of daily living (ADL, IADL)
5. Ability to climb several flights of stairs and walk several blocks
6. Life satisfaction
7. Self-report of "Aged Successfully?"

As justified in Chapter Two, Literature Review and Conceptual Framework, these outcome variables were used as they paralleled the elements of successful aging identified in the review by Phelan and Larson [Phelan 2002]. In addition, two outcomes indicative of physical limitations, incorporated in the SF-36 series – ability to walk several blocks and ability to climb several flights of stairs – were also used.

All outcome variables except for survival to an advanced age were derived from responses to the SAQ-1996 (n=1,438); survival to an advanced age was determined from mortality data in the MFUS database (n=2,298). As described in Chapter Four, Results, the distributions of sample characteristics and longitudinal weight patterns were almost identical between the two samples. Hence it was reasonable to perform analyses on what may have appeared as two different datasets.

Each of the outcome variables are now described in more detail.

3.6.1 Outcome Variables – Survival to an Advanced Age (OUT_SURV75)

For the purpose of the current project, survival to an advanced age was defined as surviving to at least 75 years of age before July 1, 2005, the date of the most recent data used for the current project. This also corresponds to the year in which the youngest man at entry to the study, eighteen years of age in 1948, would have had his 75th birthday. A binary variable (OUT_SURV75) using the date of death and birthdate fields in the MFUS database was constructed representing the two possible outcome values – "1" for "survived to 75 years" or "0" for "did not survive to 75 years". As mentioned earlier, this was the only outcome variable that was not derived from the SAQ-1996.

Survival to an Advanced Age (75 years)	***OUT_SURV75***
Description	Value
YES, survived to an advanced age (75 years)	1
NO, did not survive to an advanced age (75 years)	0
Missing values coded	None possible

3.6.2 Outcome Variables – Self-Rated Health (OUT_SRHe)

Self-rated health has been reported to be a valid and reliable measure of health status among the elderly. It was included on the first page of the SAQ-1996 as a multiple-choice question with Likert scale responses as follows:

How would you describe your health compared to others your age?

1. Excellent
2. Good
3. Fair
4. Poor
5. Bad

A binary variable (OUT_SRHe) was derived from the original variable, with "1" representing "Excellent" and "0" otherwise. Missing values were possible for non-responses.

Self-Rated Health	***OUT_SRHe***
Description	Value
"Excellent"	1
"Good", "Fair", "Poor" or "Bad"	0
Missing values coded	yes

3.6.3 Outcome Variables – Physical and Mental Functioning (OUT_PCS and OUT_MCS)

Indicators of physical and mental functioning were determined using the SF-36 survey instrument, embedded in its entirety on pages 5 through 9 of the SAQ-1996. As mentioned earlier, this instrument has been widely used in health research to assess functioning in diverse populations, including the elderly.

The SF-36 consists of a series of thirty-six items, assessing the following eight multi-item health domains (abbreviated names and numbers of SF-36 items for each domain in parentheses) [Ware 1992]:

- limitations in physical activities due to health problems (PH, 10 items)
- limitations in social activities due to physical or emotional problems (SF, 2 items)
- limitations in usual role activities due to physical problems (RP, 4 items) and emotional problems (RE, 3 items)
- bodily pain (BP, 2 items)
- general mental health (MH, 5 items)
- vitality (VT, 4 items) and
- general health perceptions (GH, 5 items)

Each of the thirty-six items are scored on Likert response scales. Scores for the eight domains are derived by adding the scores of the applicable items and scaling those raw scores to a value between 0 and 100, with 100 corresponding to the best possible health state, zero the worst and 50 the expected median score of a reference population.

In the event of missing responses, a weighted average of non-missing data items are calculated, provided a sufficient number of such items are available within a domain subset [Ware 1993].

Internal consistency for the eight domains of the SF-36 series in the SAQ-1996 was verified by the author during the current project by calculating Cronbach's alpha using SPSS 11.0. The values were $\alpha = 0.93$ (n=1,668), 0.89 (n=1,695), 0.84 (n=1,750), 0.79 (n=1,685), 0.87 (n=1,732), 0.87 (n=1,741), 0.80 (n=1,670) and 0.77 (n=1,738) for the physical functioning, role physical, bodily pain, general health, vitality, social functioning, role emotional and mental health domains respectively.

In addition to the eight domain scores, the SF-36 allows for the calculation of physical (PCS) and mental component scores (MCS). All scores are standardized to a scale from 0 to 100, with 100 being the optimal score.

As an example, the following two questions comprise the bodily pain domain:

> How much bodily pain have you had in the past 4 weeks ?
> *(Response choices: None ... Very Severe)*
>
> During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework) ?
> *(Response choices: Not at all ... Extremely)*

Values of 1 (None) to 6 (Very severe) for the first question and 1 (Not at all) to 5 (Extremely) for the second would be scored and the sum of the two values would yield a raw score for the bodily pain domain. This raw score would then be standardized producing a value for bodily pain between 0 and 100.

SF-36 Physical and Mental Component Scores (PCS and MCS)	***OUT_PCS OUT_MCS***
Description	Value
Continuous values	0 - 100
Missing values coded	yes

3.6.4 Outcome Variables – Activities of Daily Living (ADL and IADL) (OUT_ADL and OUT_IADL)

Limitations in daily activities were assessed using the Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) question series, embedded on page 4 of the SAQ-1996. These questions have been validated by their developers to ascertain limitations in activities of daily living [Katz 1963]. Internal consistency of these questions on the SAQ-1996 were verified by the author during the current project by calculating Cronbach's alpha. Using all responses to the ADL and IADL questions resulted in $\alpha = 0.92$ (n=1,451) and 0.85 (n=1,622) respectively.

The ADL series consisted of sixteen items, answered on a Yes/No basis. It began with the preamble "Are you capable of … without any help from anyone else" and listed activities like:

… going up and down the stairs
… dressing and putting shoes on
… washing or bathing or grooming
… getting up out of a chair and walking 3 meters

The IADL series, comprised of nine items and also answered on a Yes/No basis, asked the same question as the ADL but with activities like:

… doing light housework (washing up, dusting, etc.)
… doing heavy housework (cleaning floors, windows)
… preparing a hot meal
… shoveling and yardwork

ADL and IADL summary scores are derived by summing over the number of "No" responses in each of the series. The lower the scores the better, with maximum ADL and IADL scores being 16 and 9 respectively. For analysis purposes, these summary scores were dichotomized into Yes/No variables, depending on whether they exceeded commonly used cut-off values: ADL equal to zero (OUT_ADL) and IADL equal to zero or one (OUT_IADL).

Limitations in Activities of Daily Living (ADL)	***OUT_ADL***
Description	Value
No limitations	1
One or more limitations	0
Missing values coded, only if all 16 missing	yes

Limitations in Instrumental Activities of Daily Living (IADL)	***OUT_IADL***
Description	Value
At most one limitation	1
Two or more limitations	0
Missing values coded, only if all 9 missing	yes

3.6.5 Outcome Variables – Ability to Climb Several Flights of Stairs and Ability to Walk Several Blocks (OUT_STAIRS and OUT_WALKBLOCKS)

Activity limitations were also assessed using two of the ten questions in the SF-36 that asked whether the respondent's health limits him in a variety of activities. The two questions selected referred to being able to climb several flights of stairs or walking several blocks. These variables were originally coded on a three-point scale – "Yes, Limited a Lot", "Yes, Limited a Little" and "No, Not Limited at All". They were recoded into binary variables indicating unencumbered ability to perform those activities, a "1" representing "No limits" and "0" for "Limited at least a little".

Able to Climb Several Flights of Stairs Without Health Limitations	***OUT_STAIRS***
Description	Value
Yes - "Not limited at all"	1
No - "Limited a lot" or "Limited a little"	0
Missing values coded	yes

Able to Walk Several Blocks Without Health Limitations	***OUT_WALKBLOCKS***
Description	Value
Yes - "Not limited at all"	1
No - "Limited a lot" or "Limited a little"	0
Missing values coded	yes

3.6.6 Outcome Variables – Life Satisfaction (OUT_LSe)

The SAQ-1996 asked the following question on page 3 to assess respondents' sense of life satisfaction:

How would you describe your satisfaction with life in general at present?

1. Excellent
2. Good
3. Fair
4. Poor
5. Bad

Unlike other instruments that have examined life satisfaction, this was just a single item on the SAQ-1996 and therefore could not be tested for reliability. It was however felt to provide face validity and no further tests of validity were performed on this item. As with Self-Rated Health, the responses for Life Satisfaction were coded using a binary variable (OUT_LSe) with "Excellent" coded as "1" and all else as "0".

Life Satisfaction	***OUT_LSe***
Description	Value
"Excellent"	1
"Good", "Fair", "Poor" or "Bad"	0
Missing values coded	yes

3.6.7 Outcome Variables – Self-Assessment of Aged Successfully (OUT_SA)

Study members in the very last question of the SAQ-1996 were asked:

Would YOU say you have "AGED SUCCESSFULLY" ?

This was presented as an open-ended question and responses were coded into "Yes", "No", "Yes but", "No but" and "Don't know". A binary variable (OUT_SA) was created setting "1" for those who answered "Yes" and "0" otherwise (those answering "Yes but", representing less than 10% of respondents, were placed in the "0" category). Like Life Satisfaction, this single-question item could not be tested for reliability, would appear to have face validity and was not tested further for validity. The immediately preceding question asking "What is YOUR definition of successful aging ?" was included in the SAQ-1996 but data from it was not used in the current project.

Self-Assessed Aged Successfully ?	***OUT_SA***
Description	Value
"Yes"	1
"No", "Yes but …", "No but …" or "Don't know"	0
Missing values coded	yes

3.7 Relating Weight Measures with Successful Aging Outcomes – Statistical Analysis (Objective 3)

3.7.1 Variables Identified for Potential Confounding

Three variables were controlled as potential confounders in regression analyses for the current project. They were:

- Occupation history during the 35-60 year age window
- Smoking status during the age window
- Age in 1996

Occupation history was controlled as a potential confounder as occupation could well play a role in the relationship between weight patterns and successful aging outcomes. To account for both long-term activity and income level of each man, the 1982 survey was used to derive an occupation profile of each individual prior to retirement. The MFUS database contains occupation history data from surveys administered in 1974 and 1982/84, which asked respondents to indicate what line of work they were employed in since 1945. Prior to the current research project, responses had been coded into occupation groups and data-entered. A SAS program was written as part of the current project to determine the occupation group that each study member had been employed in for the longest (not necessarily continuous) period during the 35-60 year age window. These were placed into five categories (a sixth category for "occupation history unavailable" was used to exclude those members during the selection process).

Longest Held Occupation During 35-60 Year Age Window	***OCCUPATION_CODE***
Description	Value
Longest held position < 10 years	0
Pilot, at least 10 years	1
Aviation/Non-pilot, at least 10 years	2
White collar, at least 10 years	3
Blue collar, at least 10 years	4

A relationship exists between smoking and weight status, in that smoking tends to contribute to lower weight and smoking cessation often leads to weight gain [Klesges 1989]. Consequently smoking was controlled by using the results of the 1974 and 1982 surveys which asked about smoking status. In it, subjects were asked whether they had ever smoked and if so when they started, and if they had ever quit, and if so when they had quit. A SAS program was written by the author to use this data and determine how long each member smoked during the 35–60 year age window and placed each individual in one of five categories, depending on the duration smoked.

Smoking History During 35-60 Year Age Window	***SMOKING_HISTORY***
Description	Value
Did not smoke during period	0
Smoked, < 12.5 years (half of the period)	1
Smoked, at least 12.5 years, but not entire period	2
Smoked, entire period	3
Unknown	9

Finally, age was controlled in modeling to ensure that the effect of age differences between the youngest and oldest members of the selected samples might be accounted for. In reality, there was a very tight range of ages in the sample, with 80% of the men falling between 72 and 78 years of age at the time of the SAQ-1996. Age at entry (AGEENT) was used as a proxy for age at SAQ-1996, allowing age to be controlled in all models.

3.7.2 Regression Modeling

Univariate and bivariate descriptive statistics were generated during the exploratory phase of the analysis. To assess selective mortality, sample characteristics and BMI summary measure distributions were compared between survivors and those dying prematurely. Multiple linear regression and logistic regression were used to develop models using each BMI summary measure in turn as a predictor variable, adjusting for the controlled variables, with each measure of successful aging as an outcome variable. For all regression models, unadjusted and adjusted models were generated, with the reference category being "Normal Weight" when using the simple weight summary measures and "Normal Weight/Steady" for the weight summary measures using duration and trend.

