The Pennsylvania State University

The Graduate School

College of Health and Human Development

PHYSICAL DISABILITY TRAJECTORIES FROM MIDLIFE TO OLDER AGE IN ADULTS WITH AND WITHOUT DIABETES: THE ROLE OF BIOBEHAVIORAL, PSYCHOSOCIAL, AND CULTURAL MECHANISMS

A Dissertation in

Biobehavioral Health

by

Ching-Ju Chiu

Submitted in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

August 2009

The dissertation of Ching-Ju Chiu was reviewed and approved* by the following:

Linda A. Wray
Associate Professor of Biobehavioral Health
Dissertation Adviser
Chair of Committee

Patricia B. Koch
Professor of Biobehavioral Health

Sheila G. West
Associate Professor of Biobehavioral Health

Mosuk Chow
Senior Research Associate & Associate Professor of Statistics

Byron C. Jones
Professor of Biobehavioral Health and Pharmacology
Graduate Program Officer for Biobehavioral Health

*Signatures are on file in the Graduate School

ABSTRACT

The impact of diabetes on physical function from midlife to older adulthood is intuitively important but not well defined. As the number and proportion of older adults with diabetes grows within populations, there is an increasing need to understand the difficulties faced by these adults beyond the basic measure of mortality. The purpose of this three-paper thesis was to illuminate the impact of diabetes on physical function for adults from midlife to older age.

The first study employed an accelerated longitudinal design and multilevel modeling growth curve models to identify physical function trajectories for nationally representative samples of middle-aged adults with and without diabetes in the U.S. and Taiwan. Results demonstrated that adults living with diabetes experienced more physical limitations and faster rates of change in aging than did those without diabetes. In addition, U.S. women, minority group adults, and those of lower education suffered more adverse impacts of diabetes than did men, Whites, and those of higher education. The second study employed structural equation modeling to examine hypothesized mechanisms underlying gender differences in physical disability for adults with type 2 diabetes. Findings indicated that gender-related biological (e.g., BMI, HbA1c, blood pressure, early complications) and behavioral (e.g., exercise) factors directly and completely mediated the gender differences in physical function; psychosocial factors (e.g., perceived control, self-efficacy, coping, and depressive symptoms), contributed indirectly to the link. The third study investigated if the physical function trajectories experienced by adults living with diabetes in the U.S. were shaped by body weight trajectories earlier in life, using a group-based trajectory modeling approach. Results identified four distinct body weight trajectories (stable normal weight,

29.0%; stable overweight, 46.5%; loss and regain obese, 17.6%; and weight cumulating morbidly obese, 6.9%) and three disability trajectories (little or low increase, 34.6%; moderate increase, 45.4%; and chronic high, 20.1%). Various relationships among these two sets of trajectories were found. Importantly, the results strongly supported recommendations for weight control in adults with diabetes in order to prevent future disability. In conclusion, the three studies in this thesis highlighted the heterogeneity of adults living with diabetes in midlife and older age and underscored the importance of taking a multidimensional approach to providing diabetes care.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

I am deeply indebted to many people for your strong support during my graduate studies. First and foremost, I would like to thank my advisor and chair of my doctoral committee, Dr. Linda Wray, for being an exceptional mentor and friend throughout my time at Penn State. You have not only helped me to become a more confident and rigorous researcher by providing me with clear, useful feedback on all aspects of the research process, but you have also shown through example how to be a supportive, encouraging mentor. I wouldn't be the gerontologist with enthusiasm and humanity that I have become without your guidance.

I would also like to thank all of my committee members—Dr. Patricia Koch, Dr. Sheila West and Dr. Mosuk Chow—for your continuous encouragement and willingness to help in any way possible. Thank you for taking the time to read and react to this dissertation. Your thoughtful comments helped guide me through the challenges faced with the preparation of this thesis.

Much appreciation also goes to the following teachers whose classes I found particularly useful and inspiring: Dr. John Graham, Dr. Wayne Osgood, Dr. Peter Molenaar, and Dr. Michael Rovine. Thank you for your willingness to share your expertise and provide me with statistical advice over the past few years.

I am deeply grateful to my parents, Sen-Po and Fu-Jung, for their endless love, patience and encouragement, and my sister, Ellen, who supported me in each step I took towards my personal and professional growth.

To my husband, Jen-Chieh, who loved me when I was unlovable and tolerated me when I was intolerable. Thank you for always believing in me and encouraging me in everything I do. You are the one constant that I could always count on no matter what. I could not and would not have done this without you (definitely not the tables!).

I also want to express my deep gratitude to the faculty, staff and graduate students in Penn State's Department of Biobehavioral Health. Special thanks to Dr. Byron Jones for giving me great support and for your valuable discussions about leading a productive and rewarding academic career. Thank you to Shannon and Lisa for being very supportive throughout my graduate journey. Thanks Liz, Oralia, Jian, Miesha, Michelle, Terry, Leah, and Cynthia for being close friends during the years I spent here.

I would like to thank all my Taiwanese friends in State College: Mei-Fang, Kuan-Chen, Emily, Eden, Ji-Ming, Ko-Yu and Yi-Wen. You made my day-to-day life at Penn State an enjoyable one and I am forever grateful.

Finally, I would like to acknowledge the support from the Penn State Center on Population Health and Aging level 2 grant (parent grant, National Institute on Aging, P30-AG024395, D.F. Alwin, PI), the Hintz Award and Graduate Student Scientific Achievement Award for Outstanding Graduate Work in the department of Biobehavioral Health for funding the completion for this thesis.

Chapter 1

INTRODUCTION

Diabetes and the complications that often accompany it have challenged public health officials over the last several decades. Studies from across the world report an increasing prevalence of diabetes (Colagiuri, Borch-Johnsen, Glumer, & Vistisen, 2005) and project more dramatic increases in the future (Wild, Roglic, Green, Sicree, & King, 2004). Although preventing diabetes is an important public health task, it is equally crucial to families and their members living with diabetes, as well as to their diabetes care providers who aim to promote their quality of life, to prevent or delay unwanted complications, and avoid premature mortality.

To develop programs of diabetes care tailored to individuals, as recommended increasingly by professional organizations and researchers (American Diabetes Association, 2008; Beverly, Miller, & Wray, 2008; Boyd et al., 2005; Brown, Mangione, Saliba, & Sarkisian, 2003; Fisher & Glasgow, 2007; Huang, Gorawara-Bhat, & Chin, 2004), a fuller understanding of the diabetes experience is essential. While there is a wealth of information on the impacts of diabetes on kidney, eye, neurological, vascular diseases, and premature death, less attention has been paid to the effects of diabetes on physical function from midlife to older adulthood. Physical function is one of the most relevant predictors of quality of life (Verbrugge & Jette, 1994). For example, limitations in physical function are associated with lower rates of employment, higher rates of absenteeism, lower income levels, increased likelihood for hospitalization, and poor self-rated health—important diabetes-related health outcomes in middle-aged and older adults (Wray, Ofstedal, Langa, & Blaum, 2005).

An understanding of the aging trajectories for physical function from midlife to older age for adults with and without diabetes, identification of factors moderating these trajectories, and

ascertaining mechanisms underlying these moderating effects are important to providing more effective diabetes care. It is also crucial to extend diabetes-related knowledge beyond Western society to other countries. Taiwan offers a striking contrast to the U.S. on several cultural and social dimensions that directly affect the health of the elderly, yet the Taiwan population also shares certain demographic characteristics with Western populations, such as a similar cause-of-death structure, high life expectancy, and high level of industrialization (Beckett, Goldman, Weinstein, Lin, & Chuang, 2002). Studies focusing on Taiwan as a cross-country, cross-cultural comparison to the U.S. may contribute importantly to both the literature and clinical practice.

The following sections are provided in this introductory chapter: current diabetes diagnosis and treatment guidelines in the U.S. and Taiwan; the diabetes epidemic and its complications in middle-aged and older adults; definitions and measurements of physical function; theoretical background; empirical evidence of differential diabetes experiences/outcomes by gender, race/ethnicity, age, and education; similarities and differences between the U.S. and Taiwan; conceptual framework of the thesis; an overview of the research; and a summary of the significance of this research.

Diabetes Diagnosis and Treatment Guidelines in the U.S. and Taiwan

In the past decade, in order to diagnose adults with diabetes, both the U.S. and Taiwan have adopted the latest diagnostic criteria provided by the World Health Organization (WHO, 1999) (Alberti & Zimmet, 1998) and the American Diabetes Association (ADA, 2003; 1997) employing a fasting plasma glucose level≥ 126 mg/dl (7.0mmol/l), or a casual plasma glucose ≥ 200 mg/dl (11.1 mmol/l), or 2-h plasma glucose≥200 mg/dl (11.1 mmol /l) during an oral

glucose tolerance test. The diagnostic criteria are the same for all types of diabetes except for gestational diabetes.

Guidelines for the prevention and management of diabetes complications have been provided by many task forces and organizations (Brown et al., 2003; International Diabetes Federation, 2000; Norris, Kansagara, Bougatsos, & Fu, 2008; U.S. Preventive Services Task Force., 2008). Medication use, exercise, smoking cessation, moderate alcohol use, diet and body weight control are generally specified in diabetes care because these factors have been confirmed to help reduce microvascular and macrovascular complications, such as CVD, nephropathy, retinopathy, and neuropathy (ADA, 2008). However, less is known about whether these behaviors are also beneficial in lowering the risks of physical disability, an underappreciated diabetes complication recently highlighted by the American Geriatric Society (ADA, 2008; Brown et al., 2003).

There is also a dearth of diabetes treatment guidelines tailored specifically to older adults, men versus women, or adults living in different countries. It is generally acknowledged that due to biology and environment, illness patterns and behaviors differ by gender or sex (Krieger, 2003; Pinn, 2003, 2006), yet evidence-based research individualized to men and women with diabetes has been limited (Gucciardi, Wang, DeMelo, Amaral, & Stewart, 2008; Nilsson, Theobald, Journath, & Fritz, 2004; Ponzo et al., 2006). In addition, since Taiwan has largely borrowed its diabetes treatment guidelines from the U.S., it is imperative to determine if those guidelines are adequate across ethnocultures. Thus, this research represents one of the first evidence-based studies designed to assess the impact of gender, lifestyles and ethnocultures on the physical and mental health of older adults living with diabetes in the U.S. and Taiwan.

Diabetes Epidemic and Its Complications in Middle-aged and Older Adults

The number of people with diabetes has increased throughout the world, and the burden of this disease is expected to intensify in the future as prevalence increases due to population aging (Boyle et al., 2001; Colagiuri et al., 2005; King, Aubert, & Herman, 1998). Currently, adults with diabetes constitute approximately 20% of adults aged 65 and above in the U.S. and Taiwan (Centers for Disease Control and Prevention, 2005; Chang et al., 2000; Chuang, Tsai, Huang, & Tai, 2001; Cowie et al., 2006; Mainous et al., 2007; Tseng et al., 2006). Alarmingly, the total number of people with diabetes worldwide is projected to double in the next two decades (Wild et al., 2004).

Diabetes in midlife and older age is associated with higher risks of microvascular (e.g., retinopathy, nephropathy, neuropathy) and macrovascular (e.g., coronary heart disease, stroke, peripheral arterial disease) complications (Gregg, Engelgau, & Narayan, 2002). There is also increasing evidence that adults with diabetes in older age are at greater risk for several often inter-related geriatric syndromes, including physical disability, depression, cognitive impairment, injurious falls, neuropathic pain, and urinary incontinence (Blaum, Ofstedal, Langa, & Wray, 2003; Cummings et al., 1995; Fultz, Ofstedal, Herzog, & Wallace, 2003; Gregg et al., 2002; Gregg et al., 2000; Ueda, Tamaki, Kageyama, Yoshimura, & Yoshida, 2000; Wray, Ofstedal et al., 2005). However, recent studies have indicated that although the association of diabetes and physical disability is explained in part by classic complications of diabetes (e.g., coronary heart disease, peripheral arterial disease, and visual impairment), a 60% excess prevalence of disability remains after controlling for those complications (Gregg et al., 2000; Gregg et al., 2002). As acknowledged by Gregg and colleagues (2002), these underappreciated complications of

physical disability, which directly impact quality of life and demands on caregivers, may ultimately be as great concerns to older people with diabetes as the more traditionally recognized vascular complications. Research documenting the long-term experience of diabetes in physical function among older individuals may fill the gap in this field.

Definitions and Measurement of Physical Disability

The definitions of physical function have commonly followed three schemes: the International Classification of Impairments, Disabilities and Handicaps (ICIDH) model (World Health Organization, 1980), the Nagi scheme (Nagi, 1964; Nagi & Marsh, 1980), and the Verbrugge and Jette disablement process model (VJ model) (Verbrugge & Jette, 1994). Among the three schemes, the VJ model—that has its main foundation in the Nagi scheme, but also draws on the scope and detail of ICIDH—describes concepts relating to functional limitations and disability, and therefore sheds light on the measurement feasibility of physical function in surveys.

According to the VJ model (Verbrugge & Jette, 1994), functional limitations are restrictions in the ability to perform fundamental physical and mental actions in daily life. Physical actions include overall mobility, discrete motions, and strengths. Examples are walking, lifting objects, and climbing stairs—activities falling within the concept of Nagi strength and mobility activities (Nagi, 1976). Disability, on the other hand, involves experiencing difficulty in performing activities in three domains of life: personal care (basic activities of daily living; ADL), household management (instrumental activities of daily living; IADL), and social roles (job). ADLs are necessary for survival, including abilities to eat, toilet, transfer (get in and out of bed/chair), dress and bathe (Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963). IADLs are

necessary for maintaining a dwelling in a given sociocultural setting, and include the ability to prepare own meals, do light housework, manage own money, use the telephone, and shop for personal items. Social roles generally refer to the ability to participate in paid employment or volunteer activities (Lawton & Brody, 1969).

There is no consensus in the literature on the impact of diabetes on multiple domains of physical function or disability. Some studies have found that diabetes is associated with increased rates of functional decline in IADLs, mobility and strength activities, but not with ADLs (Wang, van Belle, Kukull, & Larson, 2002); however, other research has indicated that diabetes is predictive of change in both ADL and IADL (Wu et al., 2003). The more recent literature suggests a comprehensive approach to measuring physical function in diabetes-related research. This approach combines measures of limitations in Nagi strength and mobility activities (Nagi, 1969) and measures of VJ model disability, including difficulties doing personal care (activities of daily living, ADL) and household management activities (instrumental activities of daily living, IADL) (Verbrugge & Jette, 1994; Verbrugge, Merrill, & Liu, 1999) to assess physical function. This composite measure, which captures the known effects of diabetes on higher-order mobility and strength tasks in older adults and a broad range of physical disability from early or ‘‘preclinical’’ disability to later personal care disability (Wang, Sheu, & Protas, 2007; Wray, Ofstedal et al., 2005), was adopted in this thesis.

Theoretical Background

This thesis sought to examine the impacts of diabetes on physical function from midlife to older adulthood in heterogeneous samples of U.S. and Taiwanese adults. Two theoretical frameworks were especially useful in guiding the research design: (1) the life-span

developmental (LSD) perspective (Alwin & Wray, 2005); and (2) the Mandala of Health Model (MHM) (Hancock, 1985).

First, the LSD perspective was relied upon during the investigation of possible moderating factors between diabetes and physical function outcomes. The LSD perspective provides a theoretical principle for understanding the development of health inequalities relating to ascribed statuses (e.g., gender, race/ethnicity, and age) and achieved statuses (e.g., educational and other socioeconomic differences). The perspective is useful in understanding why people across varying ascribed and achieved social statuses may be differentially exposed to risks of disease or protective factors (Alwin & Wray, 2005). For example, many of the risky behaviors or consequences of risky behaviors (e.g., obesity, physical inactivity, cigarette smoking) associated with diabetes and its comorbid conditions are disproportionately prevalent in older adults with diabetes compared to their older and younger counterparts without diabetes, as well as in African Americans and Latino Americans compared to European Americans (Wray, Alwin, & McCammon, 2005). Similarly, many of these risk factors vary widely by achieved social status such that lower levels of schooling, income, or wealth are associated with increasing numbers of risky health behaviors (Blaum et al., 2003; Wray, Alwin et al., 2005; Wray, Ofstedal et al., 2005).

The MHM framework, on the other hand, offers insight into methods for taking cultural factors into consideration when analyzing diabetes experiences in heterogeneous populations. As suggested in the MHM model (Figure 1.1), the culture biosphere factor outside of the inner circles suggests that cultural factors beyond biological, psychosocial, and behavioral differences may have direct or indirect effects on personal health. For example, research has found that older adults in India had significantly poorer performance-based functional status than did adults in the U.S. even when matched for age, gender, medical conditions, and self-rated disability (Albert,

Alam, & Nizamuddin, 2005). Such findings highlight the need to consider cultural factors when investigating health differences across populations. Further, the cultural factors outside the complex inner circles also imply that the effect of factors in the inner circle on personal health may hinge on culture. For example, different countries may have very different gender roles, and therefore the effect of gender in modifying the impact of diabetes on physical function trajectories may differ across countries. Diabetes outcomes may be better in men than in women in one country but different in the other country. However, the hypothesis has not been proven due to a lack of empirical evidence. By and large, this theoretical basis offers a structure for understanding the multidimensional complexities of diabetes in different ethnocultural populations, which is critical for assessing the generalizability of commonly held knowledge of diabetes care across social statuses and diverse cultural and geographic settings.

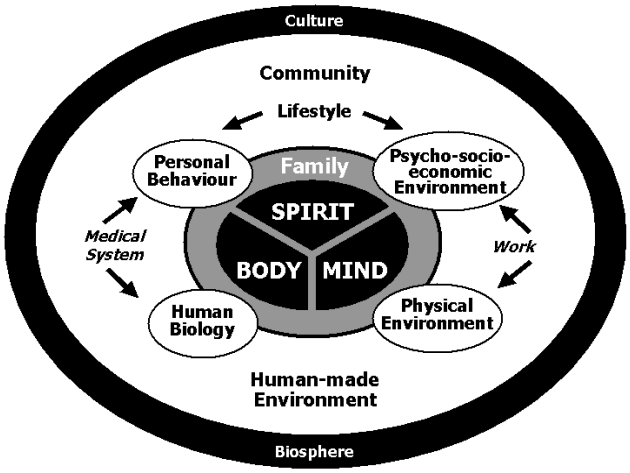

Figure 1.1 The Mandala of Health Model (Hancock & Perkins, 1985)

Empirical Evidence of Different Diabetes Experiences and Outcomes by Gender, Race/ethnicity, Age, and Education

Gender is embodied by a socially constructed set of expectations that differentiate the roles and attributes of the sexes and often accounts in part for a division of labor by sex or

gender (Alwin & Wray, 2005). Research has suggested that men and women who have diabetes differ in many domains of life. Compared to men, women reported higher levels of social support from their diabetes health care team, had more positive attitudes toward diabetes, viewed self-management as being beneficial (Gucciardi et al., 2008; Ponzo et al., 2006), and had lower rates of retinopathy, nephropathy, neuropathy and foot ulcers than did men (Basit, Hydrie, Hakeem, Ahmedani, & Masood, 2004). In contrast, women with diabetes appear to manage diabetes with fewer economic and social resources (McCollum, Hansen, Lu, & Sullivan, 2005; Sabolsi, Solomon, & Manson, 2001; Wray, Alwin, McCammon, Manning, & Best, 2006); received fewer benefits through spousal assistance in the family (Fitzgerald, Anderson, & Davis, 1995; Umberson, 1992); had more depressive symptoms (Anderson, Freedland, Clouse, & Lustman, 2001), higher body mass (Legato et al., 2006; McCollum, Hansen, Ghushchyan, & Sullivan, 2007; Nilsson et al., 2004; Szalat & Raz, 2007; Tang, Pang, Chan, Yeung, & Yeung, 2008; Wexler, Grant, Meigs, Nathan, & Cagliero, 2005), and HbA1c levels (Nilsson et al., 2004); and engaged in less physical activity (Barrett, Plotnikoff, Courneya, & Raine, 2007).