Logistic regression was used with the categorical outcome variables: survival to an advanced age, limitations in activities of daily living, self-rated health, life satisfaction, and "Aged Successfully". Linear regression was used in the case of continuous outcome variables, namely the SF-36 component scores.

A power analysis was conducted to determine minimum sample size required to detect statistically significant and clinically meaningful results from regression analyses in the Manitoba Follow-up Study. The analysis found that approximately 2,000 subjects provide sufficient power to detect small to moderate associations [Tate 2003a]. This was in agreement with the anticipated sample size of the current project.

3.8 Programming Considerations

Data manipulation programming and statistical analyses were conducted using *SAS* Version 8.2 (SAS Institute Inc., Cary, NC), while some statistical reporting and graphics were performed with *SPSS* Version 11.0 (SPSS Corporation, Chicago, IL). The author wrote SAS programs for derivation of variables including smoking status, occupation history and chronic disease assessment, data selection, construction of weight pattern summary measures, reporting and regression modeling. SAS programs were written to facilitate modification of parameters and structured into modules for simple code maintenance and re-use.

3.9 Summary

The current research project related weight patterns during middle age with measures of successful aging in later life through the use of a series of regression models. Predictor variables were derived from a set of measures characterizing weight patterns of the men over the 35-60 year age window. Outcome variables were comprised of a series of measures of successful aging derived primarily from the 1996 Successful Aging Questionnaire. Confounding variables such as smoking and occupation history, and age were controlled in the regression modeling.

Chapter Four
RESULTS

4.1 Overview

The current research project addressed the question of what relationship exists between longitudinal weight patterns of men during middle age and outcomes of successful aging in later life. This question was explored through the following three objectives:

1. To determine weight patterns during middle age
2. To operationalize outcomes of successful aging in later life and
3. To relate those weight pattern characterizations with successful aging outcomes

After a description of the sample characteristics, this chapter presents the results of each of the three objectives.

4.2 Sample Characteristics

Sample characteristics are presented in Table 4.1. At the beginning of the study in 1948 the average age of subjects selected for the current project was just under 29 years. Forty-eight years later, the mean age of respondents of the SAQ-1996 was 76 years, with approximately 90% of respondents between 71 and 80 years. This relatively tight age range helped allay any concerns that age might be a factor affecting successful aging outcomes. Nevertheless, age at entry to the study in 1948, related linearly to the age at mailing of the SAQ-1996, was included in all regression models to control for possible age effects.

Table 4.1: Sample characteristics.

Characteristic	Men Selected for Analysis (n=2,298) Mean ± SD [Range] or Number (%)	Men Selected Responding to SAQ-1996 (n=1,438) Mean ± SD [Range] or Number (%)
Mean age at July 1, 1948	28.7 ± 3.1 [18.0, 37.9] [1]	28.1 ± 3.0 [18.7, 36.3] [1]
Mean age at SAQ-1996 mailing	–	76.0 ± 3.0 [66.5, 84.1]
Age: 66-70 years	–	29 (2.0)
71-75	–	640 (44.5)
76-80	–	646 (45.0)
81 or older	–	123 (8.5)
Smoking status during age 35-60 years		
Did not smoke	595 (25.9)	448 (31.2)
Smoked, but less than 12.5 years	401 (17.5)	276 (19.2)
Smoked, 12.5 to less than 25 years	530 (23.1)	357 (24.8)
Smoked, entire duration	697 (30.3)	331 (23.0)
Unknown	75 (3.3)	26 (1.8)
Longest-held occupation during age 35-60 years		
Longest position < 10 years	153 (6.7)	98 (6.8)
Pilot, at least 10 years	661 (28.8)	400 (27.8)
Aviation/non-pilot, at least 10 years	253 (11.0)	160 (11.1)
White collar, at least 10 years	800 (34.8)	535 (37.2)
Blue collar, at least 10 years	431 (18.8)	245 (17.0)

[1] Includes 18 and 6 men selected with baseline weight measurements taken prior to July 1, 1948, prior to the SAQ-1996 and responding to the SAQ-1996 respectively. These men were consequently older than 35 years at July 1, 1948 but selected for analysis as they met all other selection criteria.

About a quarter of the men did not smoke at any point during the 35-60 year age window, with the remainder about evenly split between the three smoking categories: smoked for less than half the period, smoked for more than half the period but less than the entire period, or smoked throughout the entire period of middle age.

During middle age, about a third of the men in the sample worked predominantly in white collar occupations, such as sales or management. This was almost matched by the number who were employed as professional pilots during middle age, many who flew for commercial airlines after the war. These occupations might be considered generally higher-paying, more sedentary and more stressful than blue collar occupations, which represented about 20% of the men.

As described in Chapter Three, the data used for analyses was comprised of two samples – one a sample of 2,298 men used to assess survival to an advanced age and the second a sub-sample of the first comprised of the 1,438 men who completed the SAQ-1996. It is evident that most of the characteristics were very similar between the two samples, particularly the mean age at the beginning of the study, some components of the distribution of smoking status and the distribution of longest-held occupations.

The numbers of men who did not smoke during middle age differed, with roughly 5% more non-smokers among the SAQ respondents. Also there were 7% fewer men who smoked throughout the entire period among the SAQ respondents. This could possibly be explained by the "survivor effect", where some longtime smokers may have succumbed at younger ages than non-smokers, as well as the possibility that some longtime smoking survivors did not answer the SAQ because of health or other reasons.

4.3 Results of Objective 1: Characterization of Weight Patterns

4.3.1 Simple Weight Summary Measures

Five simple weight summary measures were examined, measures commonly used in studies reported in the literature: BMI at the beginning and end of the period of observation (ie. at age 35 and 60 years), as well as the minimum, maximum and mean BMIs during the period. The distributions of all five measures were virtually identical between the larger sample and the subset sample of SAQ-1996 respondents (Table 4.2).

Very few men were underweight or obese during the period, with only 2% of the sample ever being underweight and 13% ever being obese. Almost 60% of the men at age 35 years were normal weight but by age 60 years this dropped to about forty percent, the others gaining weight and becoming either overweight or obese. From the mean BMI, the sample was about equally split between normal weight and overweight men.

Table 4.2: Simple weight summary measures, grouped according to the World Health Organization's categorization system.

Weight Summary Measure During Age 35-60 years	Men Selected for Analysis (n=2,298) Mean ± SD or Number (%)	Men Selected Responding to SAQ-1996 (n=1,438) Mean ± SD or Number (%)
BMI, at Age 35 years	24.6 ± 2.6	24.5 ± 2.5
Underweight	10 (0.4)	7 (0.5)
Normal weight	1,324 (57.6)	837 (58.2)
Overweight	909 (39.6)	568 (39.5)
Obese	55 (2.4)	26 (1.8)
BMI, at Age 60 years	25.7 ± 2.9	25.7 ± 2.7
Underweight	11 (0.5)	4 (0.3)
Normal weight	981 (42.7)	608 (42.3)
Overweight	1,126 (49.0)	725 (50.4)
Obese	180 (7.8)	101 (7.0)
BMI, Minimum	23.5 ± 2.4	23.5 ± 2.3
Underweight	45 (2.0)	25 (1.7)
Normal weight	1,693 (73.7)	1,064 (74.0)
Overweight	546 (23.8)	344 (23.9)
Obese	14 (0.6)	5 (0.4)
BMI, Maximum	27.1 ± 2.8	27.0 ± 2.6
Underweight	0 (0.0)	0 (0.0)
Normal weight	486 (21.2)	303 (21.1)
Overweight	1,502 (65.4)	950 (66.1)
Obese	310 (13.5)	185 (12.9)
BMI, Mean	25.4 ± 2.4	25.3 ± 2.3
Underweight	0 (0.0)	0 (0.0)
Normal weight	1,071 (46.6)	677 (47.1)
Overweight	1,127 (49.0)	709 (49.3)
Obese	100 (4.4)	52 (3.6)

4.3.2 Longitudinal Weight Patterns

To examine the relationship between weight during middle age and outcomes later in life, one would be prudent to examine weight patterns using all longitudinal data available, classifying subjects into readily identifiable patterns. These patterns should be both meaningful and usable, providing an easily interpreted set of patterns representative of the variety of patterns encountered in the sample while providing a practical set of patterns that could subsequently be used as predictors in regression modeling.

As detailed in Chapter Three, an algorithm was devised resulting in the characterization of the weight patterns for each man in the study sample and classifying his pattern into weight/trend categories. The first step was to determine the predominant WHO weight category during middle age for each man, that category in which the man had the longest, not necessarily continuous, duration during the 35-60 year age window. Table 4.3 shows that the sample had an approximately equal split of men who were predominantly normal weight and overweight during middle age. Less than 5% were

Table 4.3: Weight summary measure using predominant WHO weight categories.

Predominant WHO Weight Category [1] During Age 35-60 Years	Men Selected for Analysis (n=2,298) Number (%)	Men Selected Responding to SAQ-1996 (n=1,438) Number (%)
Normal weight [2]	1,044 (45.4)	653 (45.4)
Overweight	1,156 (50.3)	730 (50.8)
Obese	98 (4.3)	55 (3.8)

[1] Weight category in which subject had longest, not necessarily continuous duration during age 35-60 years.

[2] Includes the only two subjects classified as predominantly "underweight" (BMI < 18.5).

predominantly obese during middle age, and only two men were deemed predominantly underweight. Upon visual inspection of those two predominantly underweight men's weights and disease profiles, those men were deemed to be sufficiently close to normal weight throughout the period, and subsequently included with the predominantly normal weight subjects.

Table 4.4: Distribution of results of curve fitting of BMI and age.

Best Fitting Curve [1]	Men Selected for Analysis (n=2,298) Number (%)	Men Selected Responding to SAQ-1996 (n=1,438) Number (%)
Quartic, $y=a + bx + cx^2 + dx^3 + ex^4$		
Positive, $e > 0$	83 (3.6)	53 (3.7)
Negative, $e < 0$	83 (3.6)	60 (4.2)
Cubic, $y=a + bx + cx^2 + dx^3$		
Positive, $d > 0$	130 (5.7)	80 (5.6)
Negative, $d < 0$	120 (5.2)	69 (4.8)
Quadratic, $y=a + bx + cx^2$		
Positive, $c > 0$	100 (4.4)	54 (3.8)
Negative, $c < 0$	366 (15.9)	214 (14.9)
Linear, $y=a + bx$		
Positive, $b > 0$	515 (22.4)	331 (23.0)
Negative, $b < 0$	165 (7.2)	100 (7.0)
Null Model		
Constant (slope zero), $y=a$	498 (21.7)	331 (23.0)
No best fit	238 (10.4)	146 (10.2)

[1] The label "positive" refers to curves with positive lead coefficients (ie. coefficient of the highest-order term > 0) and "negative" to those with negative coefficients. Positive curves ultimately increase as x gets larger, while "negative" curves ultimately decrease.

The second step consisted of fitting a series of four polynomials to the BMI values for each man over time, from quartic (fourth degree) down to straight line (first degree) using least squares regression of BMI and age. All combinations of models were compared using each model's sums of squares and degrees of freedom to compute F-values and level of significance, determining the best fitting model, if any, for each subject's BMI pattern with age. Table 4.4 gives the distribution of polynomial fits for the sample data. Although approximately half of the sample's weight patterns were initially best fit by a straight line (linear positive, linear negative or constant due to the null model), the remainder were best fit by higher-order polynomials or did not follow any of those fits. The weight patterns of the remaining half of the sample were best fit by a quadratic (20%), cubic (10%) or quartic (7%), or did not follow a discernible pattern (10%).

The third step consisted of using those best-fit curves and assessing the general trends over the period in question, determining whether weight patterns were "steady", "increasing", "decreasing", "cycling", or "non-discernible". As described in Chapter Three, the best-fit curves were each assigned to one of twenty-four curve families, enumerated in Table 4.5. From there each weight pattern was assigned to one of the five trend categories, based on the orientation of the best-fit curve and location of its extrema. Table 4.6 shows the distribution of the five trend categories and the curve families that comprised each trend category. Approximately half of the men exhibited relatively steady weight patterns throughout middle age, with another quarter with increasing weight, and the remainder split among those whose weight cycled, declined or showed no discernible pattern.

Table 4.5: Distribution of curve families.

Curve Family	Symbol	Curve	Men Selected for Analysis (n=2,298) Number (%)	Men Selected Responding to SAQ-1996 (n=1,438) Number (%)
Constant [1]	CON		498 (21.7)	331 (23.0)
Linear				
Increasing, > 0.2 kg/m^2 /year	Li1		60 (2.6)	35 (2.4)
Increasing, 0.1-0.2 kg/m^2 /year	Li2		235 (10.2)	154 (10.7)
Small change < 0.1 kg/m^2 /year	Li3		319 (13.9)	213 (14.8)
Decreasing, 0.1-0.2 kg/m^2 /year	Li4		58 (2.5)	27 (1.9)
Decreasing, > 0.2 kg/m^2 /year	Li5		8 (0.4)	2 (0.1)
Non-linear, flat	FLAT		217 (9.4)	134 (9.3)
Quadratic, concave-up				
Full decline, full incline	QU1		54 (2.4)	32 (2.2)
No decline, full incline	QU2		23 (1.0)	8 (0.6)
Full decline, no incline	QU3		4 (0.2)	1 (0.1)
Slight decline, full incline	QU4		20 (0.9)	15 (1.0)
Full decline, slight incline	QU5		1 (0.0)	0 (0.0)
Quadratic, concave-down				
Full incline, full decline	QD1		129 (5.6)	73 (5.1)
No incline, full decline	QD2		22 (1.0)	9 (0.6)
Full incline, no decline	QD3		109 (4.7)	67 (4.7)
Slight incline, full decline	QD4		8 (0.4)	4 (0.3)
Full incline, slight decline	QD5		28 (1.2)	18 (1.3)
Cubic				
Incline, decline, incline	Cu1		35 (1.5)	22 (1.5)
Decline, incline, decline	Cu2		30 (1.3)	16 (1.1)
Increasing (no bump)	Cu3		120 (5.2)	84 (5.8)
Decreasing (no bump)	Cu4		48 (2.1)	25 (1.7)
Quartic				
W-shaped	Qt1		17 (0.7)	10 (0.7)
M-shaped	Qt2		17 (0.7)	12 (0.8)
No fit	NoFt		238 (10.4)	146 (10.2)

[1] The null model (ie. constant BMI over time) was the best fitting model for these men.

Table 4.6: Weight summary measure using trend.

Weight Trend During Age 35-60 Years	Men Selected for Analysis (n=2,298) Number (%)	Men Selected Responding to SAQ-1996 (n=1,438) Number (%)
Steady CON, Li3, FLAT	1,034 (45.0)	678 (47.2)
Increasing Li1, Li2, QU2, QU4, QD3, QD5, Cu3	595 (25.9)	381 (26.5)
Cycling Qt1, Qt2, Cu1, Cu2, QU1, QD1	282 (12.3)	165 (11.5)
No Discernible Trend NoFt	238 (10.4)	146 (10.2)
Decreasing Li4, Li5, QU3, QU5, QD2, QD4, Cu4	149 (6.5)	68 (4.7)

Finally, the summary weight measure was derived for each man by combining his predominant WHO weight category with his weight pattern's trend. There were few men in the "decreasing" (6.5%), "cycling" (12.3%) or "no discernible trend" (10.4%) categories, so these were combined with the "increasing" category, forming the trend category "varying weight". Very few men were predominantly obese, so the "obese" category was not combined with the trend categories. Hence the following five weight pattern categories were used: "normal weight/steady", "normal weight/varying", "overweight/steady", "overweight/varying", and "obese". As shown in Table 4.7, each of the first four categories were comprised of approximately a quarter of the sample, with the obese category represented by only about 4% of the sample.

Table 4.7: Weight summary measure combining predominant WHO weight categories and trends.

Predominant WHO Weight Category and Trend During Age 35-60 Years	Men Selected for Analysis (n=2,298) Number (%)	Men Selected Responding to SAQ-1996 (n=1,438) Number (%)
Normal weight, steady	531 (23.1)	346 (24.1)
Normal weight, varying [1]	513 (22.3)	307 (21.4)
Overweight, steady	487 (21.2)	320 (22.3)
Overweight, varying	669 (29.1)	410 (28.5)
Obese, all	98 (4.3)	55 (3.8)

[1] "Varying" comprised of not "steady" (ie. "increasing", "decreasing", "cycling", or "no discernible trend")

4.4 Results of Objective 2: Outcomes of Successful Aging in Later Life

Table 4.8 presents a summary of the successful aging outcomes. All outcomes except for survival to an advanced age came from the SAQ-1996. A high level of positive outcomes were reported, with almost three quarters of the sample surviving to at least 75 years of age, and over three quarters of SAQ-1996 respondents reporting minimal limitations in activities of daily living (ADL and IADL). Approximately one in three respondents rated their health as excellent and a slightly larger number rated their satisfaction with life as excellent. The mean Mental Component Score derived from the SF-36 series was slightly higher (more favorable) than the mean for the general adult population, while the Physical Component Score was slightly lower. Over 80% felt they had aged successfully.

Table 4.8: Successful aging outcomes.

Outcome	Overall Number (%) or Mean ± SD [Range]
Survival to an Advanced Age, 75 Years (n=2,298)	1,686 (73.4)
Excellent Self-Rated Health (n=1,430)	452 (31.6)
Limitations in Activities of Daily Living	
No limitations in Activities of Daily Living (ADL) (n=1,427)	1,197 (83.9)
At most one limitation in Instrumental Activities of Daily Living (IADL) (n=1,427)	1,085 (76.0)
Able to walk several blocks (n=1,403)	1,090 (77.7)
Able to climb several flights of stairs (n=1,412)	847 (60.0)
Excellent Life Satisfaction (n=1,426)	551 (38.6)
"Aged Successfully ?" (n=1,438)	1,228 (85.4)
Physical and Mental Functioning (n=1,359)	
SF-36 Physical Component Score (PCS)	47.0 ± 9.9 [13.1, 63.1]
SF-36 Mental Component Score (MCS)	55.1 ± 7.7 [20.5, 71.7]

4.5 Results of Objective 3: Relationship between Weight Patterns and Successful Aging in Later Life

4.5.1 Simple Weight Summary Measures and Successful Aging Outcomes

Significant differences between normal weight men and their overweight counterparts were noted in limitations in daily living and ability to walk several blocks (Table 4.9). Men who were normal weight on average during middle age had roughly 35% to 50% increased odds of reporting no limitations in Activities of Daily Living (ADL), at most one limitation in Instrumental Activities of Daily Living (IADL), or being able to walk several blocks, compared to overweight men. No differences in survival to an advanced age, self-rated health, life satisfaction, or self-assessed successful aging were observed between normal weight and overweight middle-aged men.

Although relatively few obese men were in the sample under study, especially using the measures BMI_{35}, BMI_{MIN}, and BMI_{AVG}, statistically significant results were found. Based on weights at age 60 years or maximum weight during middle age, normal weight men had almost twice the odds of reporting the same favorable outcomes in later life mentioned above compared to men who were obese during middle age. These results were even more pronounced with the weights at age 35 years and minimum weight during middle age. Men who were normal weight at age 60 years had about a 40% increased odds of surviving to at least age 75 years compared to men obese at that age, and had twice the odds of being able to climb several flights of stairs or feeling they had aged successfully. No differences in self-rated health or life satisfaction were observed between normal weight and obese men using any of the simple summary measures.

Table 4.9: Adjusted odds ratios with 95% confidence intervals for all Successful Aging outcomes using simple weight summary measures for men with normal weight relative to men overweight or obese.[1] (Continued on next page)

Successful Aging Outcome	Normal Weight vs Overweight	Normal Weight vs Obese
Survival to an Advanced Age (75y)		
BMI_{35}	1.10 (0.90, 1.34)	**2.44 (1.38, 4.30)**
BMI_{60}	0.90 (0.74, 1.10)	**1.44 (1.01, 2.05)**
BMI_{MIN}	1.09 (0.87, 1.36)	**4.21 (1.42, 12.5)**
BMI_{MAX}	0.94 (0.74, 1.19)	1.25 (0.90, 1.73)
BMI_{AVG}	1.04 (0.86, 1.27)	**2.26 (1.45, 3.50)**
Excellent Self-Rated Health		
BMI_{35}	1.14 (0.90, 1.44)	1.34 (0.55, 3.25)
BMI_{60}	0.99 (0.78, 1.25)	1.31 (0.81, 2.11)
BMI_{MIN}	1.24 (0.95, 1.63)	1.66 (0.18, 15.1)
BMI_{MAX}	1.05 (0.79, 1.39)	1.36 (0.90, 2.06)
BMI_{AVG}	1.14 (0.90, 1.43)	1.28 (0.68, 2.39)
No limitations in activities of daily living (ADL)		
BMI_{35}	**1.51 (1.12, 2.04)**	**3.94 (1.69, 9.23)**
BMI_{60}	1.34 (0.99, 1.83)	**2.16 (1.27, 3.67)**
BMI_{MIN}	**1.76 (1.28, 2.42)**	3.21 (0.50, 20.7)
BMI_{MAX}	1.29 (0.87, 1.90)	**2.45 (1.50, 4.01)**
BMI_{AVG}	**1.45 (1.08, 1.96)**	**2.86 (1.48, 5.52)**
At most one limitation in activities of daily living (IADL)		
BMI_{35}	1.15 (0.89, 1.49)	**2.55 (1.12, 5.79)**
BMI_{60}	1.15 (0.69, 1.93)	1.24 (0.95, 1.61)
BMI_{MIN}	**1.37 (1.03, 1.82)**	0.53 (0.06, 5.15)
BMI_{MAX}	1.18 (0.86, 1.63)	**1.61 (1.05, 2.48)**
BMI_{AVG}	**1.36 (1.05, 1.76)**	1.39 (0.72, 2.68)

[1] All models adjusted for smoking status and occupation history during age 35-60 years, as well as age at entry to the study.

Table 4.9 (Continued from previous page): Adjusted odds ratios with 95% confidence intervals for all Successful Aging outcomes using simple weight summary measures for men with normal weight relative to men overweight or obese.[1]

Successful Aging Outcome	Normal Weight vs Overweight	Normal Weight vs Obese
Being able to walk several blocks		
BMI_{35}	**1.36 (1.05, 1.78)**	**2.78 (1.22, 6.34)**
BMI_{60}	1.27 (0.96, 1.67)	**2.13 (1.32, 3.45)**
BMI_{MIN}	**1.53 (1.14, 2.04)**	1.92 (0.79, 4.63)
BMI_{MAX}	1.34 (0.95, 1.88)	**1.95 (1.25, 3.05)**
BMI_{AVG}	**1.49 (1.14, 1.94)**	**2.62 (1.41, 4.89)**
Being able to climb several flights of stairs		
BMI_{35}	1.08 (0.86, 1.35)	1.73 (0.77, 3.90)
BMI_{60}	**1.35 (1.07, 1.70)**	**1.99 (1.28, 3.11)**
BMI_{MIN}	1.21 (0.94, 1.56)	0.66 (0.11, 4.11)
BMI_{MAX}	1.18 (0.89, 1.55)	**1.59 (1.08, 2.34)**
BMI_{AVG}	1.24 (0.99, 1.56)	1.77 (0.98, 3.18)
Excellent life satisfaction		
BMI_{35}	0.91 (0.73, 1.13)	1.88 (0.74, 4.78)
BMI_{60}	0.97 (0.77, 1.22)	1.23 (0.78, 1.92)
BMI_{MIN}	1.06 (0.82, 1.37)	1.99 (0.22, 18.2)
BMI_{MAX}	0.83 (0.63, 1.09)	0.96 (0.65, 1.42)
BMI_{AVG}	0.98 (0.79, 1.22)	1.41 (0.76, 2.61)
"Aged successfully ?"		
BMI_{35}	1.08 (0.79, 1.47)	**3.50 (1.48, 8.28)**
BMI_{60}	1.09 (0.79, 1.50)	**2.08 (1.23, 3.53)**
BMI_{MIN}	1.17 (0.83, 1.65)	1.43 (0.14, 14.1)
BMI_{MAX}	1.22 (0.83, 1.80)	1.37 (0.81, 2.31)
BMI_{AVG}	1.16 (0.85, 1.58)	**2.29 (1.16, 4.51)**

[1] All models adjusted for smoking status and occupation history during age 35-60 years, as well as age at entry to the study.