Compared to Whites, members of minority groups (i.e., non-Hispanic African-Americans and Mexican-Americans) were less likely to report having had diabetes-related glycosylated hemoglobin (HbA1c) and dyslipidemia diagnosis testing but more likely to report having received foot examinations; when they were tested, minority group members had higher HbA1c and blood pressure readings, as well as better levels of total and HDL cholesterol (Heisler et al., 2007). Further, although White men were more overweight than were African-American and Mexican-American men, rates of treatment with insulin or oral agents, eye examination, blood pressure check, and proportion of hypertension were similar for each race and ethnic group

(Gary, McGuire, McCauley, & Brancati, 2004; Harris, 2001; Heisler et al., 2007; LeMaster, Chanetsa, Kapp, & Waterman, 2006).

Considerably fewer investigations have compared diabetes outcomes in midlife and older age. Mortality selection is the main inhibitor of this kind of research, in that the surviving adults at older ages are substantially more homogenous on many measures of social status and health conditions (Alwin & Wray, 2005). However, as suggested by the theory of cumulative advantage or disadvantage (Crystal & Shea, 1990; Dannefer, 2003; Merton, 1968; O'Rand, 1996; Ross & Wu, 1996), it is possible that the effects of diabetes on physical function increase with age. The higher prevalence of diabetes complications and comorbidities in older versus younger age (Standl, 2002; Wray et al., 2006) largely supports this conjecture; however, at which age diabetes manifests its adverse effects remains unclear in the literature.

Education, an important factor in many aspects of health outcomes (Alwin & Wray, 2005; Herd, 2006), was also less studied in diabetes research. Studies have shown that participation in risky health behaviors varies by education (Alwin & Wray, 2005; Wray, Alwin et al., 2005), and this, in turn, may lead to differential diabetes outcomes. Previous research also has indicated that higher- (versus lower-) education levels may influence the experience of diabetes by increasing knowledge about the links between health behaviors and diabetes (Wray et al., 2006; Wray, Ofstedal et al., 2005), or through many facets of cumulative economic opportunity, such as exposure to occupational risk factors or the availability of health insurance and preventive care from secure employment. In addition, educational differences in social networks, community influences, individual self-efficacy, and other protective psychosocial attributes also have been closely linked to the prevalence of behavioral risk factors over many years of adulthood (Wray, Alwin et al., 2005).

Taken together, it is conceivable that the impacts of diabetes on physical function from midlife to older age may hinge on gender, race/ethnicity, age, and education. Comparative investigations are critical to assessing the long-term needs of men and women in adults of different racial/ethnic and educational backgrounds, as well as at different ages.

Similarities and Differences between U.S. and Taiwan

The comparison of health across a variety of settings and populations has emerged as an important area of study in recent years. Such comparative investigations may provide critical evidence to researchers that enables them to assess the generalizability of commonly held hypotheses across diverse cultural and geographic settings (Ofstedal, Zimmer, & Lin, 1999).

Taiwan, in comparison with many other Asian countries, is more similar to the United States in terms of levels of socioeconomic development (Ofstedal et al., 2007). In addition, Taiwanese adults share certain sociodemographic characteristics with U.S. adults, such as a similar cause-of-death structure and high life expectancy (Beckett et al., 2002). Further, diabetes has gained notoriety as a major chronic disease in both countries—currently, adults with diabetes constitute approximately 20% of the population aged 65 and above in the U.S. (Centers for Disease Control and Prevention, 2005; Cowie et al., 2006; Mainous et al., 2007), and 17–22% of the older population in Taiwan (Chen, Chen, Gregg, Engelgau, & Narayan, 2001; Chen, Chen, Gregg, Williamson, & Narayan, 1999; Chuang et al., 2001; Tseng et al., 2006). The percentages of U.S. and Taiwanese adults with diabetes and related comorbidities are expected to increase markedly in future decades as the proportion of people over age 65 increase in both countries (Wild et al., 2004). This suggests that, as in the United States, diabetes and its comorbidities will become an increasingly important issue for diagnosis and treatment in Taiwan.

However, Taiwan provides a striking contrast to U.S. society on several biological, social and cultural levels. First, as an Asian country, Taiwan shares many biological characteristics with other Asian populations. As indicated in the literature, Asian populations have greater amounts of body fat for any given level of BMI, waist circumference, or waist-hip ratio than do Caucasians; and the metabolic risk factors for cardiovascular events increases at lower values of indices in Asians compared with Western people (Deurenberg, Deurenberg-Yap, & Guricci, 2002; Huxley et al., 2008; Nakagami et al., 2003; Pan et al., 2004; Tomlinson, Deng, & Thomas, 2008). A recent literature review on diabetes research in Asia found that people in Asia who develop diabetes tend to be less obese and are diagnosed at younger ages, suffer longer with the complications of diabetes, and die sooner than do people in other world regions (Yoon et al., 2006). Comparisons of metabolic disorders between Taiwan and the U.S. revealed that for most BMI values, the prevalences of hypertension and diabetes were higher for Taiwanese than for U.S. Whites (Pan et al., 2004).

Taiwan also differs from the U.S. with regard to many social factors. For example, socioeconomic development occurred much later and more rapidly in Taiwan than in the U.S. (Ofstedal et al., 2007). Although educational levels are similar for contemporary adults in Taiwan and the U.S., the distributions of years of completed education are quite different for older Taiwanese and Americans observed a decade ago. Another example is health care coverage. Unlike in the U.S., Taiwan has provided universal health care since 1995, so that all citizens are covered by high-quality health insurance and have access to high-quality health care, which directly affects the health of the elderly (Cheng & Chiang, 1997; Cheng & Chiang, 1998; Davis & Huang, 2008; Wen, Tsai, & Chung, 2008).

Cultural variations in health behaviors, leisure time activities, and family relationship are also innate within each country. For example, Taiwanese are more likely to engage in health-promoting behaviors than are their American counterparts in terms of healthy diet behavior, stress management, health responsibility, and social support, but they also engage less frequently in exercise and life appreciation (e.g., feeling happy and content, believing that life has purpose) (Chen, James, & Wang, 2007). It also has been found that there are distinct gender differences in leisure time activities engaged in by Taiwanese adults, a pattern that differs from that observed in Western society (Zimmer & Lin, 1996). The family organization and familial systems of support in Taiwan in comparison to the U.S. are also different. Family interactions are more frequent, and a higher percentage of older persons co-reside with and/or are cared for by their children in Taiwan than in the U.S. (Ofstedal et al., 1999).

Based on this literature, it is reasonable to speculate that trajectories of physical function may not be the same in the U.S. and Taiwan for adults with and without diabetes. A comparative study of the role of diabetes in physical function from midlife to older age may provide important information in forecasting health needs in both countries.

Conceptual Framework

Figure 1.2 presents a conceptual framework for understanding how age, race/ethnicity, gender, education, comorbidities, and enthocultural factors theoretically shape the impact of diabetes on physical disability trajectories, after age 50. Specifically, we hypothesized that physical function is a function of time which constitutes the trajectories. However, the chronic disease of diabetes changes the longitudinal trajectories over and beyond natural aging processes. Patterns of change are not consistent across populations; they depend largely on gender,

race/ethnicity, and education. As the gender role is embedded in cultural contexts, we hypothesized that gender affects the impact of diabetes on physical function in different ways across different countries. The utility of this model illuminates the effects of policy-relevant ascribed and achieved social factors on health outcomes, and emphasizes the importance of longitudinal examinations of these complex mechanisms across a variety of cultural and geographic settings.

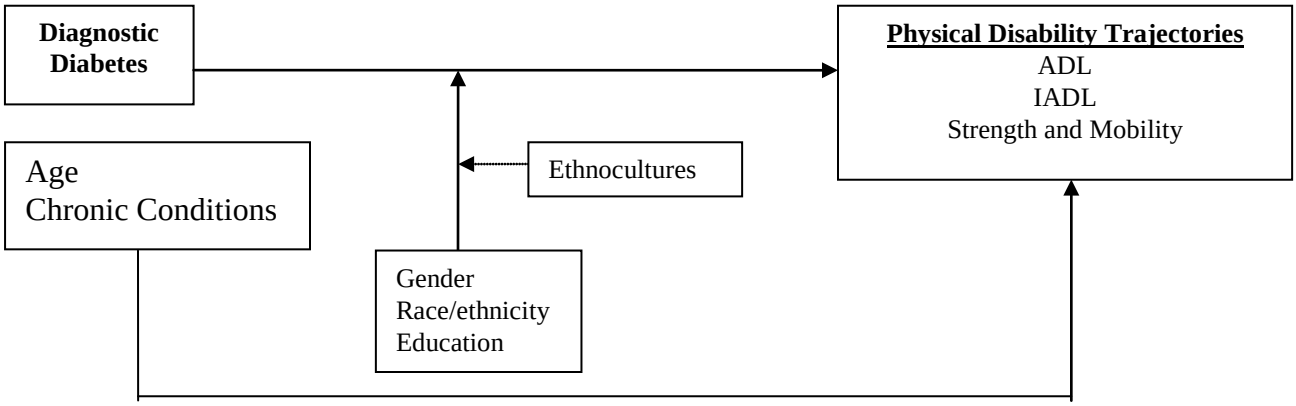

Figure 1.2 Conceptual Framework Linking Diabetes and Physical Disability Trajectories

Overview of the Research

In the following three studies of diabetes and physical function in middle-aged and older adults in the United States and Taiwan, various methods were utilized to gain a better understanding of how diabetes may change physical function from midlife to older adulthood, the extent to which biobehavioral and psychosocial factors explain gender differences in physical function outcomes of diabetes, and how body mass index trajectories in adults with diabetes relate to patterns of disability trajectories later in life.

The first study, “Physical Disability Trajectories for Adults With and Without Diabetes from Midlife to Older Adulthood: A Cross-national Comparison between the U.S. and Taiwan,” had three specific aims: (1) to identify the average forms of physical function trajectories in U.S. and Taiwanese adults ages 50 and above; (2) to determine the independent effects of diabetes on physical health over time, controlling for attrition, time-invariant demographic factors, and time-varying disease conditions; and (3) to test if the impacts of diabetes are the same by gender, race/ethnicity, and educational levels. We used 1998, 2000, 2002, 2004, and 2006 data from the U.S. representative Health and Retirement Study (HRS) and 1996, 1999, and 2003 data from the nationally representative Survey of Health and Living Status of the Elderly in Taiwan (HLSES) study. All participants in the two studies who were age 50 and above were assessed using an accelerated longitudinal multilevel modeling approach. Study variables included self-reported diabetes at baseline, physical function (16 questions about limitations in physical function, including ADLs, IADLs, strength and mobility, which were identical or similar in the HRS and HLSES), and covariates of follow-up status, time-invariant demographic factors (gender, race/ethnicity, education), and time-varying chronic diseases (high blood pressure, cancer, lung disease, heart disease, stroke, arthritis).

The second study, “Gender Differences in Physical Disability in Adults Living with Type 2 Diabetes: Biobehavioral and Psychosocial Mediators,” sought to determine if gender differences in limitations to physical function were attributed to biological factors (blood pressure, BMI, HbA1c, and early complications), self-care behaviors (medication, blood sugar test, diet and exercise), or psychosocial well-being (perceived diabetes control, perceived diabetes-specific family/friends support, coping, and mood). We used data from the 2002 and 2004 core interviews of the HRS and its 2003 diabetes-specific mail survey (758 men and 861

women with type 2 diabetes, mean age=69.5). All mediators were measured during 2002–2003, and physical function was measured in 2004. Structural equation modeling was used to test the mediation model shown below (Figure 1.3).

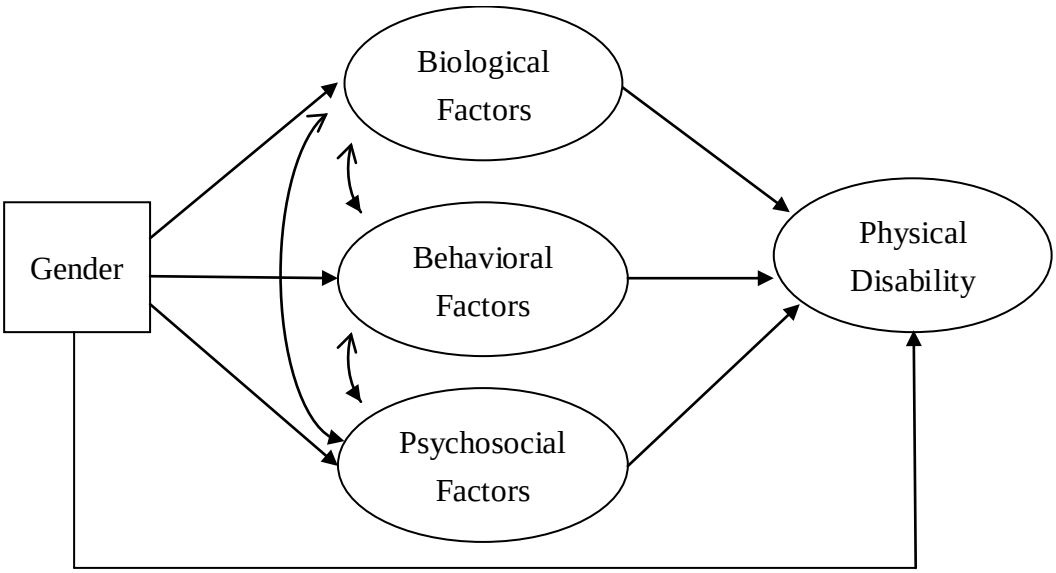

Figure 1.3 Mediation Model of Gender Differences in Physical Disabilities in Adults with Type 2 Diabetes

The third study, "BMI Trajectories in U.S. Middle-aged and Older Adults Living with Diabetes and Link with Future Disability Trajectories," aimed to identify the distinct trajectories experienced by middle-aged and older adults living with diabetes, to understand the proportion of those trajectories in the population, and to reveal how those trajectories are shaped by body weight trajectories earlier in life. Data were drawn from all available waves of HRS data (biennial data from 1992–2006) for 1,064 adults aged 50–61 who self-reported having diabetes in 1992. The key variables in this study included: (1) physical function, measured as overall difficulties with ADLs, IADLs, strength and mobility activities (score 0–16); and (2) Body Mass

Index, calculated by self-reported height and weight. Group-based trajectory modeling using SAS Proc Traj was employed to answer our research questions relating to the specific aims with the following stages: (1) identification of the latent class of BMI trajectories of the participants' data from 1992–1998; (2) identification of the latent class of disability trajectories of the participants' data from 1998–2006; and (3) matching the two trajectories to understand the association between disability and BMI trajectories.

Summary

The impact of diabetes on physical function from midlife to older adulthood is intuitively important but not well defined. As the number and proportion of older adults with diabetes grow within populations worldwide (Wild & Forouhi, 2007; Zimmet, Alberti, & Shaw, 2001), there is an increasing need to understand the difficulties faced by these diabetes subgroups beyond the basic measure of mortality. The present investigation is expected to contribute valuable knowledge about the impact of diabetes on functional health after age 50 by identifying trajectories with two longitudinal data sets and analytic methods that account for differing attrition patterns. The results have implications for the provision of health care to accommodate the needs of middle-aged and older adults with diabetes. Unlike much of the extant literature on functional ability for only the oldest old (Romoren & Blekeseaune, 2003) or those at the stage of later life (Covinsky, Eng, Lui, Sands, & Yaffe, 2003), this research focused on adults aged 50 and above. Further, the study provided a cross-national comparison to identify ethnocultural differences in diabetes burden in the East and West. This information will help clarify the generalizability of commonly held diabetes concepts across diverse cultural and geographic settings and enable the assessment of these generalizations across these settings.

The three studies fill three gaps in the literature. First, they offer important findings regarding how diabetes affects the physical health trajectory from midlife to older age and identify if that impact exists equally by gender, racial/ethnic, and educational levels in the U.S. and Taiwan. Second, they provide evidence regarding the possible mechanisms underlying documented gender differences in physical health for U.S. adults living with diabetes—specifically, how biological, behavioral, and psychosocial factors mediate those gender differences in rates of change in functional health over time in adults with diabetes. Third, they reveal how body weight affects the physical health of adults with diabetes by specifically identifying the distinct trajectories in U.S. adults with diabetes and then examining how those trajectories were associated with body weight trajectories earlier in life.

Practical implications from this series of studies include: (1) the identification of risk groups who are most vulnerable to the adverse effects of diabetes; (2) the illumination of mechanisms underlying gender differences in physical health for U.S. adults living with diabetes; and (3) the provision of knowledge about distinct trajectories experienced by middle-aged and older adults living with diabetes and how those trajectories were shaped by body weight trajectories earlier in life.

Chapter 2

METHODS

Data

The data for this thesis were drawn from two nationally representative longitudinal surveys: (1) the Survey of Health and Living Status of the Elderly in Taiwan (HLSES, 1996-2003); and (2) the Health and Retirement Study core survey (HRS, 1992-2006) and its 2003 HRS diabetes specific mail survey. The following paragraphs summarize the mission and administration of each data source.

Survey of Health and Living Status of the Elderly in Taiwan (HLSES). The HLSES, an on-going nationally representative data collection effort initiated in 1989, aims to trace the longitudinal change of health, behavioral, financial and emotional well-being of middle-aged and older adults in Taiwan. It is jointly conducted by the Taiwan National Institute of Family Planning (now the Bureau of Health Promotion) and the Population Studies Center at the University of Michigan, and is funded by the U. S. National Institute on Aging. The first wave, fielded in 1989, involves a nationally representative probability sample of 4,049 individuals age 60 and above. The second wave of the survey was conducted in 1993 and included interviews with 3,155 survivors of the initial sample. The third wave, conducted in 1996, included 2,669 survivors aged 67 and older from the 1989 survey (1,047 died and 333 dropped out in this wave, resulting in 66% of the initial sample) and included an “aged-in” component: 2,462 national representative individuals aged 50 to 66 who were interviewed for the first time using a questionnaire similar to that employed in 1989; their inclusion resulted in a replenishment of the younger part of the age distribution of respondents. As a result, since 1996, the HLSES sample is representative of the entire Taiwan population age 51 and older living in the community and in

nursing homes and was comparable with data in the HRS in the U.S. The thesis used data from the third, fourth, and fifth waves of the survey (1996, 1999, 2003). A total of 5,131 persons, who are representative of Taiwanese aged 51 and older living in communities or nursing homes in 1996, comprised the baseline data for the first study. The responding sample sizes were 4,440 in 1999 and 3,778 in 2003, providing response rates of 87% and 74%, respectively.