4.5.2 Longitudinal Weight Patterns and Successful Aging Outcomes

The following sections describe in detail the results of regression models performed using longitudinal weight patterns to predict successful aging outcomes. The tables give the results of logistic regression models expressed as odds ratios in the case of binomial outcomes and as linear regression coefficients for the continuous SF-36 summary score outcomes. In all tables showing odds ratios, the odds ratio indicates the odds of the men predominantly normal weight with steady patterns having that outcome compared to men in the other weight pattern category.

4.5.2.1 Longitudinal Weight Patterns and Survival to an Advanced Age

Men who were predominantly normal weight with steady weight patterns during middle age had almost twice the adjusted odds of surviving to at least 75 years, compared to their counterparts who were predominantly obese during that time (Table 4.10). Roughly seventy-five percent of the normal/steady weight men lived to at least 75 years, while only sixty-five percent of the obese men survived to that advanced age.

Results from the unadjusted models were very similar to those from the adjusted models, indicating smoking and occupation history had no effect on the relationship between weight patterns and survival to an advanced age. No evidence was found of significant differences in odds of surviving to an advanced age when comparing normal/steady weight men to the other weight patterns during middle age.

Table 4.10: Odds ratios with 95% confidence intervals for Survival to an Advanced Age (75 years) for men with a normal, steady weight pattern during middle age relative to four other weight patterns.

Weight Pattern	# Survived to 75 years / Total (1686/2298)	%	Unadjusted OR (95% CI)	Adjusted [1] OR (95% CI)
Normal weight, steady	402 / 531	75.7	-	-
Normal weight, varying	367 / 513	71.5	1.24 (0.94, 1.63)	1.22 (0.92, 1.62)
Overweight, steady	373 / 487	76.6	0.95 (0.71, 1.27)	1.00 (0.75, 1.35)
Overweight, varying	480 / 669	71.8	1.23 (0.95, 1.59)	1.25 (0.96, 1.64)
Obese, all	64 / 98	65.3	**1.66 (1.04, 2.63)**	**1.90 (1.17, 3.06)**

[1] Adjusted for smoking status and occupation history during age 35-60 years, as well as age at entry to the study.

4.5.2.2 Longitudinal Weight Patterns and Self-Rated Health

As can be seen in Table 4.11, men who were normal weight with steady weight patterns during middle age had over one-and-a-half times the adjusted odds of reporting excellent self-rated health than either men who were predominantly normal weight or overweight with varying weight during middle age. Approximately forty percent of the normal/steady weight men reported excellent self-rated health while less than thirty percent of the normal/varying weight or of the overweight/varying weight men did.

Odds ratios were very similar between the unadjusted and adjusted models, implying that smoking status and occupation had no effect on the relationship between middle-age weight patterns and self-rated health in later life. No evidence was found of significant differences in odds of that outcome when comparing normal weight/steady men to the other two weight patterns examined during middle age.

Table 4.11: Odds ratios with 95% confidence intervals for Excellent Self-Rated Health for men with a normal, steady weight pattern during middle age relative to four other weight patterns.

Weight Pattern	# Reporting Excellent SRH / Total (452/1430)	%	Unadjusted OR (95% CI)	Adjusted [1] OR (95% CI)
Normal weight, steady	136 / 343	39.7	-	-
Normal weight, varying	87 / 305	28.5	**1.65 (1.18, 2.29)**	**1.64 (1.17, 2.29)**
Overweight, steady	108 / 319	33.9	1.28 (0.94, 1.76)	1.33 (0.97, 1.84)
Overweight, varying	105 / 408	25.7	**1.90 (1.39, 2.59)**	**1.90 (1.39, 2.61)**
Obese, all	16 / 55	29.1	1.60 (0.86, 2.98)	1.70 (0.91, 3.18)

[1] Adjusted for smoking status and occupation history during age 35-60 years, as well as age at entry to the study.

4.5.2.3 Longitudinal Weight Patterns and Activities of Daily Living (ADL)

Limitations in activities of daily living in later life appeared to be more frequent among men who were overweight with varying weight patterns than men with normal/steady weight during middle age. This result was statistically significant only in the unadjusted model, and became insignificant in the model adjusted for occupation history, smoking status and age. Approximately 86% of normal/steady weight men reported being free of limitations in daily activities, as assessed by the ADL measure, while 76% of the obese men reported that outcome.

Table 4.12: Odds ratios with 95% confidence intervals for No Limitations in Activities of Daily Living (ADL) for men with a normal, steady weight pattern during middle age relative to four other weight patterns.

Weight Pattern	# Without Limitations in Activities / Total (1197/1427)	%	Unadjusted OR (95% CI)	Adjusted [1] OR (95% CI)
Normal weight, steady	294 / 342	86.0	-	-
Normal weight, varying	266 / 304	87.5	0.88 (0.55, 1.38)	0.83 (0.52, 1.33)
Overweight, steady	268 / 319	84.0	1.17 (0.76, 1.79)	1.17 (0.76, 1.81)
Overweight, varying	327 / 407	80.3	**1.50 (1.01, 2.22)**	1.49 (0.99, 2.23)
Obese, all	42 / 55	76.4	1.90 (0.95, 3.79)	2.01 (0.99, 4.10)

[1] Adjusted for smoking status and occupation history during age 35-60 years, as well as age at entry to the study.

4.5.2.4 Longitudinal Weight Patterns and Instrumental Activities of Daily Living (IADL)

There was a 70% increased adjusted odds of reporting more than a single limitation in instrumental activities of daily living in later life by men who were overweight with varying weight patterns during middle age compared to men who were normal/steady weight. Over 80% of the normal/steady weight men enjoyed either no or only one limitation in their daily activities, while 72% of the overweight men with varying weight patterns reported that extent of limitation. Smoking and occupation had no effect on the relationship between weight patterns and limitations in IADLs as unadjusted and adjusted odds ratios were quite similar.

Table 4.13: Odds ratios with 95% confidence intervals for At Most One Limitation in Instrumental Activities of Daily Living (IADL) for men with a normal, steady weight pattern during middle age relative to four other weight patterns.

Weight Pattern	# With At Most One Limitation in Activities / Total (1085/1427)	%	Unadjusted OR (95% CI)	Adjusted [1] OR (95% CI)
Normal weight, steady	278 / 342	81.3	-	-
Normal weight, varying	233 / 304	76.6	1.32 (0.91, 1.94)	1.33 (0.90, 1.96)
Overweight, steady	240 / 319	75.2	1.43 (0.99, 2.07)	1.43 (0.98, 2.10)
Overweight, varying	292 / 407	71.7	**1.71 (1.21, 2.42)**	**1.77 (1.24, 2.54)**
Obese, all	42 / 55	76.4	1.34 (0.68, 2.65)	1.36 (0.68, 2.74)

[1] Adjusted for smoking status and occupation history during age 35-60 years, as well as age at entry to the study.

4.5.2.5 Longitudinal Weight Patterns and Ability to Walk Several Blocks

Of all the outcomes in later life examined in the current research project, the ability to walk several blocks without any limitations showed the greatest association with the other weight patterns. Men who were overweight but maintained a steady weight during middle age had a 50% increased adjusted odds of reporting limitations in walking several blocks in later life due to health issues, compared to normal weight men who also maintained steady weight patterns. In addition, men who were predominantly overweight during middle age but with varying weight patterns had almost an 80% increased odds of reporting difficulties with walking several blocks while predominantly obese men had an almost three-fold odds of those difficulties.

Over 80% of the normal/steady weight men had no limitations in this activity, while roughly three quarters of the overweight men, and two thirds of the obese men were free of limitations in walking several blocks. Since odds ratios in unadjusted and adjusted models were very similar, one can conclude that the potential confounding variables smoking and occupation history had no effect on the relationship between middle-age weight patterns and ability to walk several blocks in later life. There appeared to be insufficient statistical evidence to conclude any differences in this outcome existed between normal weight men with varying and normal weight with steady weight patterns during middle age.

Table 4.14: Odds ratios with 95% confidence intervals for Being Able to Walk Several Blocks for men with a normal, steady weight pattern during middle age relative to four other weight patterns.

Weight Pattern	# Able to Walk Several Blocks / Total (1090/1403)	%	Unadjusted OR (95% CI)	Adjusted [1] OR (95% CI)
Normal weight, steady	278 / 334	83.2	-	-
Normal weight, varying	239 / 299	79.9	1.25 (0.83, 1.87)	1.24 (0.82, 1.87)
Overweight, steady	243 / 316	76.9	**1.49 (1.01, 2.20)**	**1.56 (1.05, 2.32)**
Overweight, varying	294 / 400	73.5	**1.79 (1.25, 2.57)**	**1.79 (1.23, 2.59)**
Obese, all	36 / 54	66.7	**2.48 (1.32, 4.68)**	**2.73 (1.42, 5.23)**

[1] Adjusted for smoking status and occupation history during age 35-60 years, as well as age at entry to the study.

4.5.2.6 Longitudinal Weight Patterns and Ability to Climb Several Flights of Stairs

At least one in three men with any weight pattern in middle age had limitations climbing several flights of stairs. Men who were overweight with varying weight patterns during middle age had almost 60% greater odds of reporting limitations in climbing several flights of stairs in later life due to health issues, than their normal/steady weight counterparts. Roughly 54% and 65% of those groups respectively reported being free of such limitations.

Smoking and occupation history did not affect the relationship between weight patterns in middle age and the ability to climb several flights of stairs in later life. No evidence was found of statistically significant differences in odds of climbing several flights of stairs without limitations, when comparing normal/steady weight men to the other weight patterns during middle age.

Table 4.15: Odds ratios with 95% confidence intervals for Being Able to Climb Several Flights of Stairs for men with a normal, steady weight pattern during middle age relative to four other weight patterns.

Weight Pattern	# Able to Climb Flights of Stairs / Total (847/1412)	%	Unadjusted OR (95% CI)	Adjusted [1] OR (95% CI)
Normal weight, steady	219 / 338	64.8	-	-
Normal weight, varying	184 / 301	61.1	1.17 (0.85, 1.61)	1.15 (0.83, 1.61)
Overweight, steady	198 / 317	62.5	1.11 (0.80, 1.52)	1.16 (0.84, 1.62)
Overweight, varying	216 / 403	53.6	**1.59 (1.18, 2.14)**	**1.59 (1.17, 2.16)**
Obese, all	30 / 53	56.6	1.41 (0.78, 2.54)	1.54 (0.84, 2.82)

[1] Adjusted for smoking status and occupation history during age 35-60 years, as well as age at entry to the study.

4.5.2.7 Longitudinal Weight Patterns and Life Satisfaction

Overall, about 40% of the men reported excellent life satisfaction in later life. Men who were overweight with varying weight patterns during middle-age were less likely to report excellent satisfaction with life in later years, than their peers who were predominantly normal weight with steady weight patterns. Over forty percent of the normal/steady weight men rated their satisfaction with life as "excellent" while just over 30% of the overweight men with varying weights did so.

Unadjusted and adjusted models yielded similar odds ratios showing that smoking and occupation did not affect the relationship between weight patterns and life satisfaction in later life. Due to a lack of statistical evidence, no further conclusions about differences in the likelihood of reporting a high level of satisfaction with life between men with the other weight patterns could be made.

Table 4.16: Odds ratios with 95% confidence intervals for Excellent Life Satisfaction for men with a normal, steady weight pattern during middle age relative to four other weight patterns.

Weight Pattern	# Reporting Excellent Life Satisfaction / Total (551/1426)	%	Unadjusted OR (95% CI)	Adjusted [1] OR (95% CI)
Normal weight, steady	146 / 343	42.6	-	-
Normal weight, varying	112 / 303	37.0	1.26 (0.92, 1.74)	1.27 (0.93, 1.75)
Overweight, steady	133 / 318	41.8	1.03 (0.76, 1.40)	1.02 (0.75, 1.40)
Overweight, varying	140 / 407	34.4	**1.41 (1.05, 1.90)**	**1.40 (1.04, 1.89)**
Obese, all	20 / 55	36.4	1.30 (0.72, 2.34)	1.28 (0.71, 2.33)

[1] Adjusted for smoking status and occupation history during age 35-60 years, as well as age at entry to the study.

4.5.2.8 Longitudinal Weight Patterns and Self-Assessed as Aged Successfully

Approximately 85% of the men responding to the SAQ-1996 question reported having "aged successfully". Men who were predominantly normal weight with steady weight patterns during middle age had higher odds of assessing themselves as having aged successfully than their counterparts who were either overweight with varying weight patterns or predominantly obese during middle age. The overweight, varying weight men were at a 75% increased odds, while the obese men had twice the odds of feeling they had not aged successfully compared to the normal/steady weight men. Odds ratios between corresponding unadjusted and adjusted models were sufficiently close implying smoking and occupation history had no effect on the relationship between middle-age weight patterns and self-assessed aged successfully. No statistically significant evidence was found of differences in odds of normal/steady weight men feeling they had aged successfully relative to men with the other weight patterns during middle age.

Table 4.17: Odds ratios with 95% confidence intervals for "Aged Successfully?" for men with a normal, steady weight pattern during middle age relative to four other weight patterns.

Weight Pattern	# Self-Assessed as Aged Successfully / Total (1228/1438)	%	Unadjusted OR (95% CI)	Adjusted [1] OR (95% CI)
Normal weight, steady	308 / 346	89.0	-	-
Normal weight, varying	259 / 307	84.4	1.50 (0.95, 2.37)	1.57 (0.99, 2.50)
Overweight, steady	277 / 320	86.6	1.26 (0.79, 2.00)	1.32 (0.82, 2.12)
Overweight, varying	341 / 410	83.2	**1.64 (1.07, 2.51)**	**1.74 (1.13, 2.69)**
Obese, all	43 / 55	78.2	**2.26 (1.10, 4.66)**	**2.43 (1.16, 5.09)**

[1] Adjusted for smoking status and occupation history during age 35-60 years, as well as age at entry to the study.

4.5.2.9 Summary of Logistic Regression Models

Table 4.18 summarizes the statistically significant results of the logistic regression modeling. Compared with their overweight counterparts with varying weight patterns, men predominantly normal weight with steady weight patterns were more likely to report excellent self-rated health, excellent satisfaction with life, fewer limitations with daily activities, and that they felt they had aged successfully. This is in contrast to men with either normal, varying weight patterns or overweight, steady patterns, who did not have significantly different outcomes from the normal, steady weight reference group. This implies that a combination of being overweight and having a varying weight pattern during middle age may confer the greatest risk for unfavorable outcomes in later life.

Table 4.18: Summary of significant results from all adjusted logistic regression models.[1] Odds ratios with 95% confidence intervals for all outcomes for men with a normal, steady weight pattern during middle age relative to the other four weight patterns.

	Weight Patterns			
Successful Aging Outcome	Normal/ Varying	Overweight/ Steady	Overweight/ Varying	Obese
Survival to an Advanced Age (75 years)	-	-	-	**1.90 (1.17, 3.06)**
Excellent Self-Rated Health	**1.64 (1.17, 2.29)**	-	**1.90 (1.39, 2.61)**	-
No limitations in activities of daily living (ADL)	-	-	-	-
At most one limitation in activities of daily living (IADL)	-	-	**1.77 (1.24, 2.54)**	-
Being able to walk several blocks	-	**1.56 (1.05, 2.32)**	**1.79 (1.23, 2.59)**	**2.73 (1.42, 5.23)**
Being able to climb several flights of stairs	-	-	**1.59 (1.17, 2.16)**	-
Excellent life satisfaction	-	-	**1.40 (1.04, 1.89)**	-
"Aged successfully ?"	-	-	**1.74 (1.13, 2.69)**	**2.43 (1.16, 5.09)**

[1] All models adjusted for smoking status and occupation history during age 35-60 years, as well as age at entry to the study.

4.5.2.10 Longitudinal Weight Patterns and Physical and Mental Functioning (SF-36)

Multiple linear regression was used to model the outcomes of physical and mental functioning based on the responses to the SF-36 series of questions in the SAQ-1996. As described in Chapter Three, the thirty-six questions were grouped into eight domains. A weighted function of the eight domain scores produced two summary scores, the Physical Component Score (PCS) and Mental Component Score (MCS), which ranged on a continuous scale from zero (most problematic) to 100 (most favorable).

Table 4.19 illustrates which weight patterns brought with them significant changes in SF-36 summary scores compared to normal/steady weight patterned men. Overall there were relatively small differences between PCS and MCS scores of men who had normal, steady weight patterns during middle age compared to the scores of men who had any of the other middle-age weight patterns. The normal, steady weight men had slightly more favorable scores, but were at most only about three points higher than scores of men with any of the other weight patterns.

Table 4.19: Adjusted linear regression coefficients with 95% confidence intervals for SF-36 Physical and Mental Component Scores for men with a normal, steady weight pattern during middle age relative to four other weight patterns.[1]

	Weight Patterns			
Successful Aging Outcome	Normal/ Varying	Overweight/ Steady	Overweight/ Varying	Obese
Physical Component Score (PCS)	0.88 (-0.68, 2.44)	1.25 (-0.28, 2.79)	**2.57 (1.11, 4.03)**	**3.07 (0.24, 5.90)**
Mental Component Score (MCS)	**2.07 (0.85, 3.29)**	**1.43 (0.23, 2.64)**	**1.44 (0.29, 2.58)**	0.21 (-2.01, 2.43)

[1] All models adjusted for smoking status and occupation history during age 35-60 years, as well as age at entry to the study.

4.6 Summary

Results from Objective One suggest that just under half of the men in the sample under study were predominantly normal weight during middle age, just over half were overweight and very few were predominantly obese. About a half of the men in the sample maintained relatively steady weights throughout middle age, a quarter experienced weight gain during that age window, and the remainder were either weight-decliners, weight-cyclers or showed no discernible weight patterns. About a half of the predominantly normal weight men had steady weight patterns, and a half had varying weight during middle age. Of the overweight men, slightly more experienced varying weight than steady weight patterns.

Overall, the men in the sample reported favorable outcomes in later life, as seen by the results of Objective Two. Three quarters of the sample survived to at least 75 years of age and at least three quarters responding to the SAQ-1996 reported minimal limitations in their daily activities. Over 30% reported excellent health, slightly more rated their satisfaction with life as excellent and over 80% felt that they had aged successfully.

From Objective Three, men with steady weights predominantly in the normal weight range enjoyed more favorable outcomes in later life compared to their peers who were predominantly overweight with varying weight patterns throughout middle age. Fewer significant differences in outcomes were observed between the normal/steady weight men and men having the other weight patterns during middle age.

Chapter Five
CONCLUSION

5.1 Overview

Through a series of three objectives, the current research project addressed the following research question:

> **What relationship exists between longitudinal weight patterns of men during middle age (35-60 years) and measures of successful aging in later life (after age 75 years) ?**

The current project addressed this question through the use of the prospective, longitudinal dataset of the Manitoba Follow-up Study. This study provided a rare opportunity to systematically assess weight patterns over time and in more detail possible with cross-sectional or short-term prospective studies. In the process, a method for characterizing weight patterns using data over a twenty-five year period involving the duration and trend of those weight patterns was developed. Furthermore, a broad range of successful aging outcomes was used in this project, unlike other studies which typically only examined the relationship between weight and one or two outcomes in later life.

This chapter presents conclusions based on the results reported in the previous chapter and attempts to synthesize these findings with those of other researchers. Due to the uniqueness of the dataset and methodology used as well as the comprehensiveness of measures in the current project, few direct comparisons with the existing literature can be made. Consequently this thesis addresses many gaps in the literature. Most comparisons involve the results obtained with the simple summary measures commonly used by other researchers as well as the outcomes of successful aging. The chapter continues by identifying the strengths and limitations of the current research project, followed by a discussion of possible implications the current project's results might have on health policy makers, health promotion professionals, and advocacy organizations as well as on other researchers in the field. Finally, suggestions for future work are proposed.

5.2 Review of Results in the Context of Other Studies

In addressing the research question noted earlier, the current research project had the following three objectives:

1. To determine weight patterns during middle age
2. To operationalize successful aging outcomes in later life and
3. To relate those weight patterns during middle age with successful aging outcomes

5.2.1 Review of Results of Objective One

The first objective determined men's middle-age weight patterns by first deriving simple weight summary measures commonly used by other researchers and then developing a new method that utilized the full extent of the data available, combining the longitudinal characteristics of duration and trend.

The weight patterns derived using simple weight summary measures were similar to those reported by the Build Study 1979 [Society Actuaries 1980], conducted by the Society of Actuaries and Association of Life Insurance Medical Directors of America, and the Johns Hopkins Precursors Study [Brancati 1999], a longitudinal study described in Chapter Two that followed nine hundred Johns Hopkins medical school graduates of the late 1940s through early 1960s. Both studies examined body build and health outcomes of North American men who would have been roughly the same age at about the same time as the MFUS sample in the current research project.

Using simple weight summary measures, the mean BMI of the MFUS participants in the current project was 24.5 kg/m^2 at age 35 years and 25.7 kg/m^2 at 60 years, with approximately 60% of the men at 35 years being normal weight, decreasing to 40% of the men at 60 years of age being normal weight. Almost a half of the men had a mean weight during middle age considered normal weight.

In the Build Study, between 1950 and 1971, 35-year old men had a mean BMI of 25.1 kg/m^2, 0.6 kg/m^2 higher than the MFUS respondents and 55-year old men a mean BMI of 25.5 kg/m^2, almost identical to the MFUS subjects at 60 years of age (average weight data in the Build Study were not available for age 60 years). In the Johns Hopkins Precursors Study, in which several simple weight measures were used that were used in the current research project, the mean age of its all-male sample at age 35 years was 23.9 kg/m^2, 0.6 kg/m^2 lower than the MFUS sample. Data for ages near 60 years were not available (mean BMI at age 45 years was 24.1 kg/m^2).

To put this into a modern-day context, results from the 2004 Canadian Community Health Survey (CCHS), a cross-sectional survey, showed that 45% of men 35-44 years old, 42% of men 45-54 years old and 46% of men 55-64 years old were classified as overweight, closely resembling the results for the cohort of the current project [Statistics Canada 2005b]. However, a dramatic difference can be seen in the percentages who were obese. In the current project, only 4% of the men were predominantly obese during middle age, while in the recent Canadian survey 20%, 30% and 30% of the men 35-44 years, 45-54 years and 55-64 years of age were classified as obese. Hence one might conclude that a very clear shift has occurred towards the obese end of the weight spectrum among men in recent years. These results agree with the 2005

Behavioral Risk Factor Surveillance System conducted nationally by the U.S. Centers for Disease Control and Prevention (CDC) which reported 38% of adults (male and female) 35-44 years of age, 39% of those 45-54 years old, and 40% of those 55-64 years old were overweight, while 26%, 29% and 31% of adults in those age groups respectively were considered obese [CDC 2006a].

Objective One also characterized middle-age weight patterns using predominant weight duration and trend. It was noted that approximately half of the sample maintained stable weight patterns during middle age, a quarter gained weight and the remainder either lost weight, weight-cycled or had no discernible weight pattern. Since no other studies have been found in the literature assessing weight patterns during middle age using a similar approach, these results cannot be compared and on their own make a unique contribution to the literature.

5.2.2 Review of Results of Objective Two

Objective Two assessed a broad range of successful aging outcomes, including survival to an advanced age, self-rated health, limitations in daily activities, life satisfaction and self-assessed successful aging. Compared to a recent report on the health of elderly Canadians using data from the 2003 Canadian Community Health Survey [Statistics Canada 2006b], the outcomes of survival to an advanced age were in close agreement while self-rated health and limitations in daily activities differed considerably.

According to that report, 27% of Canadian men between 65 and 69 years of age died by the time they reached 73 to 78 years of age. This matches closely with the 29% of

MFUS subjects in the current project who lived to at least 65 years but died before age 75 years (result not shown).

MFUS respondents reported higher levels of self-rated health than elderly Canadian men surveyed in the CCHS, as 86% of MFUS subjects responding to the SAQ-1996 rated their health as excellent or good, at an average age of 76 years, while the report showed that only 74% of the male CCHS participants 65 years or older rated their health as excellent, very good or good.

On the other hand, the report stated that approximately 94% of Canadian men between 65 and 84 years old reported being free of limitations in Activities of Daily Living (ADL) while about 85% were free of limitations in Instrumental Activities of Daily Living (IADL). This was almost ten percentage points higher than MFUS respondents, approximately 84% and 76% of them reporting being free of those limitations respectively. This might well have been due to differences in the activities asked about in the respective ADL and IADL series, or perhaps even due to a survivor effect with greater physical limitations in the MFUS cohort but with overall higher levels of self-rated health than the general elderly male population.