Health and Retirement Study (HRS). The HRS is an ongoing U.S. nationally representative panel survey which aims to collect a wide range of data on physical and mental health, insurance coverage, financial status, family support systems, labor market status, and retirement planning of middle-aged and older Americans. It was conducted by the Institute for Social Research (ISR) at the University of Michigan and with reinterviews every two years since its inception in 1992. The target population for the original HRS was adults born in the years 1931–1941 (thus, 51-61 in 1992), and included over-samples of Hispanic or Latino, Black or African American, and Florida residents. The initial wave of data collection spanned April 1992 through January 1993, and included 12,543 individuals age 51-61 years and their spouses or partners of any age in 1992. Re-interviews have occurred biennially (Juster & Suzman, 1995). The 1998 survey not only reinterviewed those who survived from the 1992 survey, but also reinterviewed another nationally representative cohort of persons age 75 and above in 1998 who were the survivors of the parallel Survey of Asset and Health Dynamics of the Oldest Old (AHEAD) fielded in 1993 (Soldo, Hurd, Rodgers, & Wallace, 1997). In addition, the 1998 survey replenished its data collection efforts with information from respondents age 51-56 and age 68-74 to fill in the age gap between the original HRS and AHEAD samples.

As a result, 21,384 adults (age 25-105 years) living in communities or nursing homes were interviewed in 1998. Among them, 20,443 were representative of the entire population of U.S. adults born in 1947 or earlier (age 51 or over in 1998), comparable to the HLSES in Taiwan. These participants comprised the baseline data for the first study of this thesis. The reinterview rates for the biennial follow-up interviews for the 1998 HRS sample were 88.2%, 80.2% , 73.5%, and 67.0% in 2000, 2002, 2004 and 2006, respectively. For the second study examining gender differences in physical disability, we used the 2002 and 2004 HRS core survey and the 2003 diabetes specific mail survey, one of several HRS experimental modules conducted with subsamples of the overall HRS sample. For the third study, all waves of data from 1992-2006 were used to examine the relationship of change in body mass index and future disability.

HRS 2003 diabetes-specific mail survey. The HRS 2003 diabetes-specific mail survey was funded by the National Institute on Aging through a competing supplement to the biennial HRS that began in 1992 (Juster & Suzman, 1995). The diabetes survey aimed to collect self-reported questionnaire data on aspects of treatment and self-management of diabetes, as well as a clinical biomarker of glucose control (HbA1c) for those who reported a diagnosis of diabetes in the 2002 HRS core survey. There were 3,194 interviewed respondents in the 2002 HRS who reported a diagnosis of diabetes (including respondents whose interviews were given by proxies). Of these, 680 were excluded from the 2003 Diabetes Study because of their participation in the Consumption and Activities Mail Survey (CAMS), another HRS experimental module. This exclusion was random, with the slight exception that proxy cases from 2000 were ineligible for CAMS but eligible for the Diabetes Study, resulting in their being represented at slightly higher rates prior to weighting adjustments. Of the 2,514 eligible 2002 participants, 129 were subsequently determined to have died prior to the October 2003 start of the Diabetes Study, and

so were ineligible for inclusion in the sample. Of the 2,385 remaining eligible cases, 1,901 returned questionnaires, for a response rate of 79.7%.

Features of the HRS and HLSES make them well-suited for addressing the thesis aims. First, although the surveys differ to some extent in their design and questionnaire content, both are designed to be nationally representative of the middle-aged and older populations in their respective countries. In addition, both of the surveys measure a broad array of items in physical and cognitive function, depression and many other health factors, which are seldom available in a single study but are critical for studying the role of diabetes on different domains of physical function and allow us to account for many theoretical and empirical important covariates. Second, special efforts were made in both studies to collect data on nationally representative samples by providing special weights to the "aged-in" sample or minority groups, following people who become institutionalized, and through the use of proxy respondents for individuals incapable of answering the questions. Third, the large sample sizes and longitudinal designs allow us to examine trajectories of physical health in heterogeneous samples and reveal complex moderating effects while accounting for time-dependent and time-independent covariates and different attrition patterns. Finally, although the HRS and HLSES data are largely self-reported, these data—and particularly the health data—have been shown to be quite reliable, as indicated in the following section (Alwin, 2007; Bowman & DeLucia, 1992; Goldman, Lin, Weinstein, & Lin, 2003; Payette, Kergoat, Shatenstein, Boutier, & Nadon, 2000; Wallace & Herzog, 1995).

Measures

Information on the variables used in the three studies was assessed by self-reported data, except for the HbA1c values, which were drawn from the laboratory tests (described in greater

detail below). The quality of self-reported diabetes and other health conditions was assessed as high for population-based surveys of middle-aged and older adults (Bowman & DeLucia, 1992; Goldman et al., 2003; Payette et al., 2000); and the self-reports of difficulties in performing functional activities were also confirmed to be valid for identifying a broad range of limitations and disability in older age (Langlois et al., 1996). The specific measures used in each study are described in greater detail in each manuscript chapter. Below I briefly describe the main variables used in the thesis.

Our variable of primary analytic interest—diabetes—was measured in response to the question "Has a doctor ever told you that you have diabetes or high blood sugar?" asked of the HRS respondents at each study wave. In HLSES, self-reported diabetes was assessed with two questions "Have you ever had the disease of diabetes?" and "Do you have diabetes currently?" at each study wave. For the sake of using data that are most comparable to the HRS questions, we used the first question to define diabetes in the HLSES. Self-reported measures of diabetes have been shown to have good agreement with medical records (Goldman et al., 2003). In the HRS, self-reports of diabetes at one wave were disputed (and most often later re-confirmed) in future waves in approximately 5% or less of cases. The available information related to those disputes allowed us to impute diabetes status in the majority of those cases with considerable confidence.

The main dependent variable—physical disability—was measured with the modified Katz Activities of Daily Living (ADL) scale (Katz et al., 1963), the Lawton Instrumental Activities of Daily Living (IADL) scale (Lawton & Brody, 1969), and Nagi strength and mobility activities (Nagi, 1964). In general, the Katz (ADL) scale concerns the most basic personal care tasks, whereas the Lawton (IADL) and Nagi (strength and mobility) items require greater physical activity. Participants in both the HRS and HLSES studies were asked at each

wave if they had any difficulty performing a certain task, avoidance of it, or the need for help or equipment in its performance from these scales. The same set of ADL items was included in both HRS and HLSES surveys, including bathing, dressing, eating, getting out of bed/ standing up/ sitting in a chair, walking around the room, and going to the toilet (range 0-6). Both HRS and HLSES used six items in measuring the IADL; however, some items were different. In the HRS, the IADLs included using a map, preparing a hot meal, shopping for groceries, making phone calls, taking medications if you need to do so, and managing your money. In the HLSES, the IADLs comprised buying personal use items, managing money/paying bills, riding the bus or train alone, doing physical work around the house, performing light tasks around the house, and making a phone call. Five out of the six IADLs are identical (or nearly so) in the two surveys: preparing meals, shopping, managing money, using the telephone, and using maps/ taking public transportations independently. These five IADLs were used in the thesis (range 0-5). Both of the two surveys collected information on “Nagi-like” items that reflect the ability to conduct upper and lower body movements. Twelve items relate to strength and mobility in the HRS: walking several blocks, running or jogging about a mile, walking one block, sitting/standing for about two hours, getting up from a chair after sitting for long periods, climbing several flights of stairs without resting, climbing one flight of stairs without resting, stooping/ kneeling/ or crouching, reaching or extending your arms above shoulder level, pulling or pushing large objects like a living room chair, lifting or carrying weights over 10 pounds like a heavy bag of groceries, picking up a dime from a table. In the HLSES, nine strength and mobility activities were measured: standing continuously for 15 minutes, sitting/standing for 2 hours, stooping/ kneeling/ or crouching, reaching above the head, grasping small objects, lifting or carrying weights over 10 pounds like a heavy bag of groceries, running or jogging 200-300 meters (approximately 0.1

mile or about one block), walking several blocks, and climbing several flights of stairs. Although eight strength and mobility activities are identical across the two surveys, we used the five items with high internal consistency in both studies to measure strength and mobility: walking several blocks, climbing several flights of stairs, stooping/ kneeling/ or crouching, reaching above the head, and lifting or carrying weights over 10 pounds like a heavy bag of groceries.

These sixteen items, which were asked identically (or nearly so) in the two datasets and across interview waves, were summed to obtain a physical disability score, with higher scores indicating more severe limitations (range 0-16). This composite measure captures the known effects of diabetes on higher order mobility and strength tasks in older adults and a broad range of physical disabilities from early or ‘‘preclinical’’ disabilities to later personal care disabilities (Fried, Ettinger, Lind, Newman, & Gardin, 1994; Langlois et al., 1996; Siu, Reuben, & Hays, 1990; Wang et al., 2007; Wray, Ofstedal et al., 2005). The average internal consistency of the sixteen items across all waves was .90 in the HRS and .89 in the HLSES. The method of using the scoring of overall limitations in physical function, rather than the commonly used able-disabled dichotomous scoring for each functional domain, has the advantages of capturing finer gradations in limitations in physical function (Mendes de Leon, Guralnik, & Bandeen-Roche, 2002; Wray, Ofstedal et al., 2005) and reduces the chance of ceiling or flooring effects (Wang et al., 2007).

Statistical Methods

To answer each of the research questions posed in each study of this thesis, the sample specific to each study is described at the beginning of the study as a foundation for understanding the sample as a whole with regards to the variables of interest. Three separate statistical methods

were employed for the three studies. First, multilevel modeling (MLM) in Study 1 identified physical function trajectories for adults with and without diabetes. Second, structural equation models (SEM) was used in Study 2 to examine factors mediating the gender differences in diabetes-related physical function outcomes. Last, latent class growth modeling (LCGM) analyses in Study 3 examined relationships between trajectory classes of body weight and functional health in adults with diabetes. The following sections present each statistical method in greater detail.

Multilevel Modeling

The development of multilevel modeling (MLM), or hierarchical linear models, has created a powerful set of techniques for research on individual change (Bryk & Raudenbush, 1987). The models provide an integrated approach for studying the structure and predictors of individual growth with a multiple-time-point design (Raudenbush & Bryk, 2002). Specifically, MLM has the capacity to analyze information about the levels and rates of change in targeted variables over multiple time points, taking into account inter- and intra-individual variability in change and cross-level interactions of time with predictors. At Level 1, each person's development is represented by an individual growth trajectory that depends on a unique set of parameters. These individual growth parameters then become the outcome variables in a Level 2 model, where they may depend on person-level characteristics. In MLM, the multiple observations on each individual are nested within the person. This treatment of multiple observations as nested allows the investigator to proceed without difficulty when the number and spacing of time points vary across cases (Raudenbush & Bryk, 2002).

MLM has two great advantages over traditional latent growth curve models (LGM) for studying longitudinal change. The first advantage of MLM is its flexibility in handling irregularities in data collection (Osgood & Smith, 1995). MLM allows for incorporation of individuals with incomplete data due to attrition or individuals who provide data at differing ages or unequally-spaced measures; thus, when assuming missing data are missing at random (MAR), we can estimate the trajectory of cases with incomplete data using those observations we have for each subject. Second, MLM easily handles cross-level interactions in time-varying and time-independent covariates.

Structural Equation Modeling

Structural equation modeling (SEM) (Joreskog, 1977; Joreskog & Sorbom, 2001) is a popular statistical technique for testing and estimating causal relationships when using population-based data. It helps researchers to conduct factor analysis, path analysis and regression in one step. Among its strengths is the ability to model constructs as latent variables (variables which are not measured directly, but are estimated in the model from measured variables which are assumed to "tap into" the latent variables). Thus, the unreliability of measurement in the model can be captured explicitly, which in theory allows the structural relations between latent variables to be estimated more accurately. In addition, goodness of fit indices provide evidence regarding appropriateness of the hypothesized model, which outweigh what other mediation methods, such as Baron and Kenny's mediation rule in regression (Baron & Kenny, 1986), can provide.

In SEM, parameters are estimated by comparing the actual covariance matrices representing the relationships between variables and the estimated covariance matrices of the

best fitting model. This is obtained through numerical maximization of a fit criterion provided by maximum likelihood, weighted least squares or asymptotically distribution-free methods. Some of the more commonly used measures of fit include: chi-square, Root Mean Square Error of Approximation (RMSEA), Normed Fit index (NFI), Non-Normed Fit Index (NNFI/RHO), and Comparative Fit Index (CFI). Values less than 0.05 for RMSEA, and greater than 0.95 for NFI, RHO/NNFI, and CFI are all indications of a good model fit (Hu & Bentler, 1999).

Latent Class Growth Modeling (LCGM, Group-based Trajectory Modeling)

Latent class growth modeling (LCGM, or group-based trajectory modeling) (Nagin, 1999, 2005), a semi-parametric group-based modeling, is a state-of-the art method incorporating both continuous and categorical variables as latent variables. The LCGM approach utilizes a person-centered method to identify latent class membership. This approach to modeling growth curves is different from traditional latent growth curve modeling in that the latter assumes all individuals belong to a single class and vary continuously on a latent trait, which was predetermined before analyses. In contrast, the group-based modeling assumes a number of discrete classes, each having a specific intercept and slope and an estimated population prevalence (Nagin, 1999, 2005).

Dual trajectory modeling (Nagin, 1999, 2005) further enables researchers to identify relationships between two class trajectories. The model can be used to analyze connections between the trajectories of two outcomes that are evolving contemporaneously or that evolve over different time periods. The three key outputs of the dual model are: (1) the trajectory groups for both measurement series; (2) the probability of membership in each identified trajectory

group; and (3) conditional probabilities linking membership across the trajectory groups of the two respective measures (Nagin, 1999, 2005).

In summary, the HRS and HLSES studies provided comparable data relevant for addressing the research aims of this thesis. The three statistical methods—growth curve modeling, structural equation modeling, and latent class growth curve modeling (group-based trajectory approach)—are appropriate for analyzing such large longitudinal datasets to generate comparative findings that may add to the current literature. In the following chapters, three studies utilizing these data sets and methods are presented: Chapter 3: physical disability trajectories for adults with and without diabetes from midlife to older adulthood: a cross-national comparison between the U.S. and Taiwan; Chapter 4: gender differences in physical disability in adults living with type 2 diabetes: biobehavioral and psychosocial mediators; and Chapter 5: BMI trajectories in U.S. middle-aged and older adults living with diabetes and link with future disability trajectories. Chapter 6 provides a discussion and conclusions from these three studies, as well as future directions for related research.

Chapter 3

MANUSCRIPT 1:

Physical Disability Trajectories for Adults With and Without Diabetes from Midlife to Older Adulthood: A Cross-National Comparison between the U.S. and Taiwan

Abstract

BACKGROUND: The impact of diabetes on physical function is receiving increasing research interest; however, no studies to date have compared physical disability trajectories from midlife to older adulthood in adults with and without diabetes. **OBJECTIVES**: This study examines: (1) if diabetes is significantly associated with the mean level of and change in physical function from midlife to older age; (2) if gender, racial/ethnic, and educational differences moderate physical disability trajectories; and (3) if results differ in eastern and western populations. **METHODS**: The study examines three waves of the Survey of Health and Living Status of the Elderly in Taiwan (HLSES, 1996-2003) and five waves of the Health and Retirement Study in the United States (HRS, 1998-2006). Growth curve models using accelerated longitudinal multilevel modeling analyses are employed separately for the two sets of national data. **RESULTS**: In both countries, adults with diabetes experience higher levels of physical disability and faster rates of deterioration over time. The result is net of attrition, time-invariant socio-demographic factors, and time-varying chronic disease conditions. In the U.S., but not in Taiwan, the impact of diabetes differs by educational level, gender, and race/ethnicity. At any given age, differences in physical function between U.S. adults with and without diabetes were more striking in those with lower education than in those with higher education, in women than in men, and in blacks than in whites. **CONCLUSION**: Physical disability trajectories from midlife to older age are shaped by the presence of diabetes. Future studies to examine the mechanisms

underlying the differential impacts of diabetes on physical function by gender, education, and race/ethnicity in the U.S. are recommended.

INTRODUCTION

Studies from many parts of the world have reported an explosive increase in the number of people diagnosed with diabetes during the past two decades (Colagiuri et al., 2005; Wild et al., 2004; Zimmet et al., 2001). The skyrocketing rates for diabetes are evident in all segments of the population, but middle-aged and older adults continue to comprise the largest proportion of the populations in which diabetes rates are increasing (Engelgau et al., 2004; King et al., 1998; Wild et al., 2004). Although the prevention of diabetes is certainly an important mandate for public health, understanding the long-term experience of adults living with diabetes is also critical in providing practical patient-centered clinical recommendations, and in turn, further reducing the risks of diabetes complications.

Relative to the growing information on the impact of diabetes on kidney, eye, neurological, and vascular diseases, and on premature death, research regarding the effects of diabetes on physical function from midlife to older adulthood has received less attention. Physical function is one of the most relevant predictors of quality of life (Gregg et al., 2002). For example, limitations in physical function are associated with lower rates of employment, higher rates of absenteeism, lower income levels, increased likelihood of hospitalization, and poor self-rated health or quality of life; thus, these limitations are important diabetes-related health outcomes for middle-aged and older adults (Songer, 1995; Wray, Ofstedal et al., 2005).

Studies emerging in the past decade evaluating the relationship between diabetes and physical function have suggested that the prevalence of physical disability is higher in adults

with diabetes than in those without diabetes (Blaum et al., 2003; Bruce et al., 2003; De Rekeneire et al., 2003; Figaro et al., 2006; Gregg et al., 2000; Gregg et al., 2002a; 2002b; Maty, Everson-Rose, Haan, Raghunathan, & Kaplan, 2005; Ryerson et al., 2003; Sinclair, Conroy, & Bayer, 2008; Wray, Ofstedal et al., 2005). For example, the hazard ratio of functional disability for persons living with diabetes compared to non-diabetics is about 1.3-3.0. Although these results are intriguing, results vary depending greatly on the age population examined in each study. In addition, examinations using cross-sectional analysis (De Rekeneire et al., 2003; Gregg et al., 2000; Sinclair et al., 2008) or two-point longitudinal data (Blaum et al., 2003; Wray, Ofstedal et al., 2005), as was employed in most of the previous research, are vulnerable to bias because the findings make it hard to demonstrate a causal relationship or to handle missing data, and the findings hinge on the duration of time between the two-point examinations. Recent studies (Gregg et al., 2002) have attempted to use multiple waves of data to describe the long-term patterns of the association between diabetes and physical disability. Although the findings from this research expands our knowledge regarding the longitudinal differences between adults with and without diabetes, detailed information which may provide more evidence for practical intervention remains lacking. For example, we do not yet know whether differences in physical function between adults with and without diabetes are consistent from midlife to older age, nor do we know if there are cohort differences for adults who are the same age.

Another area where considerably less attention has been directed is the role of individual differences, specifically gender, racial/ethnic, and educational differences, in moderating the impact of diabetes on physical function over time. The idea that these factors may moderate the impact of diabetes on physical function is consistent with utilizing the life-span development (LSD) perspective in health studies, as illustrated by Alwin and Wray (2005). According to this

perspective, people of different ascribed (e.g., gender, race/ethnicity, age) and achieved social statuses (e.g., educational and other socioeconomic differences) may be differentially exposed to disease risks or protective factors, and, in turn, health outcomes. Consistent with this perspective, findings have revealed that compared to men, women reported higher levels of social support from their diabetes health care teams, had more positive attitudes toward diabetes, saw self-management as being beneficial (Gucciardi et al., 2008; Ponzo et al., 2006), and showed lower incidence of diabetes complications in retinopathy, nephropathy, neuropathy, and foot ulcers than did men (Basit et al., 2004). In contrast, women with diabetes managed diabetes with fewer economic and social resources (McCollum et al., 2005; Sabolsi et al., 2001; Wray et al., 2006), received less spousal assistance (Fitzgerald et al., 1995; Umberson, 1992), reported more depressive symptoms (Anderson et al., 2001) and higher body mass (Legato et al., 2006; McCollum et al., 2007; Nilsson et al., 2004; Szalat & Raz, 2007; Tang et al., 2008; Wexler et al., 2005), displayed higher levels of glucose control (Nilsson et al., 2004), and engaged in lower levels of physical activity (Barrett et al., 2007).

Compared to Whites, members of minority groups (i.e., African-Americans, Native Americans, and Mexican-Americans) were less likely to report having had diabetes-related glycosylated hemoglobin (HbA1c) and dyslipidemia diagnosis tests but were more likely to report having received foot examinations. When tested, minority group members reported higher HbA1c and blood pressure readings (Gary et al., 2004; Heisler et al., 2007; Hertz, Unger, & Ferrario, 2006; LeMaster et al., 2006; Quandt et al., 2005) but better levels of total cholesterol and HDL cholesterol (Heisler et al., 2007). Further, although White men were disproportionately overweight compared to African-American and Mexican-American men, rates of treatment with insulin or oral agents, eye examinations, and blood pressure checks were similar for each race or

ethnic group (Gary et al., 2004; Harris, 2001; Heisler et al., 2007; LeMaster et al., 2006). Taken together, it is conceivable that the impact of diabetes on physical function trajectories from midlife to older age may hinge on gender, race/ethnicity, or education, an important factor affecting many aspects of health outcomes (Alwin & Wray, 2005; Herd, 2006) but less studied in diabetes-specific research.

Additionally, there has been very little investigation into the effect of diabetes on physical function across countries. Among many critical factors, culture may profoundly influence not only the prevalence but also the impact of diabetes (Zimmet, 2003). The Mandala of Health Model (MHM) (Hancock, 1985) is a useful framework for understanding the multidimensional complexities of diabetes in different ethnocultural populations. A literature review of diabetes research in Asia found that people in Asia tend to develop diabetes with a lesser degree of obesity at younger ages, suffer longer with complications of diabetes, and die sooner than do people in other regions of the world (Yoon et al., 2006). Another literature review indicated that older adults in India had significantly poorer performance-based functional status than did adults in the U.S., even when matched for age, gender, medical conditions, and self-rated disability (Albert et al., 2005). These facts, plus differential genetic, social, and environmental factors inherent to eastern and western countries, add to the likelihood that distinct trajectories of physical function from midlife to older age may exist across populations, and that the impact of diabetes may vary across countries as well. However, due to the lack of comparable cross-national studies in the current literature, this hypothesis remains an unanswered question.

The current investigation addresses these gaps in the literature for the first time using two large, nationally representative data sets for U.S. and Taiwanese adults aged 51 and above.

Taiwan provides a striking contrast to American society in several biological (e.g., body composition) (Pan et al., 2004), cultural (e.g., diet behaviors, social norms regarding alcohol use) (Chen et al., 2007) and social dimensions (e.g., insurance and medical systems) (Cheng & Chiang, 1997; Cheng & Chiang, 1998; Davis & Huang, 2008; Wen et al., 2008) that directly affect the health of middle-aged and older adults. On the other hand, Taiwanese adults share certain demographic characteristics with Western populations, such as similar cause-of-death structures, long life expectancies, and high levels of industrialization (Beckett et al., 2002). In addition, diabetes has gained notoriety as a major chronic disease epidemic in both countries—currently, adults with diabetes constitute approximately 20% of the population aged 65 and above in the U.S. (Centers for Disease Control and Prevention, 2005; Cowie et al., 2006; Mainous et al., 2007), and 17-22% in Taiwan (Chen et al., 1999; 200; Chuang et al., 2001; Tseng et al., 2006). A better understanding of the role that diabetes plays with respect to physical function from midlife to older age may provide important information for forecasting health needs in both countries.

Based on the life-span developmental (LSD) perspective (Alwin & Wray, 2005) and the Mandala of Health Model (MHM) (Hancock, 1985), as well as our review of the literature, we developed a conceptual framework (Figure 3.1) for understanding how age, race/ethnicity, gender, education, comorbidities, and enthocultural factors theoretically shape the impact of diabetes on physical disability trajectories after age 50. Specifically, we hypothesized that physical function is a function of time which constitutes the trajectories. However, the chronic disease of diabetes changes the longitudinal trajectories over and above natural aging processes. Patterns of change are not consistent across populations; they depend largely on gender, race/ethnicity, and education. As the gender role is embedded in cultural contexts, we

hypothesized that gender affects the impact of diabetes on physical function in different ways across different countries. The utility of this model illuminates the effects of policy-relevant ascribed and achieved social factors on health outcomes, and emphasizes the importance of longitudinal examinations of these complex mechanisms across a variety of cultural and geographic settings.

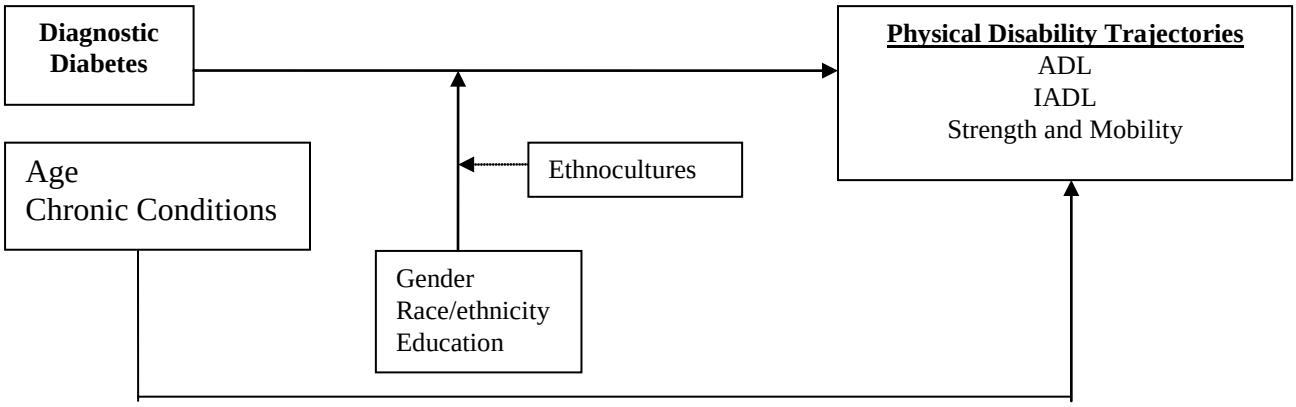

Figure 3.1 Conceptual Framework Linking Diabetes and Physical Disability Trajectories

METHODS

Data and Sample

Our data are drawn from two different national surveys of middle-aged and older adults: (1) the U.S. Health and Retirement Study (HRS, 1998-2006), and (2) the Survey of Health and Living Status of the Elderly in Taiwan (HLSES, 1996-2003). The HRS is an ongoing nationally representative panel survey that collects a wide range of data on the physical and mental health, insurance coverage, financial status, family support systems, labor market status, and retirement planning of middle-aged and older Americans, including over-samples of Hispanic or Latino, Black or African American, and Florida residents (Juster & Suzman, 1995). It was funded by the

National Institute on Aging and conducted by the Institute for Social Research (ISR) at the University of Michigan. The initial wave of data collection was fielded in 1992 and interviewed 12,543 individuals born in the years 1931–1941 (thus, 51-61 years of age), along with their spouses or partners of any age. Reinterviews have occurred biennially and are ongoing. The 1998 survey not only reinterviewed those who had survived from the 1992 survey (*N*=10,584), but also re-interviewed another nationally representative cohort of persons born in 1922 or earlier who were the survivors of the 1993 Study of Asset and Health Dynamics of the Oldest Old (AHEAD; *N*=5,860) (Soldo et al., 1997), and added respondents to the 1942-1947 (*N*=2,529) and 1923-1930 birth cohorts (*N*=2,320) to fill the age gap between the original HRS and AHEAD samples. As a result, 21,384 adults (age 25-105 years) were interviewed in 1998. Among them, 20,443 were representative of the entire population of U.S. adults born in 1947 or earlier (age 51 or over in 1998). The reinterview response rates for the biennial follow-up interviews for the 1998 HRS sample were 88.2%, 80.2%, 73.5%, and 67.0% in 2000, 2002, 2004 and 2006, respectively.

Comparable to the research aims and design of the HRS, the HLSES is an ongoing Taiwan nationally representative survey. Fielded in 1989, this survey aims to trace the longitudinal changes in health, behavioral, financial, and emotional well-being of middle-aged and older adults in Taiwan. It was jointly conducted by the Taiwan National Institute of Family Planning (now the Bureau of Health Promotion) and the Population Studies Center at the University of Michigan. At the first wave, a nationally representative sample of 4,412 adults aged 60 and older (born in 1929 or earlier) was selected and 4,049 individuals were successfully interviewed (response rate=91.8%). The second wave of data collection was conducted in 1993, in which 3,155 (77.9%) survivors of the initial sample were reinterviewed. The third wave of

data collection conducted in 1996 successfully reinterviewed 2,669 (66.0%) survivors of the initial survey. In addition, a nationally representative sample of individuals born in 1930-1945 were interviewed in 1996 to replenish the younger part of the age distribution of respondents (*N*=2,462). As a result, the HLSES sample in 1996 was representative of the entire Taiwan population born in 1945 or earlier (age 50 or over) living in the community and in nursing homes (*N*=5,131). The reinterview response rates for the 1996 HLSES sample were 83.5% and 71.1% in 1999 and 2003, respectively.

Given that the focus in this study was to examine changes in physical function from midlife to older adulthood for adults with and without diabetes in two comparable national data sets, this study utilized data on participants aged 51 or above in the 1998 HRS and the 1996 HLSES who had answered questions on their diabetes status. This yielded eligible sample sizes of 20,433 in the HRS and 5,121 in the HLSES.

Measures

The independent variable of primary interest—diabetes—was obtained by a self-reported answer measured at baseline. In the HRS 1998 survey, respondents were asked “Has a doctor ever told you that you have diabetes or high blood sugar?” A dichotomous answer (1=yes, 0=no) was obtained. In the HLSES 1996 survey, the respondents were asked “Have you ever had the disease of diabetes?” A dichotomous answer (1=yes, o=no) was obtained.

The dependent variable, physical disability, was measured with the modified Katz Activities of Daily Living (ADL) scale (Katz et al., 1963), the Lawton Instrumental Activities of Daily Living (IADL) scale (Lawton & Brody, 1969), and Nagi strength and mobility activities (Nagi, 1964). In general, the Katz (ADL) scale concerns the most basic personal care tasks,

whereas the Lawton (IADL) and Nagi (strength and mobility) items require greater physical activity. Participants in both the HRS and HLSES studies were asked at each wave if they had any difficulty performing a certain task, avoidance of it, or the need for help or equipment in its performance from ADLs (bathing, dressing, eating, walking across a room, getting in/out of bed, and using a toilet independently), IADLs (preparing meals, shopping, managing money, using the telephone, and using maps/ taking public transportations independently), and strength and mobility activities (walking several blocks, climbing several flights of stairs, stooping/ kneeling/ or crouching, reaching above the head, and lifting or carrying weights over 10 pounds like a heavy bag of groceries) (1=yes, 0=no). Among the extensive questions asked in the two datasets, sixteen items were identical in the two datasets and across interview waves. These items were summed to obtain a physical disability score, with higher scores indicating more severe limitations (range 0-16). This composite measure captures the known effects of diabetes on higher order mobility and strength tasks in older adults and a broad range of physical disabilities from early or ‘‘preclinical’’ disabilities to later personal care disabilities (Fried et al., 1994; Langlois et al., 1996; Siu et al., 1990; Wang et al., 2007; Wray, Ofstedal et al., 2005). The average internal consistency of the sixteen items across all waves was .90 in the HRS (1998-2006) and .89 in the HLSES (1996-2003). The method of using a score of overall limitations in physical function, rather than the commonly used able-disabled dichotomous scoring for each functional domain, has the advantages of capturing finer graduations in limitations in physical function (Mendes de Leon et al., 2002) and reducing the chance of ceiling or flooring effects (Wang et al., 2007).

The variable for age measures the respondent's age at the time of each interview wave and is represented as a continuous variable, centering on the grand mean or median age in the

analyses (depending on the model). Respondent age in the baseline ranges from 50-105 in the HRS and 50-97 in the HLSES. Eight cohorts based on respondents' baseline age were categorized: 50-55, 56-60, 61-65, 66-70, 71-75, 76-80, 81-85, and 86 and above. Based on the 8-year longitudinal examination, cohorts 1 to 8 each contribute to longitudinal observations of age 50-63, 56-68, 61-73, 66-78, 71-83, 76-88, 81-93, and 86-109, respectively. The sample size for each cohort ranged from n=1,031 for cohort 1 to n=3,991 for cohort 7 in the HRS, and ranged from n=101 for cohort 1 to n=1,092 for cohort 5 in the HLSES.

Three time-invariant variables were used: gender, education and race/ethnicity. Gender is represented as a dummy variable in the models, with men serving as the reference group. Ethnicity was categorized into three groups in Taiwan (Fukienese, Mainlanders, Hakka and others) and three groups in the United States (non-Hispanic Whites, non-Hispanic Blacks, and Hispanics and others). Education was categorized at three levels in each country. However, because the sample distributions for the number of years of completed education are quite different for Taiwan and the United States, and because a year of education may differ in terms of its impact on physical function in the two settings, we opted to use different cut-points for education in order to make the sample distributions of the categorical variable more similar across the two data sets (in the HRS: low=less than high school, medium=GED or high school graduate, high=some college and above; in the HLSES: low=0 years of formal education, medium=1-6 years of formal education, high=7 or above years of formal education).

Seven diabetes-related chronic conditions were included as time-varying covariates. The chronic conditions, which included high blood pressure, cancer, lung disease, heart disease, stroke, and arthritis, were chosen by significant association with self-reported diabetes in chi-square tests. In both the HRS and the HLSES, the chronic conditions were determined in each

wave by asking respondents if the condition was ever diagnosed. A dichotomous measure for each condition was obtained. In the HRS, the exact wording describing these conditions was "Has a doctor ever told you that you have…?": (1) high blood pressure or hypertension; (2) cancer or a malignant tumor of any kind except skin cancer; (3) chronic lung disease, except asthma, such as chronic bronchitis or emphysema; (4) heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems; (5) stroke or transient ischemic attack; and (6) arthritis or rheumatism. In the HLSES, the exact wordings for these conditions was "Have you ever had the disease of…?": (1) hypertension; (2) cancer or a malignant tumor; (3) chronic lung disease, such as chronic bronchitis; (4) coronary heart disease except irregular heartbeats; (5) ischemic or hemorrhagic stroke; and (6) arthritis or rheumatism.

Design

We use an accelerated longitudinal design (also called a cohort-sequential design) for this study (Duncan, Duncan, & Hops, 1996; Miyazaki & Raudenbush, 2000; Schaie, 1965; Tonry, Ohlin, & Farrington, 1991), allowing us to piece together the longer-term change pattern from the shorter-term change pattern of people who are different ages at the beginning. Up to five assessments of physical function status over an 8-year period (1998-2006) in the U.S. data of adults aged 50-105 at baseline, and three assessments over a 7-year period (1996-2003) of adults aged 50-97 at baseline in the Taiwan data, approximated the physical function trajectories for adults with and without diabetes from midlife to older adulthood (age 50-105). Specifically, cohort 1 contributes to the estimation of longitudinal change from ages 50-63; cohort 2 contributes to the estimation from ages 56 to 68; and similarly, cohort 3, ages 61-73; cohort 4, ages 66-78; cohort 5, ages 71-83; cohort 6, ages 76-88; cohort 7, ages 81-93; and cohort 8, ages

86-109. Therefore, changes in the broad age-range participants (eight five-year birth cohorts) during the seven- to eight- year observation period can reasonably approximate age-related changes from age 50-109.

Statistical Analysis

Multilevel models (MLM) using maximum likelihood estimation were fitted to the large longitudinal data using the SAS Proc Mixed procedure. MLM has two major advantages in relation to the data being analyzed here. First, MLM is flexible in accommodating an unbalanced research design (i.e., the number and spacing of time points may be different across participants) (Raudenbush & Bryk, 2002). Such flexibility allows participants who missed one or more measurement points during the follow-up period to not be eliminated from the analysis. In addition, the flexibility enables us to bring multiple over-lapping cohorts into the model and test the significance of cohort effects on age trajectory (Miyazaki & Raudenbush, 2000). Second, MLM has the capability to incorporate randomly varying effects of time-varying covariates. Such capability enables us to efficiently control for the time-varying covariates when studying the independent effect of diabetes on the levels of physical function and on changes in the physical function trajectory. Three-stage analyses were performed.

First, we aim to describe the most accurate form (shape) of intra-individual change in physical function from midlife to older adulthood. A cohort-based model was employed in this stage (it will be called the *full* model in the next stage of analysis). The cohort-based model estimates the mean trajectories of physical function for each cohort without the assumption that all age cohorts follow a common trajectory. Thus, a separate mean trajectory, which bases the age trend strictly on how subjects changed over the seven or eight years of the study, is estimated

for each cohort. A two-level multilevel model was used to define the mean trajectory for the sample (fixed effects) and to determine information about individual variation in the trajectory (random effects). At the first level of the model, each person's observed physical function score is conceived as a polynomial function of age (centering at the median age of each cohort) plus random error. At the second level of the model, these individual coefficients are assumed to vary as a function of the cohort plus person-specific random effects. We expressed our multi-cohort age trajectory as the following:

$$\begin{aligned} &\text{Level 1: } L_{ti} = \pi_{0i} + \pi_{pi}(\text{age}_{ti} - \overline{age}_{.i})^p + e_{ti} \\ &\text{Level 2: } \pi_{0i} = \beta_{00} + \sum_{j=1}^{8} \beta_{0j}\text{Cohort}_{ji} + \mu_{0i} \\ &\pi_{pi} = \beta_{p0} + \sum_{j=1}^{8} \beta_{pj}\text{Cohort}_{ji} + \mu_{pi} \end{aligned} \qquad (1)$$

where L_{ti} is the number of limitations in physical function for the individual i at time t. t=1…,T_i, where T_i is the number of occasions on which person i was observed and i=1, …, n; age_{ti} is the age of person i at time t such that age_{ti} =50, 51, …, 105; and $\overline{age}_{.i}$ is the median of the age of the cohort to which the person i belongs to. Median ages are 57, 62, 67, 72, 77, 82, 87, and 97 for cohorts 1 to 8, respectively. (age_{ti} - $\overline{age}_{.i}$) represents the linear component of the growth curve, so that for a person in cohorts 2 to 7 with all time-series observations, (age_{ti} - $\overline{age}_{.i}$) is -6, -5, -4,..,0, 1, 2,…, or 7, is -7 to 7 for cohort 1, and is -11 to 12 for cohort 8. Because prior research has not provided information about the appropriate shape of physical function change from midlife to older adulthood, except for one that identified that the ADL trajectory was cubic (Li, 2005), we therefore formulate the polynomial components (age_{ti} - $\overline{age}_{.i}$)^p and test whether linear, quadratic, or cubic change functions (p=1,2,3) fit the data best. The intercept, π_{0i}, is the predicted amount of limitations in physical function of person i at cohort medium age ($\overline{age}_{.i}$). The linear coefficient, π_{1i}, is the expected rate of increase per year in the number of limitations for person i

at age $\overline{age}_{.i}$, and the coefficient that characterizes the highest-order growth trajectory parameter, π_{pi}, estimates the amount of curvature in the trajectory for person *i*. e_{ti} is the random within-person error of prediction for person *i* at time *t*, conditional on that person's change parameters $\pi_{0i...}$ π_{pi}. At level 2, person-specific change parameters depend on cohort membership, where $cohort_{ji}$ is coded 8-1 for cohorts 1-8. Thus, the youngest cohort (cohort 1) is the reference group in the model. β_{00} is the expected number of limitations in physical function at age 57 for persons in cohort 1 at baseline wave; β_{0j} is the mean difference in limitations between persons in cohort j+1 and persons in cohort 1 at baseline; β_{p0} is the expected rate of change (β_{10}) or the rate of acceleration (β_{20}) in the number of limitations in physical function for persons in cohort 1; β_{pj} is the mean differences in the rate of change (β_{1j}) or rate of acceleration (β_{2j}) between persons in cohort (j+1) and persons in cohort 1; μ_{0i} and μ_{ji} specify the random effects of person *i* on limitations in physical function after accounting for the cohort differences. The deviance test was used in this stage to determine which among the linear, quadratic, and cubic models has the best fit to the data.