5.2.3 Review of Results of Objective Three

Finally the third objective related the weight patterns characterized in Objective One with the successful aging outcomes of Objective Two. As reported in Chapter Four, the current project found that using simple weight summary measures, normal weight men had better odds than obese men of surviving to an advanced age, living with minimal limitations in daily activities, being able to walk several blocks or climb several flights of stairs and assessed themselves as having aged successfully. This was also true to a lesser extent when comparing normal weight men to overweight men.

Briefly, the results of the studies cited in Chapter Two were extremely varied, with a diversity of summary measures, outcomes and results. Some of the methodologies might well be called into question, such as the use of weight change, rather than BMI change [Galanis 1998][Blair 1993], the use of absolute weight change rather than relative weight change [Lahmann 2005][Lazarus 1998] or the treatment of the inherently-discrete SF-36/HSQ-12 domain scores as continuous variables [Daviglus 2003], not to mention the use of limited numbers of weight measurements and the reliance on self-reported and recalled weights (see Section 5.3 Strengths and Limitations).

Not surprisingly, a number of the studies cited in Chapter Two reported rather conflicting results. This can also be seen in the mixed results of dozens of studies relating obesity to various health outcomes outlined in a recent meta-analysis [Katzmarzyk 2004]. The Multiple Risk Factor Intervention Trial [Blair 1993] showed that weight-decliners and weight-cyclers were at greater risk of all-cause and cardiovascular mortality than men who maintained stable weight. On the other hand, the British Regional Heart Study [Wannamethee 2002] using only three weight measurements per subject found the risk for these outcomes was no greater between those groups. The Framingham Study [Lissner 1991] found that weight variability was a significant predictor of morbidity and non-cancer morbidity while the Chicago Western Electric Company Study [Dyer 2000] showed weight gain or weight loss influenced mortality but weight variability did not influence the risk of cardiovascular or all-cause mortality.

Dyer *et al* [Dyer 2004] have recently cautioned, in light of apparently inconsistent results reported by longitudinal studies, that methodological problems including insufficient follow-up, lack of adjustment for smoking, over-adjustment for weight-related effects, such as hypertension and diabetes, and inclusion of early deaths may account for inconsistencies in reported results. The current research project took special care in avoiding these pitfalls.

Although the current research project did not include chronic disease as an outcome, it is worth noting that the Johns Hopkins Precursors Study [Brancati 1999] concluded that the risk of incident diabetes was higher among overweight men compared to normal weight men using similar simple summary measures as the current project – first, last and maximum BMI and a variation of average BMI during middle age.

In the current project, using the methodology combining duration and trend, the key result was that men who maintained steady, normal weight patterns during middle age had increased odds of more favorable outcomes in later life than their peers who were predominantly overweight with varying patterns during that time. Again due to the unique nature of the methodology used in Objective One to assess longitudinal weight patterns and the broad set of successful aging outcomes used in Objective Two, findings from studies with similar methodologies have yet to be reported in the literature.

5.3 Strengths and Limitations of the Research Project

Like any study, the current research project had both strengths and limitations, some rather unique to the project undertaken, others typical of studies of this kind.

As noted earlier, one of the key strengths of this project lay in the use of the longitudinal dataset of the Manitoba Follow-up Study, one of North America's longest running health studies. This database provided weight and medical examination data collected over half a century, from the time its subjects were young men to the present day with those men in the late stages of their lives. Without such a long-term dataset, analyses of the kind done in this research project would not have been possible.

Using measured, rather than recalled or even self-reported weights is another important strength of the current project. All of the weight data in the MFUS database came from weights measured by health professionals during medical examinations of the study participants. Many other studies including several of those cited in Chapter Two have relied on recent weights reported by their study subjects or weights recalled from years past by those participants [Roberts 2002], [Roberts 2003], [Galanis 1998], [Lissner 1991], [Janssen 2004], [Fine 1999], [Strandberg 2003]. In a recent analysis by Bayomi and Tate [Bayomi 2005] of weight recall accuracy in MFUS, it was concluded that recall by men in their 70's and 80's of weights at different points earlier in life, from 20 years of age and up was not very accurate. This contradicts a paper by Must *et al* [Must 1993], often cited by studies justifying their use of recalled weight data.

Again in part due to the long-term nature of MFUS and partly due to the study protocol requiring periodic routine medical examinations, another strength of the current research project was its ability to ensure that sufficient numbers of weight measurements were available for each man characterizing the weight patterns over the twenty-five year period of interest. This is in contrast to many of the studies cited in Chapter Two that used as few as two [Roberts 2003], [Harris 1997], [Lahmann 2005] or three weights [Wannamethee 2002], [Galanis 1998], [Fine 1999] and in some cases only a single weight [Roberts 2002], [Janssen 2004], [Han 1998], [Daviglus 2003] per subject for their analyses.

The rather unique nature of this cohort, with study members selected on the basis of their having been apparently healthy, male World War II aircrew recruits might be considered both a possible strength and a possible limitation of this study. How representative this cohort is of today's Canadian male population or indeed of Canadian men of that generation may be open to some debate. This cohort was a very homogeneous group, with few characteristics possibly confounding results. As noted earlier in this chapter, several of the sample characteristics, weight measures and outcomes closely resembled those of other Canadian male cohorts, past and present. It could be argued though that this cohort experienced their middle age under very different conditions compared to men presently in middle age. The men of the cohort under study were middle-aged mostly during the 1950s, 1960s and early 1970s, well before fast food and super-sized food portions, the digital electronics era with personal computers, video games, TV remote controls, cell phones, and the Internet, disappearance of the neighborhood grocery store and over-reliance on the automobile. If anything, one might expect the results of the current project to be a conservative estimate of what might be expected for today's middle-aged men, experiencing high calorie, sedentary lives.

The use of BMI data for assessing weight may be considered by some as a limitation. As mentioned in Chapter Three, this is a commonly used measure of weight status in population studies and was the only anthropometric measure available in the MFUS database. The use of other measures such as waist circumference, skinfold thickness and waist-to-hip ratio might have added to the research project.

Two possible concerns stem from using BMI data in conjunction with the WHO weight categorization system. Firstly, very physically fit men with high BMI values could very well be implicated as being overweight or even obese. The author tried to verify that the very few obese men in the sample were unfit, often noted as such in their medical files but the task of doing this for all of the overweight men was far too large an undertaking. Secondly, the WHO system was adopted in the late 1990s at a time when obesity levels were rising dramatically. One might argue that using that categorization system on BMI values from the 1950s, 1960s and 1970s when BMI levels were generally lower, might be somewhat artificial and that more period-specific BMI cut-offs should have been used. Unfortunately, during that time, BMI was not widely used as a weight measure and BMI categorization systems had not yet been established.

The current research project may have also been limited by having only single height measurements in the MFUS database for each man. The issue is not so much that height changes over time, since height during middle age should remain relatively constant. The concern however is that since height is used in the calculation of BMI values, if this value were erroneously measured, recorded or entered into the database for a given subject, all BMI values for that subject would be in error. Beyond randomly spot-checking a dozen files or so, this potential problem was not investigated in any detail.

Use of the SAQ-1996 to operationalize successful aging outcomes might also be considered a possible limitation in the current project, especially as it was administered to elderly men by mail and consequently all data from it were self-reported without the benefits of a face-to-face interview. Although some of the SAQ-1996 questions such as the ADL, IADL and SF-36 series come from well-established measures, other questions like those asking about life satisfaction or whether the subject had aged successfully have not been validated. Hence such questions carry with them a degree of uncertainty.

The relatively small numbers of men – ten percent or less of the sample – who were predominantly normal weight in the individual trend categories of "decreasing", "cycling", and "no discernible pattern" and the same for men overweight precluded the opportunity to split the categories "normal weight with a varying pattern" and "overweight with a varying pattern". Hence it was not possible to identify which specific direction of varying weight was related to the outcomes. Likewise the small numbers of men who were obese at any point during middle age resulted in grouping together all men who were predominantly obese, regardless of the trends in their weight patterns. This prevented a more in-depth comparison of obese men with men who followed normal weight or overweight patterns.

Finally, there are many potential factors along the path to successful aging – income, education, social networks, family relationships, activity patterns, diet, health status, and ability to adapt to the aging process, just to list a few. Unfortunately the MFUS database did not provide the opportunity to examine the effects of many of those factors and hence the current research project was unable to take them into consideration.

5.4 Implications

Results from this research project may have implications for health policy makers, health promotion professionals and advocacy organizations, as well as other researchers investigating the relationship between weight patterns and successful aging. Before discussing these potential implications, one should keep in mind that the results reported here come from a single analysis of one cohort using methodology not previously reported in the literature. It is hoped that other researchers may use similar methodology with their datasets, potentially confirming the findings of the current project.

As mentioned in the previous section, middle-aged men today experience very different conditions than those of the MFUS cohort when they were middle-aged. In today's society, middle-aged men lead much more sedentary but fast-paced lives and are surrounded by fast food and other high-calorie food choices. While the weight patterns of today's middle-aged men may well still be the same, the distribution of those patterns across the population are likely quite different. Weight patterns leading to more adverse outcomes are very likely more common among today's middle-aged men than they were in the MFUS cohort.

As levels of overweight and obesity escalate among young children and teens, much attention is being focused on encouraging healthy weight levels in the young. With good reason, government departments, school boards and parent associations throughout North America are working to stem the tide of unhealthy weight levels among children. Between protecting children from "toxic food environments", a term coined by Dr. Kelly Brownell, director of Yale University's Rudd Center for Food Policy and Obesity [Rudd 2006] and encouraging programs for increasing physical activity in schools, such as those featured in the Schools Health Index on the CDC's website [CDC 2006b], children have become important targets for healthy weight interventions.

However, with the growing numbers of overweight and obese adults in North America, combined with the aging of the population and results such as those of the current research project, more attention needs to be focused on encouraging healthy weight levels among the middle-aged too. As mentioned in Chapter One, a third of the North American population is middle-aged, representing a significant segment of society deserving more attention.

What message should health policy makers, health promotion professionals and affiliated organizations convey to the general public? The results of the current project suggest that just being predominantly overweight during middle age or just having a varying weight pattern during middle age do not by themselves each confer increased risk of unfavorable outcomes in later life compared to those who maintain normal/steady weight patterns in middle age. Rather it is the combination of being predominantly overweight along with a varying weight pattern that bring increased odds of unfavorable outcomes.

On the surface this might not be much different from what most members of the general public already perceive to be the consequences of being overweight at any point in their lives. The specific outcomes of the current research project are somewhat different though from those reported by other studies. Referring specifically to being predominantly overweight with a varying weight pattern throughout middle age, and specifically relating these to some of the more readily appreciated outcomes examined in this project, such as the ability to climb stairs or walk a few blocks in later life, may give health promoters and policy makers a slightly re-focused message to send to the public.

Of course, those who are predominantly overweight during middle age while maintaining steady weight patterns may feel they are as "healthy" as those predominantly normal weight with steady patterns and hence need not worry about reducing their weight. Again, one must interpret these results in the context of a single study examining a cohort that experienced middle age during different times than those who are middle-aged today. It may well be possible that maintaining a steady, overweight pattern may confer no additional risk but additional research, utilizing the methodology described in the current project with other cohorts is needed.

Of course the results of both health promotion and research need to be translated into on-the-ground action and interventions. Providing substantially more opportunities and facilities for physical activity in the workplace, encouraging healthier food choices in restaurants, grocery stores and worksite cafeterias, and mass media campaigns to encourage the middle-aged to maintain healthy weight levels both for themselves and as role models for the children around them are just a start. The design of new neighborhoods that encourage healthy lifestyles with amenable activity areas and nearby shops together with the updating of existing neighborhoods making them safer, more pedestrian- and cycle-friendly are not new ideas. And of course, the socio-economic context must always be kept in mind, with social equity a key factor in addressing the future weight patterns and ultimately the future health and well-being of society.

5.5 Future Work

The current research project addressed how weight patterns of men during middle age are related to outcomes of successful aging in later life. In the process, it has generated a number of questions worthy of further attention. Among these are the following questions:

- How would the relationship between middle-age weight patterns and outcomes in later life change if men with varying weight patterns were regrouped into their original categories of increasing weight, decreasing weight, weight-cycling or no discernible weight pattern ?
- Would subdividing the normal weight and overweight categories into lower- and upper-normal weight and lower- and upper-overweight have any effect on weight pattern classifications and relationships with outcomes ?
- How does the WHO weight categorization system affect results and would a different set of weight cut-offs better predict outcomes in later life ?
- What proportion of men deemed overweight in the current project were in fact lean and muscular, as opposed to overweight and unfit ? How would those predominantly overweight/physically fit men differ in their outcomes in later life with the normal weight men, or the predominantly overweight/unfit men ?
- Would including other curve-fitting techniques such as higher order polynomials (eg. fifth- and higher-degree) or splines improve the characterization process ?