After the shapes of physical function trajectories for the two samples were ascertained, we proceed with determining whether a *reduced* model, which is a common trajectory for describing change in all cohorts (i.e. ignoring the cohort effect), was tenable. Following Miyazaki and Raudenbush (Miyazaki & Raudenbush, 2000), a cohort convergence test was performed. The test is accomplished by comparing the aforementioned reduced model to the best shaped full model determined at the last stage of analysis. The comparison was based on the likelihood-ratio test. We also plot the age trends separately for groups that are different ages at the start (i.e., one line for each age group, all on the same chart) to see if those separate trends line up together. The reduced model is specified as the following:

$$\text{Level 1: } L_{ti} = \eta_{0i} + \eta_{pi}(\text{age}_{ti} - 76)^{p} + \eta_{qi}(\text{age}_{ti} - \overline{age}._{i})^{q} + \gamma_{ti}$$

$$\text{Level 2: } \eta_{0i} = \zeta_{00} + \nu_{0i} \qquad (2)$$

$$\eta_{pi} = \zeta_{pi}$$

$$\eta_{qi} = \nu_{qi}$$

where all subjects were centered at age 76, the grand mean of all age heterogeneous cohorts across all occasions. The intercept, η_{0i}, was the predicted amount of limitations in physical function at age 76. The fixed effect (ζ_{00}) and the random effect (ν_{0i}) of the intercept were both estimated. The polynomial components were specified as p=q=1,2, or 3, depending on the results from the first stage. η_{pi} estimated the instantaneous rate of change (η_{1i}), or the acceleration of the rate of change (η_{2i}), or the higher order change (η_{pi}) at age 76. Only the fixed effect, ζ_{pi}, for η_{pi} were estimated. ν_{qi} is the random effect of person *i* on the rate of increase (ν_{1i}) or acceleration (ν_{2i}) or higher order change (ν_{qi}) at the median age of the cohort the person belongs to. γ_{ti} represents the within person variation plus errors for each person *i* at time *t*.

At the last stage, when the best shape and equations for describing the physical function trajectory from midlife to older adulthood were ascertained, we tested the impact of diabetes on the average level of and change in physical function, as well as the demographic interactions which the impact of diabetes hinges on. Three models were conducted in this stage. Model 1(the diabetes model) tested if the physical function trajectories for adults with diabetes differ significantly from those without diabetes. This model was mainly performed by adding baseline diabetes status in Level 2 into either the full (1) or reduced model (2), depending on the results in stage 2. Then in model 2 (the diabetes and covariates model), we tested if diabetes, above and beyond mortality-related attrition, time-invariant demographics, and time-varying chronic health conditions, has a unique impact on the physical function trajectory by adding the attrition variable and time-invariant demographic covariates in level 2, as well as time-varying chronic

conditions at Level 1. Finally, in model 3, we tested if the impacts of diabetes are the same by gender, race/ethnicity, and educational levels by adding interaction terms at the level 2 model.

Throughout our analyses, the models were estimated with unstructured covariance matrix for the random effects, and assumed a Gaussian distribution of the outcome. Although the composition of the sixteen items for assessing limitations in physical function avoids the floor effect, the presence of skewness can pose a threat to the estimation of standard errors. We attended to this problem by estimating alternative models with square root transformation of the scores in physical function. These additional analyses yielded the same substantive results. Accordingly, the results presented below are from the model using the original physical function scores.

RESULTS

Descriptive Findings

Table 3.1 presents the baseline sample characteristics of the HRS and HLSES samples as well as their associations with baseline physical function. Compared with the HRS sample, there were more women, more respondents with low or medium education levels, and lower prevalence rates of each chronic health condition in the HLSES. The prevalence rates of limitations in physical function in the eight sets of birth cohorts were slightly different in the two samples: the HLSES respondents reported fewer limitations in the younger age cohorts, but higher limitations in the older age cohorts than the HRS respondents. Diabetes was present in 15.1 % of the HRS sample and 11.4% of the HLSES sample. As expected, baseline limitations in physical function were higher in women than in men, in people with lower educational levels

than those with higher educational levels, and in respondents who reported chronic disease than in those free of chronic conditions.

Table 3.2 presents the means, standard deviations, and inter-correlations of physical function (impairment) scores in all of the measurement occasions of the HRS and the HLSES. Limitations in physical function steadily increase from the baseline wave to each follow-up wave in both the HRS (*M*=2.29 in 1998 to 2.82 in 2006) and the HLSES (*M*=1.79 in 1996 to 2.77 in 2003), suggesting a need to use trajectories, which incorporate information from multiple occasions of observations into growth curve parameters, to describe systematic changes over time.

Shape of Physical Function Trajectories from Midlife to Older Adulthood

We examined intercept only (unconditional), linear, quadratic, and cubic growth curve models to determine which best characterized the trajectory of physical function from midlife to older adulthood for the HRS and HLSES samples, respectively. Table 3.3 presents the results of the goodness of fit and deviance statistics for the series of tests. Overall, fitting physical function as a function of age (centered at the median age of each cohort) while controlling for cohort effect accounts for a meaningful amount of variation across individuals. This was indicated by a substantial decrease in the deviance score (-2LL) from the unconditional model to the linear model in both the HRS and the HLSES ($X^2_{(19)}$ =15,893, 3,303, P<.0001). For the HRS sample, a cubic model was preferred to a quadratic model on the basis of the deviance test ($X^2_{(9)}$ =24, P<.0004). However, in the HLSES, adding a cubic function of age did not significantly improve the model fit ($X^2_{(9)}$ =7, P=.64). A quadratic function was determined to best characterize the physical function trajectory from midlife to older adulthood for the HLSES sample. Figure 3.1

presents the sample raw mean versus age trajectory of limitations in physical function based on the HRS 1998-2006 and HLSES 1996-2003 data.

The Best Fitting Model and Variability in Trajectories (Cohort Convergence Test)

Inspection of the data from the last stage suggests that the mean trajectory has a cubic shape in the HRS data and a quadratic shape in the HLSES data. In this stage, we aimed to find if a simpler model (reduced model) without cohort effects fit the data as well as the model we tested in the last stage. The reduced model is a parsimonious model which enables us to use a single trajectory to approximate age-related changes over a long period of time without modeling the cohort effects. A corresponding quadratic reduced model for the HRS and a cubic reduced model for the HLSES were formed. In the HRS, we counted 43 parameters in the full model, with the deviance of 366,304. The number of parameters in the reduced model is 11, and the deviance is 365,608. By subtraction, we obtained df=32 for the likelihood ratio test ($\Delta X^2_{(32)}$ =696, p<.001), suggesting that the more complex full model provides a significantly better fit than the reduced model for the HRS. Similarly, the likelihood ratio test for the HLSES ($\Delta X^2_{(24)}$ =183, p<.001) suggests the rejection of the reduced model and a better fit from the full model.

Figure 3.2 provides visual illustrations of the full and reduced models in the HRS and HLSES, respectively. We see that the overall mean trajectory estimated by the reduced model (dotted line) does not pass through the center of each of the eight cohort trajectories (solid lines) in the full model. For the HRS data (left-hand panel), the overall mean trajectory fails to capture changes in the youngest (cohort1) and oldest (cohort 8) cohorts. For the HLSES data (right-hand panel), the overall trajectory is less biased compared to the HRS, but it still fails to capture changes in cohorts 2 and 3. Thus, both the statistical test and the configuration results suggest

that it is not appropriate to use a single underlying change continuum to describe changes from midlife to older adulthood based on the present data. Thus, in the following section that tests the impact of diabetes, the full model (cohort-based age trajectory) was chosen to be the basic model.

As presented in the first column of Tables 3.4 and 3.5, nearly all of the fixed-effect coefficients in the full basic model (Model 0) were significant, suggesting that age and cohort are meaningful predictors for describing change in physical function from midlife to older adulthood for both the U.S. and Taiwanese samples. In addition, the co-variation between random intercept and slope was significant and positive, indicating that on average, adults with more baseline physical function limitations have a more rapid increase in physical function limitations later in life. The significant variances of intercept, slope, and curvature, however, suggest that there were significant inter-individual differences in the mean age-cohort trajectory.

How Diabetes Predicts Physical Function Trajectories

Having discerned the shape of the physical function trajectories from midlife to older age and having detected significant between-person variability, we turned to our main questions. Does diabetes predict individual differences in levels of physical function and rates of change in physical function trajectories? Does diabetes impose adverse effect evenly from midlife to older age? Are differences in adults with and without diabetes equivalent across sociodemographic backgrounds? Tables 3.4 and 3.5 show the results of models that answer these questions based on the HRS and HLSES samples, respectively.

Model 1, by adding diabetes and diabetes × age, significantly improved the model fit from model 0 ($\Delta X^2_{(4)} = 855$, $p<.001$), and accounted for 4.4% ([8.211-7.849]/ 8.211) and 1.4% ([0.070-0.069]/ 0.070) of the variance in the intercept and linear change of physical function

trajectory, respectively. The main effect of diabetes was positive and significant, meaning that the level of physical function varied with diabetes status. Adults with diabetes had trajectories characterized by higher levels of limitations in physical function. The interaction of diabetes by linear age change was positive and significant, indicating that number of limitations in physical function increases at a faster rate in adults with diabetes than in those without diabetes. For example, for U.S. adults from age 57 (the medium age of cohort 1) to age 67, while non-diabetic individuals add an average of 0.72 (0.072*10) limitations in physical function, individuals with diabetes add an average of 1.45 ([0.072+0.073]*10) limitations in physical function over the period of ten years; similarly for Taiwanese adults, the increase in limitations in physical function over a ten-year period from age 57-67 is 0.88 (0.088*10) and 2.15 ([0.088+0.127]*10), respectively, for diabetic and non-diabetic adults. The trajectories for adults with and without diabetes in the HRS and HLSES are shown in Figures 3.3. Note that adults with diabetes were characterized by trajectories that were higher in both levels of physical function and rates of change in physical function trajectories, and these patterns are evident from the beginning of midlife and throughout older adulthood. However, the difference between adults with and without diabetes appears to be less distinct in older adulthood.

Results in Model 2 show estimates with the addition of the main effects of gender, gender × age, gender × diabetes, and gender × age × diabetes interaction terms. This model significantly improved the model fit from model 1 in both the HRS ($\Delta X^2_{(12)}$ =410, p<.001) and the HLSES ($\Delta X^2_{(12)}$ =159, p<.001). As expected, the main effect of gender was significant in both samples. Being a woman in both countries was associated with higher levels of limitations in physical function. In addition, women in Taiwan also displayed faster rates of increases in limitations in physical function over time. Despite accounting for the significant effects of

gender and gender × age, the effects of diabetes and diabetes × age remained positively significant in both the HRS and the HLSES, suggesting the pattern that higher levels of physical limitation and faster rates of change in physical function trajectories in adults with diabetes compared to those without diabetes was evident in both men and women. Results of the diabetes × gender interaction reveal that although diabetes had similar impacts for men and women in the Taiwan sample (-0.089, *ns*), it imposed disproportionally greater adverse impacts on women than on men in the U.S. sample (0.648, $p<.001$). The interaction between gender and diabetes for the linear change (gender × age × diabetes), however, was not significant in both country cases, indicating that the dynamic version of diabetes effects was not different by gender in either country.

Similarly, estimates with the addition of racial/ethnic- or educational-related effects are presented in Models 3 and 4, respectively. In both countries, race/ethnicity and education were significant predictors for the inter-individual variation in physical function trajectories. Being members of minority groups in the HRS (both Blacks and Hispanics) and having lower or medium educational levels were associated with higher levels of limitations in physical function, compared to their non-minority and higher educated counterparts. Controlling for the main effects of race/ethnicity or education, the impact of diabetes on the level of functional limitation (the main effect of diabetes) and the rate of change in the trajectory (diabetes × age) remains positively significant. Furthermore, the significant interactions of diabetes × black (0.287, $p<.05$) and diabetes × education_low (0.349, $p<.05$) reveal that the impacts of diabetes were more distinguishable in Blacks than in Whites and in adults with lower educational levels than in those with higher educational levels. In the HLSES, members of minority groups (both Mainlander and Hakka) were associated with lower levels of limitations in physical function, and Mainlanders

had lower rates of increases in limitations in physical function. Adults with lower or medium education levels not only had higher levels of limitations in physical function, but also showed a greater increase in rates of limitations in physical function over time. Again, accounting for racial/ethnic or educational-related effects, the effects of diabetes and diabetes × age remain positively significant in the HLSES. No interactions between diabetes and either race/ethnicity or education level in the HLSES were detected.

Comparing goodness of fit indices, including Akaike (Drevets et al.), Bayesian (BIC) information criteria and Likelihood Ratio (LR) test, and calculating the reduced random variances of each growth parameter from Models 1 to Models 2, 3, and 4 provides a perspective in which socio-demographic factors account for the most variability in the Model 1 diabetes trajectories. In the HRS, the inclusion of gender, race/ethnicity, and education explained 2.1% (7.849-7.681/7.849), 1.3% (7.849-7.750/7.849), and 4.4% (7.849-7.503/7.849) of the variance in the level of functional trajectories, respectively, but not the rate of changes. Similarly, by adding gender, race/ethnicity, and education respectively in the HLSES, there is a 4.9% (9.880-9.391/9.880), 2.0% (9.880-9.682/9.880), and 5.2% (9.880-9.366/9.880) reduction in the variance of the intercept. Thus, analyses of both the HRS and HLSES data suggest that education has the highest impact on deciding diabetes trajectories, followed by gender, and then race/ethnicity. This pattern was also supported by the BIC index.

Model 5 includes all of the aforementioned predictors plus covariates of death/dropout as well as six time-varying chronic health conditions. This model tested the independent effect of each predictor when controlling for all of the other predictors in the model. The addition of these variables accounted for 30.7% (7.849-5.438/7.849) of the variance in baseline physical function and 5.8% (0.069-0.065/0.069) of the linear change variation in the diabetes model of the HRS,

and explained 40.5% (9.880-5.883/9.880) of the variance in the intercept, 29.1% (0.127-0.090/0.127) of the linear change, and 25.0% (0.002-0.0015/0.002) of the curvature in the HLSES. Although the effects of diabetes on the intercept and linear change were diminished by 61.6% ([1.699-0.652]/1.699) and 35.6% ([0.073-0.047]/0.073) in the HRS sample, these effects remain significant and positive. Similarly in the HLSES sample, diabetes significantly and positively predicted limitations in physical function after accounting for sociodemographic factors, follow-up status, and co-morbidity effects. The results from this model suggest that diabetes has independent effects on physical function trajectories. Furthermore, although none of the gender, education, or race/ethnicity interactions with diabetes were significant in the HLSES sample, it is important to note that there were significant diabetes × gender and diabetes × age ×education effects shown in the HRS. Women were more vulnerable to diabetes-related physical limitations than were men (0.389, $p<.001$); in addition, adults with diabetes and lower educational levels displayed faster rates of increase in physical function limitations (0.059, $p<.01$) than did adults with diabetes but with higher educational levels. In order to illustrate the diabetes × gender and diabetes × age × education effects in the HRS data, Figures 3.4 and 3.5 provide the mean growth trajectories of limitations in physical function in adults with and without diabetes by gender and educational level.

DISCUSSION

To our knowledge, this is the first study to examine physical disability trajectories for adults with and without diabetes from age 50 to 105 and compare those patterns in eastern and western populations. The present study demonstrates a greater number of limitations in physical function and faster rates of change across the life span, from midlife to older adulthood, in

representative samples of U.S. and Taiwanese adults with diabetes compared to those without diabetes. This study also provides evidence regarding the roles of gender, education, and race/ethnicity in the longitudinal associations between diabetes and physical function. The analyses yielded five significant findings that merit discussion.

First, the age trajectories of physical disability for adults without diabetes reveal distinct aging patterns between the U.S. and Taiwan. The status of physical function for most Americans without diabetes is relatively stable before age 70; after age 70, change becomes dramatic with a positive slope, suggesting a substantial increase in physical disabilities. However, in Taiwan, there is no such watershed at age 70—deterioration in physical function is observed beginning at the starting age of our examination. Thus, although Taiwanese without diabetes showed fewer physical disabilities than did Americans during midlife (e.g., average number of limitations in physical function is 0.509 vs. 1.614 at age 57, for Taiwan and U.S., respectively), up to age 70, adults in the U.S. and Taiwan experience approximately the same number of limitations in physical function, and after age 70, Taiwanese adults have an average of about 0.5, 1, and 2 more physical disabilities than do U.S. adults at the ages of 75, 80, and 85, respectively.

Second, physical disability trajectories in adults with diabetes show three distinct characteristics compared to those observed in non-diabetic adults: the levels (intercepts) were higher, the slopes and curvatures were significantly greater, and trajectories in adjacent age cohorts never converged. The first observation regarding higher levels of limitations in physical function in adults with diabetes compared to those without diabetes was shown in all age cohorts of our examination and in both the U.S. and Taiwan. This provides cross-sectional evidence that diabetes imposes its effect on physical function at any time, independent of age. The second observation—greater slopes and curvatures shown in adults with diabetes than without

diabetes—provides further longitudinal evidence of the independent effects of diabetes on physical function, and the positive curvature suggests a faster deterioration in physical function along with aging. Most interestingly, although trajectories for adults without diabetes tend to line up together, trajectories for adults with diabetes based on different age cohorts never converge with each other for the overlapped age estimations. This finding suggests that for adults without diabetes, the number of limitations in physical functioning depends mainly on age, whereas for adults with diabetes, both age and cohort play critical roles in determining physical function. At any given age, physical disability was estimated with a longer follow-up period for younger age cohort adults than that for older cohort adults, (e.g., where age 63 is the median age 57 plus 6 years of follow-up in cohort 1, but median age 62 plus 1 year of follow-up for cohort 2). In addition, because adults in different age cohorts report random years of diabetes duration at baseline, the longer follow-up period may actually represent the accumulated years of living with diabetes. Thus, the estimated physical disability differences between any two cohorts may reflect the effects of diabetes duration.

Third, the hypothesis that differences in physical disability between adults with and without diabetes were not consistent in midlife and in older age was supported in the present study. On the one hand, the main effect of diabetes and diabetes × age interactions was highly positive and significant in the fully controlled covariate models of both datasets, suggesting that diabetes contributes to both the higher levels and steeper rates of change at any given age. These results are in line with previous studies finding independent effect of diabetes on disability using different covariates and methodologies (Wray, Ofstedal et al., 2005). On the other hand, as illustrated in the trajectories, the magnitude of the differences between adults with and without diabetes for the levels of limitation and the rates of change were greater in younger ages than in

older ages. These results also complement those from previous research on female-only populations (Gregg et al., 2002). Reasons for the attenuated difference were well-discussed in the previous study (Gregg et al., 2002). For example, due to differential mortality rates, adults with diabetes at older ages may be healthier and less affected by their diabetes than are adults with diabetes at younger ages.

Fourth, the results based on the U.S. data alone reveal that the impacts of diabetes on physical disability were not the same across populations with different sociodemographic backgrounds. In line with previous research suggesting diabetes health outcomes differ by gender, education, and race/ethnicity (Gary et al., 2004; Heisler et al., 2007; Hertz et al., 2006; LeMaster et al., 2006; Quandt et al., 2005), we found that at any given age, physical disability differences between adults with and without diabetes were substantially greater in women than in men, in adults of lower education than of higher education, and in members of racial/ethnic minority groups compared to White adults. Additionally, our results reveal that the moderating effects of education and gender were not explained by the other sociodemographic factors, diabetes comorbidities, or follow-up status in our model; in contrast, the effects of race/ethnicity may be mainly caused by factors in our fully controlled model, such as educational levels or comorbidities.

Finally, two distinctly different findings between the U.S. and Taiwan deserve further discussion: Compared to U.S. adults, Taiwanese adults increased their levels of disability more rapidly over time; and the impact of diabetes on disability in that country did not differ by sociodemographic backgrounds (e.g., gender, education and ethnicity). Based on our data that older adults in Taiwan during 1996-2003 had lower educational levels than did their counterparts in the U.S. and the wealth of studies demonstrating that education has long-term impacts on

health outcomes (Alwin & Wray, 2005; Herd, 2006; Kimbro, Bzostek, Goldman, & Rodriguez, 2008; Maty et al., 2005; Schillinger, Barton, Karter, Wang, & Adler, 2006; Wray et al., 2006), we suspect that the faster increase rate in physical disability in adults in Taiwan may be explained—at last in part—by the lower achieved social status. In addition, studies have shown that older Taiwanese adults' lower confidence in the effects of prescribed medication effects may lead to decreased adherence to drug therapies, compared to older adults in the West (Chia, Schlenk, & Dunbar-Jacob, 2006; Lai, Chie, & Lew-Ting, 2007; Lai, Lew-Ting, & Chie, 2005). Thus, the cultural differences in medication use behaviors may contribute to the poorer health outcomes observed in Taiwan. Regarding the similarity of the diabetes impacts across demographic groups in Taiwan, we suspect that universal health care in Taiwan may also play a critical role. Unlike in the U.S. where only older adults are eligible for universal health care, Taiwanese adults at all ages have been covered by universal health care since 1995 (Cheng & Chiang, 1997). This coverage may have minimized any potential sociodemographic differences in physical function outcomes by equalizing access to care and assistive technology for adults with diabetes.

A major strength of this study includes its research design and the advanced analytical method which enable the identification of physical disability trajectories with both cross-sectional and longitudinal evidence. To our knowledge, no previous studies have taken advantage of the accelerated longitudinal nature (cohort-sequential design) of the HRS and the HLSES by linking adjacent and overlapping segments of available longitudinal data from different age cohorts to approximate a longer term change, such as from midlife to older adulthood. This technique enables us to delineate the disability trajectory for people from 50 to 105 without having to follow a sample of age 50 for 55 years. Instead of arbitrarily assuming a

common developmental trend across cohorts, we used a cohort convergence test to determine the best model for the trajectory. Our final model bringing age cohort heterogeneity to bear upon the long-term trajectories enriches our research quality by providing both cross-sectional and longitudinal perspectives. Specifically, on the one hand the growth parameter of age provides the longitudinal evidence of change in physical function; and on the other hand, by connecting the intercept (median age) of each cohort, limitations in physical function in each 5-year period of age can be understood with cross-sectional data.

An additional strength of this study is its examination of the dynamic relationship between diabetes and physical function. Few studies have examined whether diabetes shapes physical function trajectories, including levels of physical function limitations and rates of change in limitations from midlife to older age. This study fills an empirical void by describing the dynamic impact of diabetes on physical function. With age (longitudinal) and age cohort (cross-sectional) effects being modeled as major within-individual changes in physical function over time, we teased out effects confounded with natural aging processes and facilitated simultaneous tests of cross-sectional and longitudinal relationships between diabetes and physical function.

Further, the study is unique in that we provide evidence based on two large national samples from eastern and western populations, which are seldom performed in one study. The cross-national comparison of the diabetes burden helps clarify the generalizability of commonly held diabetes concepts across diverse cultural and geographic settings.

Limitations

Limitations in this study also warrant comment. First, our results share the limitations for research based on secondary data analysis. The measures of diabetes, physical function, and co-morbidities were based on self-reported data. Since the tendency for reporting limitations in the two countries was not clear, important cultural differences may lead to differential tendencies for difficulties in reporting, different findings may have resulted if adults with pre-diabetes or undiagnosed diabetes were included or performance-based measures had been used. In addition, some important factors that might have a substantial impact on moderating the relationship between diabetes and physical function, such as duration of diabetes, glycemic control, medication, psychological factors, and lifestyles, were not examined in the study. Future research with available data is encouraged to address their contribution to the diabetes-physical function relationship. Aggregating physical function items also limited our ability to identify which aspect of physical function was more sensitive to diabetes. Future studies are also encouraged to investigate each domain of physical function separately.

An additional limitation is related to period and cohort effects. Our results were based on middle-aged and older Americans and Taiwanese born in 1891-1947 and 1898-1945 respectively, and their data during 1996-2003 in Taiwan and 1998-2006 in the U.S. It is not clear if the results found here will generalize to other, more recently born middle-aged and older adults in the two countries. For example, contemporary older adults in Taiwan experienced tremendous social changes during the early 1900s compared to more recently born adults, which may lead to differential relationships between sociodemographic backgrounds and diabetes-physical function outcomes.

Implications

In summary, this longitudinal examination of multiple cohorts of adults in the U.S. and Taiwan, with controls for follow-up status, sociodemographic factors and chronic health conditions, indicated that adults with diabetes have more physical limitations and greater rate of deterioration over time than do adults without diabetes. These results point to the need for current diabetes care guidelines to focus not only on the prevention of traditional diabetes co-morbidities, but also on preventing the negative impact of diabetes on physical function to ensure a higher quality of life in adults with diabetes. The largely consistent findings between the U.S. and Taiwan support the generalizability of the concepts preventing negative impacts of diabetes on physical function for middle-aged and older adults with diabetes across diverse cultural and geographic settings. The finding in the U.S., but not in Taiwan, that middle-aged women and adults with lower levels of education suffered more adverse impacts of diabetes than did men and those with higher education support the need to develop diabetes care that specifically targets the needs of women and adults with lower education in the U.S.

Table 3.1 Baseline Characteristics[a] and Association with Limitations in Physical Function[b]

	HRS (n=20,433)		*P*	HLSES (n=5,121)		*P*
	%[a]	Mean (SD)[b]		%[a]	Mean (SD)[b]	
Age		66.8 (10.4)			66.2 (9.5)	
(Age) Cohort			<.0001			<.0001
1	5.1	1.48(2.37)		1.97	0.39(1.46)	
2	6.7	1.69(2.50)		4.65	0.79(2.13)	
3	10.4	1.85(2.60)		9.76	1.16(2.74)	
4	12.8	1.96(2.60)		17.5	1.60(3.17)	
5	14.1	2.25(2.89)		21.3	2.16(3.59)	
6	17.8	2.98(3.44)		12.9	3.71(4.57)	
7	19.5	4.05(3.99)		15.0	5.26(4.87)	
8	13.6	5.56(4.42)		16.9	6.33(5.03)	
Gender			<.0001			<.0001
Women	43.1	2.64 (3.25)		53.8	2.33 (3.62)	
Men	56.9	1.80 (2.76)		46.2	1.33 (3.25)	
Education[c]			<.0001			<.0001
Low	29.0	3.43 (3.69)		32.6	2.98 (4.03)	
Medium	35.3	2.10 (2.82)		39.2	1.28 (2.98)	
High	35.7	1.54 (2.44)		28.2	1.12 (2.98)	
Ethnicity			<.0001			.0006
White/Fukienese	82.5	2.14 (2.94)		67.2	1.89 (3.55)	
Black/Hakka	14.1	2.99 (3.60)		15.1	1.67 (3.32)	
Mainlander/Mainlander	3.4	2.67 (3.46)		17.8	1.38 (3.11)	
Diabetes Status			<.0001			
Yes	15.1	3.45 (3.60)		11.4	3.09 (4.42)	
No	84.9	2.07 (2.92)		88.6	1.62 (3.27)	
High Blood Pressure			<.0001			<.0001
Yes	49.1	1.72 (2.62)		27.6	2.69 (4.17)	
No	50.9	2.86 (3.39)		72.4	1.44 (3.00)	
Cancer			<.0001			<.0001
Yes	11.5	2.81 (3.22)		1.4	3.81 (5.14)	
No	88.5	2.21 (3.05)		98.6	1.66 (3.42)	
Lung Disease			<.0001			<.0001
Yes	10.3	3.98 (3.61)		10.9	2.87 (4.22)	
No	89.7	2.08 (2.95)		89.1	1.65 (3.33)	
Heart Disease			<.0001			<.0001
Yes	21.7	3.65 (3.69)		15.9	2.96 (4.04)	
No	78.3	1.92 (2.76)		84.1	1.56 (3.22)	
Stroke			<.0001			<.0001
Yes	7.69	5.57 (4.57)		4.7	8.38 (6.35)	
No	92.3	2.01 (2.75)		95.3	1.47 (2.89)	

Arthritis			<.0001			<.0001
Yes	55.5	3.11 (3.34)		22.2	2.64 (3.65)	
No	44.5	1.24 (2.33)		77.8	1.54 (3.35)	

[c] In HRS: low= less than high school, medium= GED or high school graduate, high=some college and above; in HLSES: low= 0 years of formal education, medium= 1-6 years formal education, high= 7 or above years of education

Table 3.2 Correlations in Physical Function Scores Overtime in the Two Samples.

	HRS						HLSES		
	1998	2000	2002	2004	2006		1996	1999	2003
N	20,433	17,987	16,319	14,893	13,545	N	5,121	4,279	3,643
1998	1.00					1996	1.00		
2000	0.77	1.00				1999	0.70	1.00	
2002	0.68	0.76	1.00			2003	0.52	0.63	1.00
2004	0.60	0.67	0.76	1.00					
2006	0.54	0.59	0.67	0.76	1.00				
M	2.29	2.36	2.53	2.60	2.82	M	1.79	2.28	2.77
SD	3.08	3.15	3.20	3.20	3.30	SD	3.45	3.81	4.15

Note. HRS= Health and Retirement Study; HLSES=Health and Living Status of the Elderly in Taiwan Study
M=mean; SD= standard deviation

Table 3.3 Comparison of Unconditional, Linear, Quadratic, and Cubic Change Models

Full model	HRS			HLSES		
	Deviance Score (-2LL[a])	DF	Model Comparison[b] ΔX^2 (Δdf)	Deviance Score (-2LL[a])	DF	Model Comparison[b] ΔX^2 (Δdf)
Unconditional	382,585	3		68,705	3	
Linear	366,692	22	15,893(19)***	65,402	22	3,303(19)***
Quadratic	365,632	34	1,060(12)***	**65,265**	**34**	**137(12)*** **
Cubic	**365,608**	**43**	**24(9)*** **	65,258	43	7(9) ns

[a] -2 Log Likelihood
[b] *** p<.001

Table 3.4 Coefficient Estimates of Trajectory of Physical Function (HRS 1998-2006, N=20,433)

	Model 0[a]	Model 1[b]	Model 2[c]	Model 3[d]	Model 4[e]	Model 5[f]
Fixed effects						
Intercept	1.784***	1.614***	1.208***	1.477***	1.232***	0.0839
Age	0.0786***	0.072***	0.068***	0.068***	0.070***	0.026*
Age^2	0.0007	0.0007	0.0007	0.0007	0.0008	0.001
Age^3	-0.0002	-0.0003	-0.0003	-0.0003	-0.0003	-0.0002
Cohort2	0.161*	0.111	0.162*	0.112	-0.005	-0.057
Cohort3	0.353***	0.235**	0.281**	0.236**	0.080	-0.119
Cohort4	0.708***	0.595***	0.649***	0.637***	0.432***	0.066
Cohort5	1.171***	1.052***	1.100***	1.113***	0.827***	0.271***
Cohort6	2.230***	2.105***	2.105***	2.149***	1.841***	0.886***
Cohort7	4.097***	4.014***	3.980***	4.047***	3.640***	2.276***
Cohort8	8.293***	8.268***	8.164***	8.288***	7.770***	5.942***
Age* Cohort2	-0.0128	-0.015	0.645	-0.015	-0.016	-0.008
Age* Cohort3	0.0288*	0.025	0.461	0.025	0.023	0.032
Age* Cohort4	0.0675***	0.064***	0.242***	0.064***	0.061***	0.061*
Age* Cohort5	0.1567***	0.153***	0.152***	0.154***	0.151***	0.149***
Age* Cohort6	0.2491***	0.243***	0.064***	0.244***	0.241***	0.226***
Age* Cohort7	0.4669***	0.462***	0.025***	0.462***	0.457***	0.436***
Age* Cohort8	0.6538***	0.653***	-0.014***	0.651***	0.635***	0.593***
Age^2* Cohort2	0.0008	0.0008	0.0007	0.0007	0.0007	-0.0007
Age^2* Cohort3	0.0059**	0.006**	0.006**	0.006**	0.005**	0.004*
Age^2* Cohort4	0.0093***	0.009***	0.009***	0.009***	0.008**	0.006**
Age^2* Cohort5	000156***	0.015***	0.016***	0.015***	0.015***	0.015***
Age^2* Cohort6	0.0255***	0.025***	0.025***	0.025***	0.025***	0.025***
Age^2* Cohort7	0.0202***	0.019***	0.019***	0.195***	0.019***	0.020***
Age^2* Cohort8	0.0072	0.007	0.007	0.007	0.006	0.002
Age^3* Cohort2	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
Age^3* Cohort3	-0.0000	-0.00002	0.000	-0.00002	-0.00001	-0.0001
Age^3* Cohort4	0.0014*	0.001*	0.001*	0.001*	0.001**	0.001**
Age^3* Cohort5	0.0008	0.0007	0.0007	0.0007	0.0007	0.0005

Age^3* Cohort6	0.0020**	0.002**	0.002**	0.002*	0.002**	0.002***
Age^3* Cohort7	0.0003	0.0004	0.0003	0.0003	0.0003	0.0003
Age^3* Cohort8	-0.0007	-0.0007	-0.0007	-0.0007	-0.0006	-0.0008
Diabetes		1.699***	1.370***	1.528***	1.396***	0.652***
Diabetes*Age		0.073***	0.076***	0.075***	0.046**	0.047**
Women			0.657***			0.718***
Women*Age			0.005			0.006
Women*Diabetes			0.648***			0.389***
Women*Diabetes*Age			-0.006			-0.005
Black				0.766***		0.413***
Hispanic				0.628***		0.427***
Black*Age				0.012		0.013
Hispanic*Age				0.025		0.029
Black*Diabetes				0.287*		0.233
Hispanic*Diabetes				0.213		0.206
Black*Age*Diabetes				-0.002		-0.009
Hispanic*Age*Diabetes				-0.042		-0.048
Education_low					1.389***	1.007***
Education_med					0.515***	0.332***
Education_low*Age					0.006	0.011
Education_med*Age					0.004	0.004
Edu_low*Diabetes					0.349*	0.199
Edu_med*Diabetes					0.022	0.011
Edu_low*Age*Diabetes					0.059**	0.059**
Edu_med*Age*Diabetes					0.015	0.014
Deceased/dropout						1.379***
High blood pressure						0.162***
Cancer						0.188***
Lung disease						0.735***
Heart disease						0.524***
Stroke						1.824***
Arthritis						0.691***
Random effects						

Variance						
Intercept (11)	8.211***	7.849***	7.681***	7.750***	7.503***	5.438***
Slope(22)	0.070***	0.069***	0.069***	0.069***	0.069***	0.065***
Curvature (33)	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
Covariance						
Intercept, slope (21)	0.204***	0.185***	0.183***	0.184***	0.178***	0.122***
Intercept, curvature (31)	-0.034***	-0.035***	-0.035***	-0.035***	-0.035***	-0.030***
Slope, curvature (32)	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***
Residual	2.047***	2.048***	2.048***	2.048***	2.049***	2.034***
Goodness of fit						
AIC	365,686	364,835	364,433	364,484	363,515	355,564
BIC	365,995	365,160	364,789	364,872	363,904	356,103
-2LL	365,608	364,753	364,343	364,386	363,417	355,428
Parameters	43	47	59	65	65	109
LR Test:						
$\Delta\chi^2$ (Degrees of freedom)	-	855 (4) ***	410 (12) ***	367 (18) ***	1,336 (18) ***	9,325 (62) ***

NOTE: AIC= Akaike's Information Criterion; BIC= Bayesian Information Criteria; LR=Likelihood Ratio; -2LL= -2 Log-Likelihood.
a. Model 0: Age & Cohort model.
b. Model 1: Diabetes model.
c. Model 2: Diabetes & Gender model.
d. Model 3: Diabetes & Race/Ethnicity model.
e. Model 4: Diabetes & Education model.
f. Model 5: Diabetes & Covariates model.