- How would weight patterns vary with different age windows during middle age, eg. age 30 – 50 years, 35 – 55 years, and how would these weight patterns relate with outcomes in later life ?
- How would controlling for other factors such as education and marital status, or changes in health during middle age affect the results obtained ?
- How do middle-age weight patterns relate with other outcomes including the development of chronic diseases such as cardiovascular disease, diabetes and cancer ?
- Do weight patterns in middle age predict how study members perceive successful aging, as derived from coded responses to the SAQ-1996 question "What is YOUR definition of successful aging" ?
- Since MFUS has administered the SAQ several times since 1996 to its members, how do middle-age weight patterns relate to outcomes at older ages and with trajectories of successful aging outcomes over time ?
- Using the methodology developed in this project for characterizing weight patterns, how do the weight patterns of other cohorts of adult men compare with this study's ? Do women have similar middle-age weight patterns, and are they related to outcomes in later life in similar ways ?

It is the hope of the author that the current research project has only just "opened the door" and may motivate the pursuit of future work in this area.

5.6 Summary

The current research project used both simple weight summary measures used by other researchers and a novel method for assessing longitudinal weight patterns during middle age. The current project indeed found relationships between weight patterns during middle age and a broad range of measures of successful aging outcomes in later life. The main result of this project was that men who maintain steady, normal weight patterns throughout middle age enjoy more favorable outcomes in later life than do men who are predominantly overweight with varying weight during that time. Roughly a quarter of the Manitoba Follow-up Study cohort in the current project were predominantly overweight with varying weight during middle age.

Health policy makers, health promotion professionals, and researchers in the field might benefit from the use of these results and the methodology used. Considering that the cohort studied was middle-aged during very different times than are today's middle-aged men, one might anticipate an even greater proportion of today's middle-aged men are maintaining unhealthy weight patterns. The current project's results may well provide new insight into the relationship between longitudinal weight patterns and successful aging in later life. Numerous related questions remain to be answered, and it is hoped that future work will continue examining the relationship between longitudinal weight patterns and successful aging.

REFERENCES

[Baltes 1990] Baltes PB and Baltes MM. Psychological perspectives on successful aging: The model of selective optimization with compensation. In PB Baltes & MM Baltes, eds. *Successful Aging: Perspectives from the Behavioral Sciences.* Cambridge, England: Cambridge University Press, 1990.

[Bayomi 2005] Bayomi DJ and Tate RB. Long-term recall of body weight by elderly males: The Manitoba Follow-up Study. Poster presented at the 2005 Joint Meeting of the Canadian Society for Biostatistics and Epidemiology and the Society for Epidemiologic Research, Toronto, June 27-30, 2005.

[Blair 1993] Blair SN, Shaten J, Brownell K, Collins G, Lissner L. Body weight change, all-cause mortality, and cause-specific mortality in the Multiple Risk Factor Intervention Trial. *Ann Intern Med.* 1993 Oct 1;119(7 Pt 2):749-57.

[Brancati 1999] Brancati FL, Wang NY, Mead LA, Liang KY, Klag MJ. Body weight patterns from 20 to 49 years of age and subsequent risk for diabetes mellitus: the Johns Hopkins Precursors Study. *Arch Intern Med.* 1999 May 10;159(9):957-63.

[CDC 2006a] Behavioral Risk Factor Surveillance System: Prevalence Data. U.S. Centers for Disease Control and Prevention. Online at http://www.cdc.gov/brfss Last visited: August 16, 2006.

[CDC 2006b] Schools Health Index, U.S. Centers for Disease Control and Prevention. Online at http://apps.nccd.cdc.gov/shi Last visited: June 19, 2006.

[Daviglus 2003] Daviglus ML, Liu K, Yan LL, Pirzada A, Garside DB, Schiffer L, Dyer AR, Greenland P, Stamler J. Body mass index in middle age and health-related quality of life in older age: the Chicago Heart Association Detection Project in Industry Study. *Arch Intern Med.* 2003 Nov 10;163(20):2448-55.

[Doll 2000] Doll HA, Petersen SE, Stewart-Brown SL. Obesity and physical and emotional well-being: associations between body mass index, chronic illness, and the physical and mental components of the SF-36 questionnaire. *Obes Res.* 2000 Mar;8(2):160-70.

[Dyer 2000] Dyer AR, Stamler J, Greenland P. Associations of weight change and weight variability with cardiovascular and all-cause mortality in the Chicago Western Electric Company Study. *Am J Epidemiol.* 2000 Aug 15;152(4):324-33.

[Dyer 2004] Dyer AR, Stamler J, Garside DB, Greenland P. Long-term consequences of body mass index for cardiovascular mortality: the Chicago Heart Association Detection Project in Industry study. *Ann Epidemiol.* 2004 Feb;14(2):101-8.

[Fine 1999] Fine JT, Colditz GA, Coakley EH, Moseley G, Manson JE, Willett WC, Kawachi I. A prospective study of weight change and health-related quality of life in women. *JAMA* 1999 Dec 8;282(22):2136-2142.

[Fontaine 2001] Fontaine KR and Barofsky I. Obesity and health-related quality of life. *Obesity Reviews* 2001(2):173-182.

[Fries 1980] Fries JF. Aging, natural death, and the compression of morbidity. *N Engl J Med.* 1980 Jul 17;303(3):130-5.

[Fries 2002] Fries JF. Successful aging – an emerging paradigm of gerontology. *Clin Geriatr Med.* 2002 Aug;18(3):371-82.

[Galanis 1998] Galanis DJ, Harris T, Sharp DS, Petrovitch H. Relative weight, weight change, and risk of coronary heart disease in the Honolulu Heart Program. *Am J Epidemiol.* 1998 Feb 15;147(4):379-86.

[Han 1998] Han TS, Tijhuis MA, Lean ME, Seidell JC. Quality of life in relation to overweight and body fat distribution. *Am J Public Health* 1998 Dec;88(12):1814-20.

[Harris 1997] Harris TB, Launer LJ, Madans J, Feldman JJ. Cohort study of effect of being overweight and change in weight on risk of coronary heart disease in old age. *BMJ* 1997 Jun 21; 314(7097):1791-4.

[Havighurst 1953] Havighurst RJ and Albrecht R. *Older People.* New York, NY: Longmans, 1953.

[Health Canada 2003] Health Canada. *Canadian Guidelines for Body Weight Classification in Adults.* Online at: http://www.hc-sc.gc.ca/fn-an/nutrition/weights-poids/guide-ld-adult/weight_book_tc-livres_des_poids_tm_e.html
Last modified: March 13, 2003. Last visited: June 18, 2006.

[Janssen 2002] Janssen I, Heymsfield SB, Ross R. Application of simple anthropometry in the assessment of health risk: implications for the Canadian Physical Activity, Fitness and Lifestyle Appraisal. *Can J Appl Physiol.* 2002 Aug;27(4):396-414.

[Janssen 2004] Janssen I, Katzmarzyk PT, Ross R. Duration of overweight and metabolic health risk in American men and women. *Ann Epidemiol.* 2004 Sep;14(8):585-91.

[Katz 1963] Katz S, Ford AB, Moskowitz RW, Jackson BA, Jaffe MW. Studies of illness in the aged. The index of ADL: A standardized measure of biological and psychosocial function. *JAMA* 1963 Sep 21;185:914-9.

[Katzmarzyk 2002] Katzmarzyk PT. The Canadian obesity epidemic: an historical perspective. *Obes Res.* 2002; 10: 666-674.

[Katzmarzyk 2004] Katzmarzyk PT and Janssen I. The economic costs associated with physical inactivity and obesity in Canada: an update. *Can J Appl Physiol.* 2004 Feb;29(1):90-115.

[Klesges 1989] Klesges RC, Meyers AW, Klesges LM, La Vasque ME. Smoking, body weight, and their effects on smoking behavior: a comprehensive review of the literature. *Psychol Bull.* 1989 Sep;106(2):204-30.

[Knight 2003] Knight T and Ricciardelli LA. Successful aging: perceptions of adults aged between 70 and 101 years. *Int J Aging Hum Dev.* 2003;56(3):223-45.

[Kolotkin 2001] Kolotkin RL, Meter K, Williams GR. Quality of life and obesity. *Obesity Reviews* 2001;2:219-229.

[Kushner 2000] Kushner RF and Foster GD. Obesity and quality of life. *Nutrition* 2000;16:947-952.

[Lahmann 2005] Lahmann PH, Schulz M, Hoffmann K, Boeing H, *et al.* Long-term weight change and breast cancer risk: the European prospective investigation into cancer and nutrition (EPIC). *Br J Cancer* 2005 Sep 5; 93(5):582-9.

[Lazarus 1998] Lazarus R, Sparrow D, Weiss S. Temporal relations between obesity and insulin: longitudinal data from the Normative Aging Study. *Am J Epidemiol.* 1998 Jan 15;147(2):173-9.

[Lissner 1991] Lissner L, Odell PM, D'Agostino RB, Stokes J 3rd, Kreger BE, Belanger AJ, Brownell KD. Variability of body weight and health outcomes in the Framingham population. *N Engl J Med.* 1991 Jun 27;324(26):1839-44.

[Manson 1987] Manson JE, Stampfer MJ, Hennekens CH, Willett WC. Body weight and longevity: A reassessment. *JAMA* 1987 Jan 16;257(3):353-358.

[Mathewson 1987] Mathewson FA, Manfreda J, Tate RB, Cuddy TE. The University of Manitoba Follow-up Study – An investigation of cardiovascular disease with 35 years of follow-up (1948-1983). *Can J Cardiol.* 1987 Nov-Dec;3(8):378-82.

[Matthews 1990] Matthews JNS, Altman DG, Campbell MJ, Royston P. Analysis of serial measurements in medical research. *Br Med J.* 1990;300:230-5.

[Must 1993] Must A, Willett WC, Dietz WH. Remote recall of childhood height, weight, and body build by elderly subjects. *Am J Epidemiol.* 1993 Jul 1;138(1):56-64.

[Newman 2003] Newman AB, Arnold AM, Naydeck BL, Fried LP, Burke GL, Enright P, Gottdiener J, Hirsch C, O'Leary D, Tracy R; for the Cardiovascular Health Study Research Group. "Successful aging": effect of subclinical cardiovascular disease. *Arch Intern Med.* 2003 Oct 27;163(19):2315-22.

[Phelan 2002] Phelan EA and Larson EB. "Successful aging" – where next? *J Am Geriatr Soc.* 2002 Jul;50(7):1306-8.

[Phelan 2004] Phelan EA, Anderson LA, LaCroix AZ, Larson EB. Older adults' views of "successful aging" – how do they compare with researchers' definitions? *J Am Geriatr Soc.* 2004 Feb;52(2):211-6.

[Roberts 2002] Roberts RE, Strawbridge WJ, Deleger S, Kaplan GA. Are the fat more jolly? *Ann Behav Med.* 2002 Summer;24(3):169-80.

[Roberts 2003] Roberts RE, Deleger S, Strawbridge WJ, Kaplan GA. Prospective association between obesity and depression: evidence from the Alameda County Study. *Int J Obes Relat Metab Disord.* 2003 Apr;27(4):514-21.

[Roos 1991] Roos NP and Havens B. Predictors of successful aging: A twelve-year study of Manitoba elderly. *Am J Public Health* 1991;81:63-68.

[Rowe 1987] Rowe JW and Kahn RL. Human aging: Usual and successful. *Science* 1987;237:143-149.

[Rowe 1997] Rowe JW and Kahn RL. Successful aging. *Gerontologist* 1997;37:433-440.

[Rudd 2006] Rudd Center for Food Policy and Obesity, Yale University. Online at http://www.yaleruddcenter.org Last visited: June 19, 2006.

[Ryff 1982] Ryff CD. Successful aging: A developmental approach. *Gerontologist* 1982; 22:209-214.

[Sakurai 1999] Sakurai Y, Teruya K, Shimada N, Umeda T, Tanaka H, Muto T, Kondo T, Nakamura K, Yoshizawa N. Association between duration of obesity and risk of non-insulin-dependent diabetes mellitus. The Sotetsu Study. *Am J Epidemiol.* 1999 Feb 1;149(3):256-60.