Table 3.5 Coefficient Estimates of Trajectory of Physical Function (HLSES 1996-2003, N=5,121)

	Model 0[a]	Model 1[b]	Model 2[c]	Model 3[d]	Model 4[e]	Model 5[f]
Fixed effects						
Intercept	0.631***	0.509***	-0.071	0.584***	-0.008	-0.528
Age	0.0972***	0.088***	0.060**	0.094***	0.045	0.003
Age^2	0.0084	0.008	0.008	0.008	0.0008*	0.008*
Cohort2	0.692***	0.584**	0.564**	0.629**	0.370*	0.319*
Cohort3	1.164***	1.066***	1.063***	1.189***	0.918***	0.791***
Cohort4	1.864***	1.727***	1.833***	2.018***	1.608***	1.293***
Cohort5	3.076***	2.941***	2.989***	3.227***	2.705***	2.179***
Cohort6	5.163***	5.055***	5.024***	5.243***	4.622***	3.624***
Cohort7	7.708***	7.593***	7.493***	7.704***	7.078***	5.880***
Cohort8	11.584***	11.626***	11.518***	11.726***	10.964***	9.327***
Age* Cohort2	0.0387	0.035	0.033	0.038	0.029	0.025
Age* Cohort3	0.0814**	0.076*	0.075*	0.084**	0.070*	0.053
Age* Cohort4	0.0198***	0.191***	0.193***	0.206***	0.189***	0.168***
Age* Cohort5	0.3354***	0.328***	0.325***	0.342***	0.322***	0.286***
Age* Cohort6	0.5512***	0.542***	0.533***	0.552***	0.527***	0.481***
Age* Cohort7	0.6952***	0.684***	0.674***	0.666***	0.667***	0.608***
Age* Cohort8	0.8908***	0.889***	0.866***	0.888***	0.844***	0.765***
Age^2* Cohort2	-0.0054	-0.005	-0.005	-0.005	-0.006	-0.006
Age^2* Cohort3	-0.0021	-0.002	-0.002	-0.002	-0.002	-0.004
Age^2* Cohort4	0.0077	0.008	0.008	0.008	0.008	0.010
Age^2* Cohort5	0.0079	0.008	0.008	0.008	0.008	0.006
Age^2* Cohort6	0.0246	0.024**	0.023**	0.024**	0.024**	0.023**
Age^2* Cohort7	0.0110**	0.011	0.011	0.011	0.011	0.008
Age^2* Cohort8	0.0276	0.027	0.026	0.027	0.025	0.020
Diabetes		1.984***	1.910***	2.024***	1.782***	1.166***
Diabetes*Age		0.127***	0.111**	0.132***	0.190***	0.142*
Women			1.210***			0.938***
Women*Age			0.060***			0.043*
Women*Diabetes			-0.089			0.248

Women*Diabetes*Age			0.010			0.068
Mainlander				-1.235***		-0.570***
Hakka				-0.267*		-0.142
Mainlander*Age				-0.060*		-0.005
Hakka*Age				-0.028		-0.013
Mainlander*Diabetes				0.210		0.093
Hakka*Diabetes				-0.510		-0.227
Mainlander*Age*Diabetes				0.020		-0.055
Hakka*Age*Diabetes				-0.049		-0.037
Education_low					1.610***	0.899***
Education_med					0.476***	0.188
Education_low*Age					0.081***	0.032
Education_med*Age					0.055***	0.036
Edu_low*Diabetes					-0.059	-0.325
Edu_med*Diabetes					0.438	-0.147
Edu_low*Age*Diabetes					-0.121	-0.183*
Edu_med*Age*Diabetes					-0.066	-0.084
Deceased/dropout						1.558***
High blood pressure						0.127*
Cancer						-0.257**
Lung disease						0.364***
Heart disease						0.426***
Stroke						4.721***
Arthritis						0.131*
Random effects						
Variance						
Intercept (11)	10.202***	9.880***	9.391***	9.682***	9.366***	5.883***
Slope (22)	0.129***	0.127***	0.126***	0.127***	0.126***	0.090***
Curvature (33)	0.002***	0.002***	0.002***	0.002***	0.0016***	0.0015***
Covariance						
Intercept, slope (12)	0.503	0.474***	0.436***	0.463***	0.453***	0.280***
Intercept, curvature (13)	-0.019	-0.022*	-0.024**	-0.022*	-0.022*	-0.019**
Slope, curvature (23)	0.009	0.008***	0.008***	0.008***	0.008***	0.007***

Residual	3.394***	3.383***	3.401***	3.391***	3.393***	3.464***
Goodness of fit						
AIC	65,327	65,171	65,020	64,998	64,992	62,557
BIC	65,530	65,387	65,262	65,266	65,260	62,949
-2LL	65,265	65,105	64,946	64,916	64,910	62,437
Parameters	34	38	50	56	56	100
LR Test						
$\Delta\chi^2$ (Degrees of freedom)	-	160(4) ***	159(12) ***	189(18) ***	195(18) ***	2,668(62) ***

NOTE: AIC= Akaike's Information Criterion; BIC= Bayesian Information Criteria; LR=Likelihood Ratio; -2LL= -2 Log-Likelihood.
a. Model 0: Age & Cohort model.
b. Model 1: Diabetes model.
c. Model 2: Diabetes & Gender model.
d. Model 3: Diabetes & Race/Ethnicity model.
e. Model 4: Diabetes & Education model.
f. Model 5: Diabetes & Covariates model.

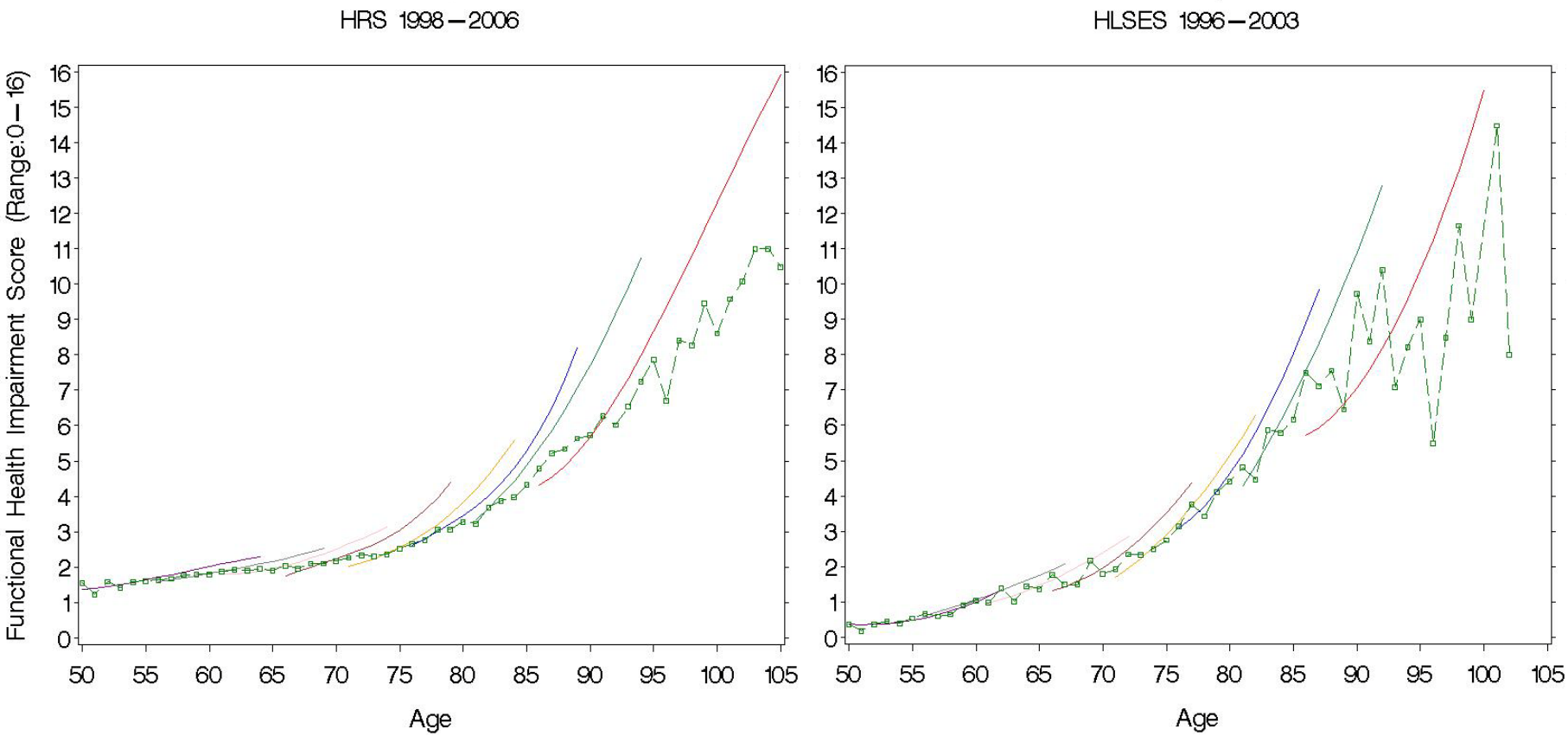

Figure 3.2 Sample Raw Mean versus Age Trajectory of Limitations in Physical Function (HRS 1998-2006 and HLSES 1996-2003)

Notes: The solid line indicates estimated trajectories over time in each cohort; the dashed line indicates raw mean limitations in physical function for each age.

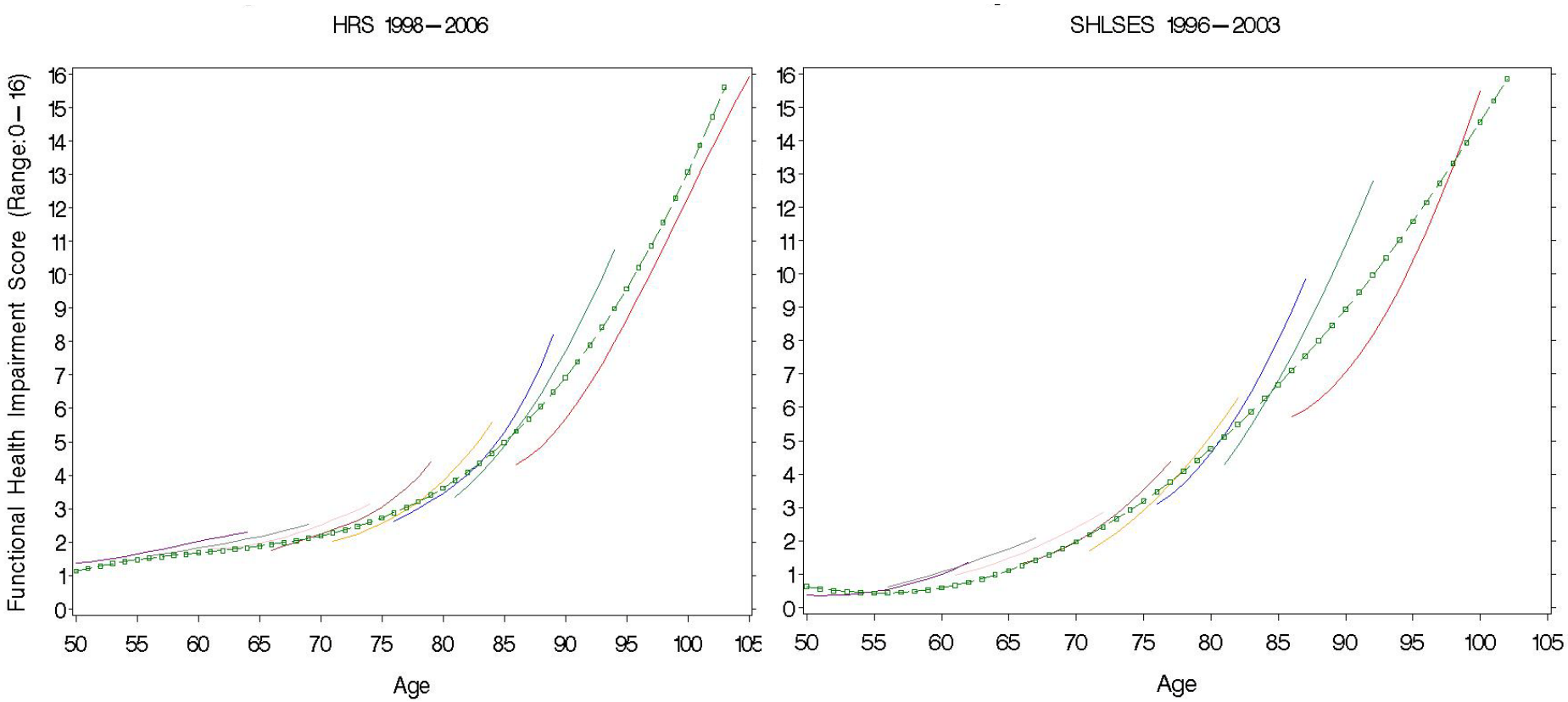

Figure 3.3 Age Trajectory of Limitations in Physical Function Estimated by Full Model versus Reduced Model (HRS 1998-2006 and HLSES 1996-2003)

Notes: The solid lines are estimated by full model; the dashed line is estimated by reduced model.

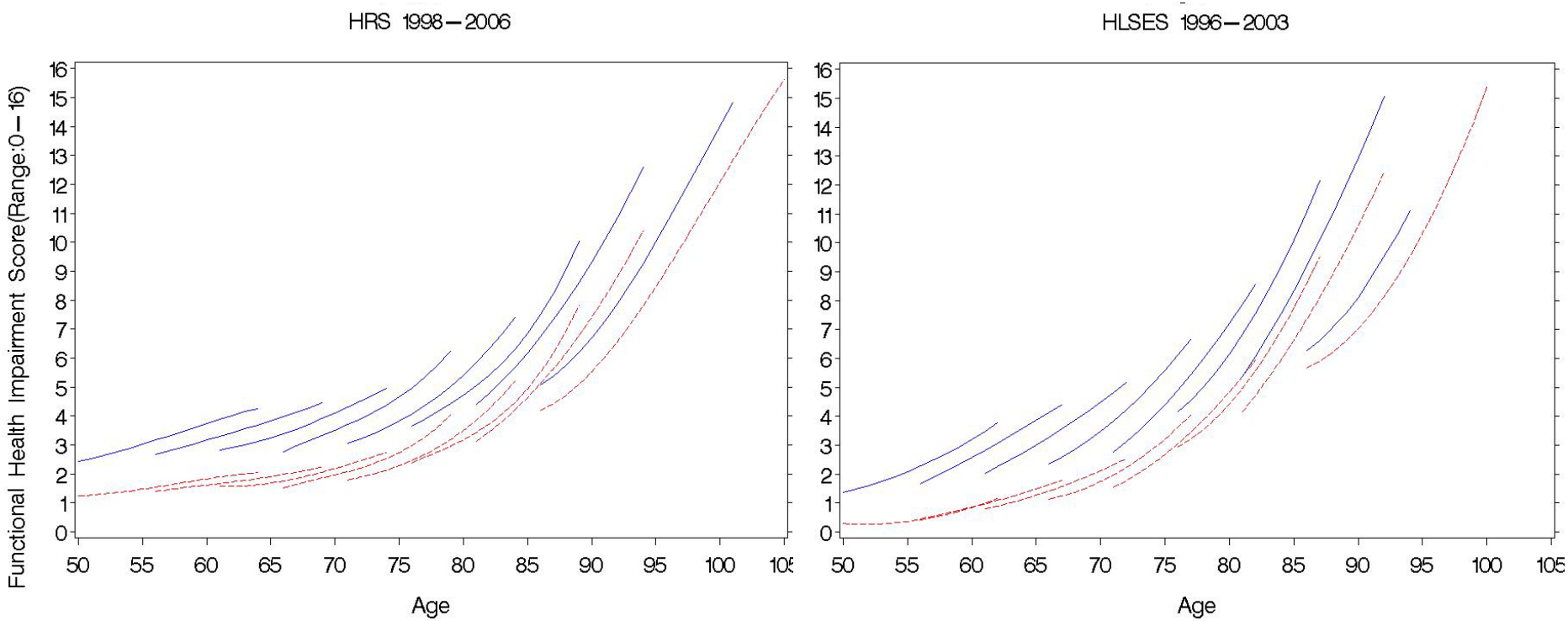

Figure 3.4 Physical Function Trajectories in Adults with and without Diabetes (HRS 1998-2006 and HLSES 1996-2003)

Notes: The solid lines are estimated for adults with diabetes; the dashed lines are estimated for adults without diabetes.

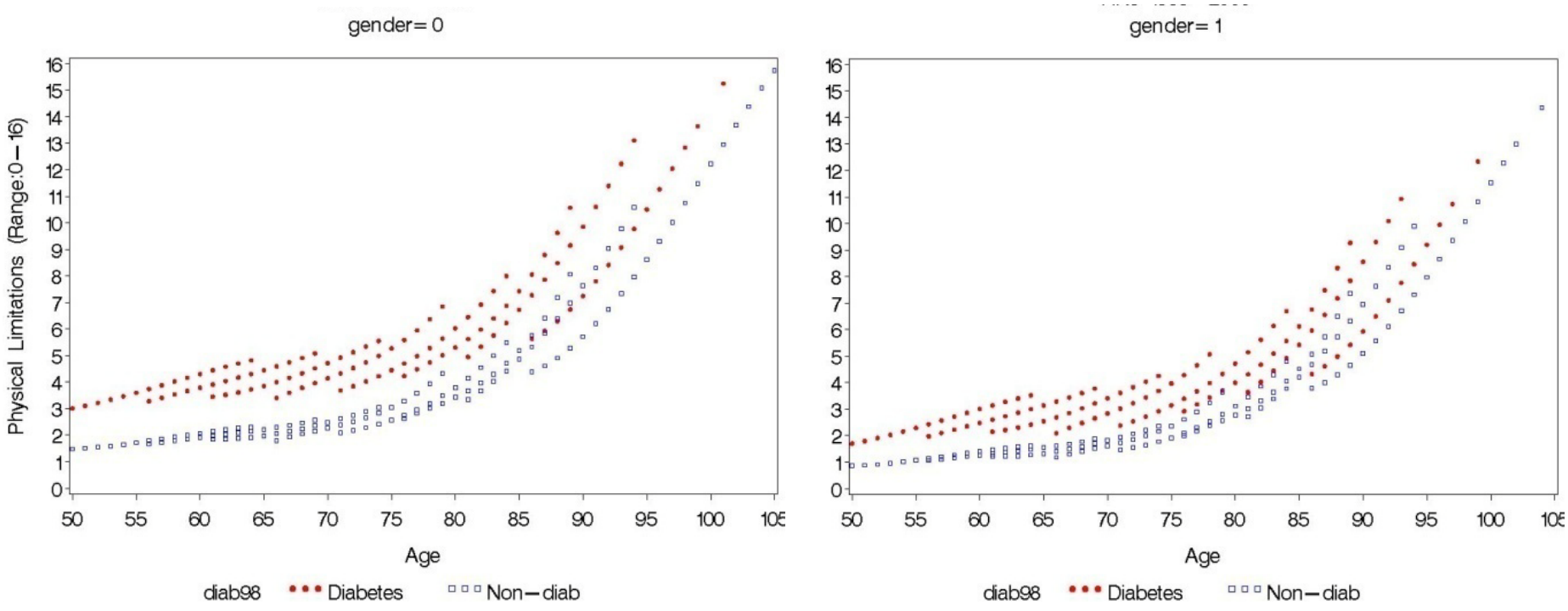

Figure 3.5 Diabetes by Gender Interaction (HRS 1998-2006)

Notes: The left panel presents estimated trajectories in women with and without diabetes; the right panel presents patterns in men.

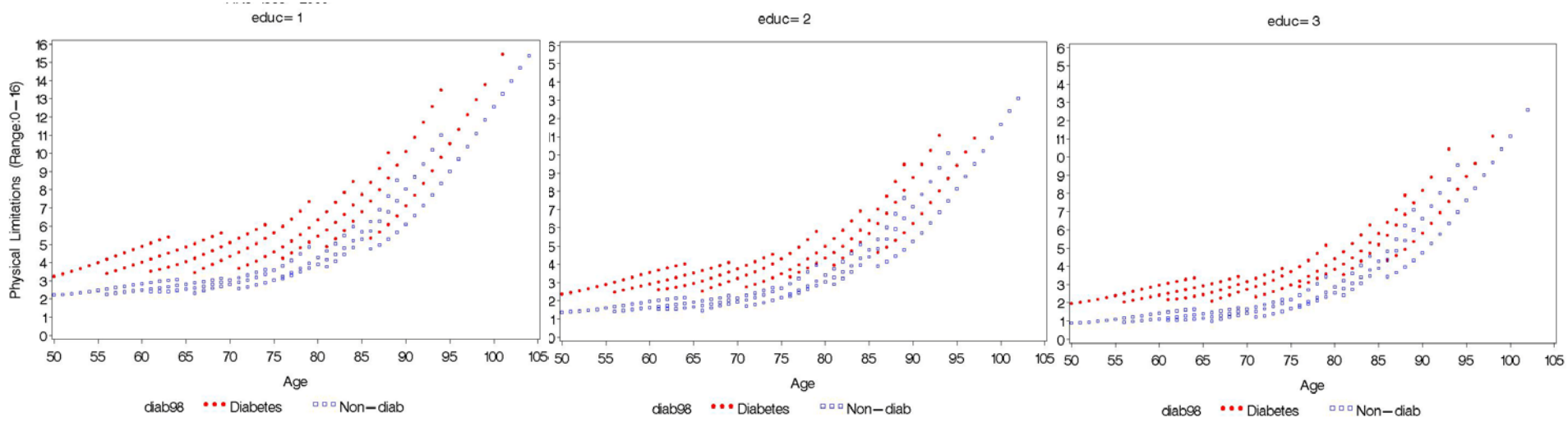

Figure 3.6 Diabetes by Education Interaction. (HRS 1998-2006)

Notes: From left to right are trajectories estimated in adults of low, medium, and high educational levels.