[Schulz 1996] Schulz R and Heckhausen J. A life span model of successful aging. *Am Psychol* 1996;51:702-714.

[Sobal 1991] Sobal J. Obesity and socioeconomic status: a framework for examining relationships between physical and social variables. *Med Anthropol.* 1991 Sep;13(3):231-47.

[Society Actuaries 1980] *Build Study 1979.* Society of Actuaries and Association of Life Insurance Medical Directors of America. March 1980, pg 41.

[Statistics Canada 2005a] Statistics Canada. *Population projections for 2001, 2006, 2011, 2016, 2021 and 2026, at July 1.* Online at http://www40.statcan.ca/l01/cst01/demo23c.htm Last modified: August 17, 2005. Last visited: October 15, 2005.

[Statistics Canada 2005b] Tjepkema, Michael. *Adult obesity in Canada: Measured height and weight.* Nutrition: Findings from the Canadian Community Health Survey. Ottawa: Statistics Canada, 2005. Catalog No. 82-620-MWE2005001. Online at http://www.statcan.ca/english/research/82-620-MIE/2005001/pdf/aobesity.pdf Last visited: August 16, 2006.

[Statistics Canada 2006a] *Population by sex and age group: July 2005.* Online at http://www40.statcan.ca/l01/cst01/demo10a.htm Last modified: May 29, 2006. Last visited: May 28, 2006.

[Statistics Canada 2006b] *Health at Older Ages; Special Issue Supplement to Volume 16, Health Reports: How Healthy Are Canadians ?* Ottawa: Statistics Canada, February 2006. Catalog No. 82-003-SPE. Online at http://www.statcan.ca/english/freepub/82-003-SIE/2005000/pdf/82-003-SIE2005000.pdf Last visited: June 19, 2006.

[Strandberg 2003] Strandberg TE, Strandberg A, Salomaa VV, Pitkala K, Miettinen TA. Impact of midlife weight change on mortality and quality of life in old age. Prospective cohort study. *Int J Obes Relat Metab Disord.* 2003 Aug;27(8):950-4.

[Strawbridge 1996] Strawbridge WJ, Cohen RD, Sherma SJ, Kaplan GA. Successful aging: Predictors and associated activities. *Am J Epidemiol.* 1996;144:135-141.

[Tamakoshi 2003] Tamakoshi K, Yatsuya H, Kondo T, Ishikawa M, Zhang H, Murata C, Otsuka R, Mabuchi T, Hori Y, Zhu S, Yoshida T, Toyoshima H. Long-term body weight variability is associated with elevated C-reactive protein independent of current body mass index among Japanese men. *Int J Obes Relat Metab Disord.* 2003 Sep;27(9):1059-65.

[Tate 2003] Tate, RB (Principal investigator). "Statistical power to assess significant association with Successful Aging". In The dynamic process of successful aging: The Manitoba Follow-up Study. CIHR grant application, No. 122205, September 9, 2003.

[Tate 2003b] Tate RB, Lah L, Cuddy TE. Definition of successful aging by elderly Canadian males: the Manitoba Follow-up Study. *Gerontologist* 2003 Oct;43(5):735-44.

[Vita 1998] Vita AJ, Terry RB, Hubert HB, Fries JF. Aging, health risks, and cumulative disability. *N Engl J Med.* 1998 Apr 9;338(15):1035-41.

[Wannamethee 2002] Wannamethee SG, Shaper AG, Walker M. Weight change, weight fluctuation, and mortality. *Arch Intern Med.* 2002 Dec 9-23;162(22):2575-80.

[Ware 1992] Ware JE Jr and Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care* 1992 Jun;30(6):473-83.

[Ware 1993] Ware JE, Snow KK, Kosinski M, Gandek B. *SF-36 Health Survey: Manual and Interpretation Guide.* The Health Institute, New England Medical Center: Boston, 1993.

[WHO 1946] World Health Organization. *Constitution of the World Health Organization.* Geneva: World Health Organization, July 22, 1946. Online at http://www.who.int/governance/en/ Last modified: March 2004. Last visited: October 15, 2005.

[WHO 1998] World Health Organization. *Obesity: Preventing and Managing the Global Epidemic.* Report of a WHO Consultation on Obesity, Geneva, 3-5 June 1997. Geneva: World Health Organization, 1998.

[WHO 2002] World Health Organization. *The World Health Report 2002: Reducing Risks, Promoting Healthy Life.* Geneva: World Health Organization, 2002.

[Wilson 2002] Wilson PW, D'Agostino RB, Sullivan L, Parise H, Kannel WB. Overweight and obesity as determinants of cardiovascular risk: the Framingham experience. *Arch Intern Med.* 2002 Sep 9;162(16):1867-72.

[Yatsuya 2003] Yatsuya H, Tamakoshi K, Yoshida T, Hori Y, Zhang H, Ishikawa M, Zhu S, Kondo T, Toyoshima H. Association between weight fluctuation and fasting insulin concentration in Japanese men. *Int J Obes Relat Metab Disord.* 2003 Apr;27(4):478-83.

APPENDIX I. SUCCESSFUL AGING QUESTIONNAIRE 1996

UNIVERSITY OF MANITOBA FOLLOW-UP STUDY QUESTIONNAIRE, 1996

If you are unable to complete this questionnaire yourself, please have someone assist you.

What is today's date? day _____ month _____ year _________

Who is filling out this questionnaire?

1. MFUS study member
2. Someone assisting MFUS study member, specify___________

How would you describe your health compared to others your age?

1. Excellent
2. Good
3. Fair
4. Poor
5. Bad

<u>... some general questions about your background and your living arrangements.</u>

What is your marital status?

1. Single
2. Married
3. Widowed
4. Divorced/Separated

If married, widowed, separated or divorced, for how long?

1. More than 3 years
2. From 12-36 months
3. From 6-12 months
4. From 3-6 months
5. For less than 3 months

Do any adults live in your household with you?

1. Yes, if so how many ___________
2. No

How many years or grades did you complete in school? ___________

How long have you lived in this community?

1. 0-2 years
2. 3-5 years
3. 6-10 years
4. 11-25 years
5. 26-50 years
6. 50 or more

What type of housing are you living in?

1. Whole house, or self contained townhouse
2. Self contained suite
3. Suite in Senior Citizens' housing unit or other apartment with a minimum age restriction
4. Board & Room, hostel, foster house, commercial boarding
5. Personal care or nursing home
6. Other, specify ___________________________

Do you and/or your spouse own this residence?

1. Yes, own
2. No, rent
3. No, Personal Care / Extended care, nursing home or chronic care facility

... Some questions about your work history

What was/is your major occupation? ___________________

Are you retired from your major occupation? ___________________

If so, when did you retire? ___________________

If retired from your major occupation, what was your main reason for retirement?

1. Compulsory retirement age
2. Poor health
3. Did not wish to continue working
4. Needed at home, please describe ____________________
5. Job too tiring
6. To have time to pursue other interests
7. Won the big lottery
8. Other, please specify ____________________

If different from your major occupation, what was/is your most recent occupation ? ____________________

.... the next set of questions are about your thoughts and feelings about life and daily activities.

How would you describe your satisfaction with life in general at present?

1. Excellent
2. Good
3. Fair
4. Poor
5. Bad

Do you walk ...

1. unassisted
2. with the use of a cane / walker
3. wheel chair
4. cannot walk at all
5. other, please specify ________

... now I have some questions about your ability to carry on different activities. I am interested in your capability, not whether or not you actually do them.

Are you capable of ..... without any help from anyone else?

Doing light housework (washing up, dusting etc.)	____Yes	____No
Doing heavy housework (cleaning floors, windows)	____Yes	____No
Making a cup of tea or coffee	____Yes	____No
Preparing a hot meal	____Yes	____No
Shovelling and yard work	____Yes	____No
Shopping	____Yes	____No
Managing financial affairs (banking,paying bills)	____Yes	____No
Laundry (household and personal)	____Yes	____No
Major house or household repairs	____Yes	____No

Are you capable of ..... without any help from anyone else?

Going up and down the stairs	____Yes	____No
Getting about the house	____Yes	____No
Going out of doors in good weather	____Yes	____No
Getting in and out of bed	____Yes	____No
Washing or bathing or grooming	____Yes	____No
Dressing and putting shoes on	____Yes	____No
Cutting your toenails	____Yes	____No
Eating	____Yes	____No
Taking medication or treatment	____Yes	____No
Using toilet	____Yes	____No
Nursing care	____Yes	____No
Watching televison or listening to radio	____Yes	____No
Reading or writing	____Yes	____No
Use of telephone	____Yes	____No
Buttoning a sweater	____Yes	____No
Getting up out of a chair and walking 3 meters	____Yes	____No

S1. In general, would you say your health is :

1. Excellent
2. Very Good
3. Good
4. Fair
5. Poor

S2. Compared to one year ago, how would you rate your health in general now?

1. Much better now than one year ago
2. Somewhat better now than one year ago
3. About the same as one year ago
4. Somewhat worse now than one year ago
5. Much worse than one year ago

S4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

a. Cut down the amount of time you spent on work or other activities ..... _____Yes _____No

b. Accomplished less than you would like . _____Yes _____No

c. Were limited in the kind of work or other activities.................... _____Yes _____No

d. Had difficulty performing the work or other activities (for example, it took extra effort) .... _____Yes _____No

S3. The following questions are about activities that you might do during a typical day. Does <u>your health now limit you</u> in these activities? If so, how much?

ACTIVITY	Yes, Limited A Lot	Yes, Limited A Little	No, Not Limited At All
a. Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports	________	________	________
b. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	________	________	________
c. Lifting or carrying groceries	________	________	________
d. Climbing several flights of stairs	________	________	________
e. Climbing one flight of stairs	________	________	________
f. Bending, kneeling, or stooping	________	________	________
g. Walking more than a mile	________	________	________
h. Walking several blocks	________	________	________
i. Walking one block	________	________	________
j. Bathing or dressing yourself.	________	________	________

S5. During the <u>past 4 weeks</u>, have you had any of the following problems with your work or other regular daily activities <u>as a result of any emotional problems</u> (such as feeling depressed or anxious)?

a. Cut down the <u>amount of time</u> you spent on work or other activities ..... ______Yes ______No

b. <u>Accomplished less</u> than you would like . ______Yes ______No

c. Didn't do work or other activities as <u>carefully</u> as usaual .... ______Yes ______No

S6. During the <u>past 4 weeks</u>, to what extent has your physical health or emotional problems interfered your normal social activities with family, friends, neighbours or groups?

1. Not at all
2. Slightly
3. Moderately
4. Quite a bit
5. Extremely

S7. How much <u>bodily</u> pain have you had in the <u>past 4 weeks</u>?

1. None
2. Very mild
3. Mild
4. Moderate
5. Severe
6. Very severe

S8. During the <u>past 4 weeks</u>, how much did <u>pain</u> interfere with your normal work (including both work outside the home and housework)?

1. Not a all
2. A little bit
3. Moderately
4. Quite a bit
5. Extremely

S9. These questions are about how you feel and how things have been with you <u>during the past 4 weeks</u>. For each question, please give the one answer that comes closest to the way you have been feeling.

How much of the time during the past 4 weeks ....

	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
a. Did you feel full of pep?	____	____	____	____	____	____
b. Have you been a very nervous person?	____	____	____	____	____	____
c. Have you felt so down in the dumps that nothing could cheer you up?	____	____	____	____	____	____
d. Have you felt calm and peaceful?	____	____	____	____	____	____
e. Did you have a lot of energy?	____	____	____	____	____	____
f. Have you felt downhearted and blue?	____	____	____	____	____	____
g. Did you feel worn out?....	____	____	____	____	____	____
h. Have you been a happy person?	____	____	____	____	____	____
i. Did you feel tired?	____	____	____	____	____	____

S10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with with your social activities (like visiting with friends, relatives, etc.)?

1. All of the time
2. Most of the time
3. Some of the time
4. A little of the time
5. None of the time

S11. How TRUE or FALSE is each of the following statements for you?

	Definitely true	Mostly true	Don't know	Mostly false	Definitely false
a. I seem to get sick a little easier than other people	____	____	____	____	____
b. I am as healthy as anybody I know ..	____	____	____	____	____
c. I expect my health to get worse	____	____	____	____	____
d. My health is excellent	____	____	____	____	____

What is YOUR definition of successful aging: ____________________

____

____

____

Would YOU say you have "AGED SUCCESSFULLY"? ____________________