Chapter 4

MANUSCRIPT 2:

Gender Differences in Physical Disability in Adults Living with Type 2 Diabetes: Biobehavioral and Psychosocial Mediators

Abstract

BACKGROUND: Differences in physical disability between adults with and without diabetes are more evident in women than in men. **OBJECTIVES**: We test if the gender differences in physical disability in adults living with type 2 diabetes can be attributed to biological factors (blood pressure, BMI, HbA1c, and early complications), self-care behaviors (medication, blood sugar test, diet and exercise), or psychosocial well-being (perceived diabetes control, perceived diabetes-specific family/friends support, coping, and depressive symptoms). **METHODS**: Data on 1,619 adults (mean age= 69.5, *SD*=8.7) living with type 2 diabetes from the U.S. nationally representative Health and Retirement Study (HRS) and its diabetes-specific mail survey were used. All mediators were measured during 2002-2003, and physical function was measured in 2004. The fit of a series of models to the data was analyzed using structural equation modeling. **RESULTS**: Findings indicated that although women had better diet and blood glucose self-monitoring behaviors than did men, they had less favorable levels on BMI, HbA1c, blood pressure, early complications, exercise behaviors, perceived control, self-efficacy, coping, depressive symptoms, and family support than did men. The use of structural equation modeling revealed that biological and behavioral factors directly and completely mediated the gender differences in physical function; psychosocial factors, although not directly accounting for the gender differences in physical function, made an indirect contribution in the gender-physical disability relationship by way of their strong association with biological and behavioral factors.

CONCLUSIONS: Gender differences in physical function in middle-aged and older adults living with type 2 diabetes can be attributed to differences in clinical determinants (BMI, HbA1c, blood pressure, early complications), self-care behaviors (especially exercise), and psychosocial well-being (perceived control, self-efficacy, diabetes coping, and depressive symptoms). Interventions targeting these domains may help improve the long-term health in physical function in women with type 2 diabetes.

INTRODUCTION

Substantial diabetes research has shown that diabetes confers a markedly increased risk of physical disability from midlife to older adulthood (Bruce et al., 2003; Chiu & Wray, 2009; Chou & Chi, 2005; Gregg et al., 2000; Gregg et al., 2002a; Gregg et al., 2002b; Songer, 1995; Wray, Ofstedal et al., 2005). More recent literature indicates that in adults with diabetes, women were more likely than men to have worse physical function outcomes (Shalev, Chodick, Heymann, & Kokia, 2005). Differences in physical disability between adults with and without diabetes were more evident in women than in men (Chiu & Wray, 2009; Shalev et al., 2005).

That women suffer substantially more physical disability than men in general has long been reported (Barberger-Gateau, Rainville, Letenneur, & Dartigues, 2000; Beckett et al., 1996; Freedman et al., 2004; Gorman & Read, 2006; Romoren & Blekeseaune, 2003; Shumway-Cook, Ciol, Yorkston, Hoffman, & Chan, 2005). Gender differences in achieved social status (e.g., education, income, assets), health behaviors (e.g., exercise), and psychosocial factors (e.g., depression, stressful life events) have been proposed as important factors contributing to that association in sociodemographical theories, such as Life-Span Developmental Perspective (Alwin & Wray, 2005) and in empirical literature (Gorman & Read, 2006; Strawbridge,

Camacho, Cohen, & Kaplan, 1993). Mechanisms accounting for the gender differences in physical disability in adults living with diabetes, however, have received much less attention.

In recent years, an increasing number of investigators have observed gender differences in biological factors and diabetes complications as well as psychosocial well-being in adults living with diabetes. Women generally had worse glycemic control, blood pressure, higher body fat composition, and health outcomes such as complications in microvascular diseases than did men (Legato et al., 2006; Nilsson et al., 2004; Shalev et al., 2005; Szalat & Raz, 2007; Tang et al., 2008; Wexler et al., 2005). In addition, women generally expressed more barriers to regimen adherence (Glasgow, McCaul, & Schafer, 1986), higher levels of depressive symptoms (Chiu, Wray, Beverly, & Dominic, 2009, in press; Gucciardi et al., 2008; Ponzo et al., 2006), weaker perception of family support, and diabetes-specific self-efficacy than men (Brown et al., 2000; Gucciardi et al., 2008; Ponzo et al., 2006; Umberson, 1992). These findings are intriguing and potentially important; however, a paucity of research exists evaluating to what extent these gender-related factors explain the gender differences in physical disability in adults with type 2 diabetes. As the incidence of diabetes, especially type 2 diabetes, continues to soar in society today, a better understanding of mechanisms related to the gender differences in physical disability will help physicians and health authorities to develop strategies for helping women with type 2 diabetes.

In the present study, we drew upon knowledge from current literature to investigate why women living with type 2 diabetes report greater physical disability than do men. Two specific research questions were addressed. First, do men and women with diabetes differ in their mean scores on important diabetes-related biological indicators (e.g., HbA1c, blood pressure, BMI, and early diabetes complications), self-care behaviors (e.g., exercise, diet, medication, and blood

sugar self-monitoring), and psychosocial well-being (e.g., perceived diabetes control, diabetes self-efficacy, depressive symptoms, diabetes-specific support, and coping status)? Second, do these gender-related factors mediate gender differences in physical disability? Because indicators within behavioral, biological, and psychosocial domains may be related to each other, and to reduce the measurement errors of these indicators, we formed latent biological, behavioral, and psychosocial variables as three distinct but correlated mediators in a structural equation model to determine if they are supported as factors that might account for the link between gender and physical disability, and to examine their unique as well as joint contributions. The hypothesized model is presented in Figure 4.1.

METHODS

Data and Sample

This study used longitudinal data from middle-aged and older adults who responded to the U.S. Health and Retirement Study (HRS) 2003 diabetes-specific mail survey and the 2004 HRS core telephone interview. The HRS 2003 diabetes-specific mail survey was funded by the National Institute on Aging through a competing supplement to the biennial HRS that began in 1992 (Juster & Suzman, 1995). The diabetes survey aimed to collect self-reported questionnaire data on aspects of treatment and self-management of diabetes, as well as a clinical biomarker of glucose control (HbA1c) for those who reported a diagnosis of diabetes in the 2002 HRS core survey. There were 3,194 interviewed respondents aged 38 to 99 in the 2002 HRS who reported a diagnosis of diabetes (including respondents whose interviews were given by proxies). Of these, 680 were randomly excluded from the 2003 Diabetes Study because of their participation in another competing supplemental survey. Of the 2,514 eligible 2002 participants, 129 were

subsequently determined to have died prior to the October 2003 start of the Diabetes Study, and so are ineligible for inclusion in the sample. Of the 2,385 remaining eligible cases, 1,901 returned questionnaires, for a response rate of 79.7%. The present study focuses on persons with type 2 diabetes. Diabetes type was indentified based on participants' responses to two questions in the 2003 Diabetes Study: "Which type of diabetes did your doctor say that you have?" and "At what age were you told by a doctor that you had diabetes?" Respondents who indicated they had type 2 diabetes or developed diabetes after the age of 40 were considered to have type 2 diabetes (N=1,723).

Data for 1,619 adults who were followed-up in the 2004 HRS core survey were analyzed in the present study (758 men and 861 women). Respondents ranged in age from 42-96 years in 2003 (mean= 69.5 years, *SD*=8.7); mean age at diagnosis was 56.9 years (*SD*=13.3); and average duration of diabetes was 12.2 years (*SD*=11.5). About three quarters of the respondents (77.3%) were Caucasian, 17.9% African American, and 4.8% other.

Measures

The independent variable of key interest is a dummy variable representing gender (coded 1=men, 2=women). Three sets of mediators, measured in the 2002 HRS core survey or 2003 diabetes-specific mail survey, were tested to explain the gender-physical disability association:

Biological Mediators. Four indicators were considered as biologically-related mediators: the HbA1c levels, blood pressure, body mass index (BMI), and early diabetes complications. We obtained each subject's HbA1c value from blood spot assays, which were collected through the 2003 diabetes-specific mail survey. Participants' blood pressure was determined by their self-reported last systolic blood pressure reading (range 70-194) in 2003. The self-reported diastolic

blood pressure reading was not used because a number of studies have reported that an elevated systolic blood pressure is a significantly more accurate indicator of hypertension and the need for treatment than diastolic blood pressure, particularly in older adults (Kannel, 2000a, 2000b). BMI was calculated by dividing a subject's weight in kilograms by height in meters squared (both weight and height were measured as part of the 2002 HRS core survey) (range 15.2-58.4). Early complications of diabetes were assessed according to reports of the occurrence of four symptoms during the past 12 months in 2003, including fainting/dizziness, chest pain when resting, tingling/burning sensation in feet, and ankles or legs that swell. These symptoms were suggested in recent studies as good indicators of early detection of vascular and neuropathy complications of diabetes (Marshall & Flyvbjerg, 2006; Maser, Mitchell, Vinik, & Freeman, 2003; Vinik, 2003; Vinik & Vinik, 2003). Participants rated items on a 5-point Likert-type scale ranging from 1 (more than once a week) to 5 (never). A single score is generated for the four components by reversing the scores for each item, and then summing the reversed scores. A higher score indicates a worse status in early complications (range 1-20).

Behavioral Mediators. The behavioral mediators were measured in the 2003 diabetes-specific mail survey and included exercise, diet, medication adherence, and blood glucose self-monitoring. Participants in the survey were also asked if they participated in a specific physical activity during the past two weeks. Answers to the four activities (1= yes, 0= no, including walk for exercise, outdoor household chores, attending any regular exercise program, and doing vigorous exercise, such as like running/jogging, biking, tennis, aerobic dance, or hiking) were summed to obtain an overall exercise index (range 0-4). Diet, medication adherence, and blood glucose self-monitoring behaviors were rated on a 7-point scale according to how well the individual follows recommendations for diabetes care, from 1 (1 day) to 7 (7 days) a week. Diet

behavior was indicated by the average score of four items, including days the respondent followed a healthful eating plan, ate five or more servings of fruits and vegetables, ate high fat foods (score reversed), and ate two or more servings of snack or dessert (score reversed) (range 0-7). Medication adherence was indicated by the average score of the two questions: days taking recommended insulin/pills, and days taking all doses insulin/diabetes pills (range 0-7). Blood glucose self-monitoring behavior was indicated by a single item: days testing blood sugar as recommended (range 0-7).

Psychosocial Mediators. Among a wide array of psychosocial variables, perceived control, diabetes-specific self-efficacy, depressive symptoms, perceived diabetes-specific family support, and coping status were used to measure the psychosocial construct. Perceived control, an indicator focusing on expectancy beliefs for future events and referring to individuals' beliefs about who or what determines outcomes in their lives, was measured by the 7-item revised Perceived Control Questionnaire (e.g., I have little control over things) (Wallhagen & Lacson, 1999). Responses were recorded on a 5-point Likert-type response, ranging from strongly disagree to strongly agree. The alpha coefficient for this scale was .69 in this sample. An average score of the seven items was obtained, with higher scores representing greater levels of perceived control (range 0-5). Diabetes-specific self-efficacy was measured by three items assessing the person's belief in his or her ability to perform successfully tasks related to diabetes, including getting enough physical activity, handling feelings about diabetes, and maintaining lifestyle plans for diet (Bijl, Poelgeest-Eeltink, & Shortridge-Baggett, 1999). Responses were recorded on a 5-point scale, ranging from strongly disagree to strongly agree. The alpha coefficient for this scale was .73 in this sample. An average score of the three items was obtained to index self-efficacy, with higher scores indicating greater self-efficacy (range 0-5). We used the 8-item

Center for Epidemiologic Studies Depression Scale (CESD) (Radloff, 1977) to assess depressive symptoms. Participants indicated if, during the past two weeks, they felt a symptom or not. A summary CESD score is produced by summing the number of "yes" answers across the eight items: feeling depressed, happy, lonely, enjoying life, sad, life being an effort, not getting going, and getting restless sleep (where positive items are reverse-scored). The alpha coefficient for this scale was .81 in this sample. The "reversed CESD" used in the structural equation model indicated fewer depressive symptoms with higher scores (range 0-8). Perceived diabetes-specific family support, modified on the basis of Schafer's measure of supportive family behaviors (Schafer, McCaul, & Glasgow, 1986) is an 8-item scale. Respondents using a 5-point Likert-type response format (1=strongly disagree, 5=strongly agree) rate if they can count on their family or friends to help and support them with: meal planning, taking medication, foot care, physical activities, testing sugar, seeing the doctor, weight control, and feelings about their diabetes. The alpha coefficient for this scale was .96 in this sample. An average score of the eight items was obtained to index perceived support, with higher scores indicating greater amounts of support received (range 0-5). Coping status was indicated by a 10-item Problem Areas In Diabetes scale (Welch, Jacobson, & Polonsky, 1997), asking the participants their feelings on a wide array of diabetes situations (e.g., coping with complications, feeling overwhelmed by the diabetes regimen). A 5-point scale, ranging from not a problem to a serious problem, was used. Cronbach's alpha for this scale was .89. An average score of the ten items was obtained, with higher scores representing better coping status (range 0-5).

The dependent variable, physical disability, was measured with three indicators including the modified Katz Activities of Daily Living (ADL) scale (Katz et al., 1963), the Lawton Instrumental Activities of Daily Living (IADL) scale (Lawton & Brody, 1969), and Nagi

strengths and mobility activities (Nagi, 1964). These three measures were chosen to assess ability to perform a wide range of common activities of older persons. In general, the Katz (ADL) scale concerns the most basic personal self-maintenance tasks whereas the Lawton (IADL) and Nagi (strengths and mobility) items require greater physical activity. Participants were asked in 2004 if they needed help doing the tasks included on the ADL scale (bathing, dressing, eating, walking across a room, getting in/out of bed, and using a toilet independently), the IADL scale (preparing meals, shopping, managing money, using the telephone, and using map/ take public transportations independently), and the Nagi strengths and mobility activities (walking several blocks, climbing several flights of stairs, stooping/ kneeling/ or crouching, reaching above the head, and lifting or carrying weights over 10 pounds like a heavy bag of groceries). For each set of questions, a score corresponding to the number of items with disability was calculated. Thus, higher scores (a maximum of 6 for the ADL, 5 for the IADL, and 5 for the strengths and mobility) indicated greater physical disability, and a score of 0 indicated no disability.

Statistical Analysis

We used structural equation modeling (SEM) with latent variables to evaluate the mediational effects of biobehavioral and psychosocial factors in the gender-disability link. Advantages of SEM compared to multiple regression include more flexible assumptions (particularly allowing interpretation even in the face of multicollinearity), use of confirmatory factor analysis to reduce measurement error by having multiple indicators per latent variable, the ability to test models with multiple dependents, and the desirability of testing models overall rather than coefficients individually. In addition, the SEM examines the direct and indirect

effects of mediators on dependent variables while permitting the examination of inter-correlation or complex associations among multiple mediators. Hence, the unique (i.e., independent) and combined mediational relationship can be revealed.

Analyses proceeded in two stages. First, the Student's t-tests and Pearson's correlations were carried out with SAS 9.1. Student's t-tests were used to examine gender differences in selected biological, behavioral, and psychosocial measures as well as the physical disability variables. Those variables showing significant gender differences in the t-tests and indicating less favorable levels for women were considered as potential mediational indicators. We then examined the inter-correlation of the potential mediational indicators, as a prerequisite for proceeding with the SEM. Variables with significant inter-correlations with any indicators of physical function were modeled in the following SEM.

The second stage in the SEM was performed in LISREL 8.8 (Joreskog & Sorbom, 1999). To evaluate the model's goodness of fit, we presented the chi-square statistic and four measures of practical fit: normed fit index (NFI), RHO/non-normed fit index (NNFI), comparative fit indices (CFI), and root mean square error of approximation (RMSEA). These indices are in wide use and known to be relatively unaffected by sample size (J. C. Anderson & Gerbing, 1984; Marsh, Bajaj, & MacDonald, 1988). Values less than 0.05 for RMSEA, greater than 0.90 for other practical indices indicate the model fits the data reasonably well (Hu & Bentler, 1999; Marsh, Hau, & Wen, 2004). To handle missing data, the full information maximum likelihood (FIML) method (the default in LISREL 8.8) was used to obtain the correct parameter estimates and robust standard errors (Enders & Bandalos, 2001). In addition, following the procedure suggested by Graham and Hofer (Graham & Hofer, 2000), we used fit indices calculated in RHO.EXE, in which the analytic sample size was set to N'= N* (1- % of total missing) to yield

fit indices for the present study with incomplete data. This method is suggested to be much better than using the normal sample size (Enders & Peugh, 2004). In the present study, the N'=1,506 (1,619*(1-6.98%)). Following the principles described in Baron and Kenny (Baron & Kenny, 1986), the strength of each mediator in explaining the link between gender and functional health was determined by the proportion of the indirect effect in the total effect (i.e., $\beta_{indirect}/\beta_{total}$).

RESULTS

Gender Differences in Biological, Behavioral, and Psychosocial Mediators and Physical Disability

We conducted a series of t-tests to determine if men and women differed significantly in selected biological, behavioral, and psychosocial variables, as well as physical disability indicators. The means and standard deviations of these variables, as well as the bivariate test results of gender differences, are displayed in Table 4.1. As expected, women reported significantly higher limitations in ADLs, IADLs, and strength and mobility. Regarding the mediational variables, women showed less favorable levels on all the potential mediators, except for the diet and blood glucose self monitoring behaviors, in which women did better than men. Women had significantly higher HbA1c levels, blood pressure, BMI, and more frequent occurrence of early complications than did men. In addition, women reported significantly less frequent exercise behavior, and had lower scores than men on the factors of diabetes coping status, perceived control, self-efficacy and perceived family support, as well as higher scores on depressive symptoms. There were no significant gender differences in the medication adherence score. Thus, following criterion 1 of the Baron and Kenny's mediation guidelines (Baron & Kenny, 1986)—that the regression for the mediator onto the model predictor should be

significant—the three variables of diet, medication, and blood glucose self-monitoring behaviors were excluded from the subsequent analyses.

Intercorrelations for Model Indicators

Table 4.2 summarizes the correlation coefficients between the model indicators. As shown, all of the mediation variables (except for perceived diabetes-specific family support) were highly related to at least one of the three physical disability variables. The higher the values in the biological indicators (e.g., HbA1c, blood pressure, BMI, early complications), the higher the reported physical disability. On the other hand, the higher the scores on behavioral (e.g., exercise) or psychosocial well-being (e.g., coping, perceived control, self-efficacy), the lower the incidence of physical disability was observed. Following criterion 2 for Baron and Kenny's mediation guidelines (Baron & Kenny, 1986)—that the regression of the model outcome on the mediator should be significant—the diabetes-specific family support variable was excluded from the structural equation model.

Structural Equation Modeling

Given the results of the above analyses, a structural equation model with a four-measure biological latent factor, a single-measure latent behavioral factor, and a four-measure psychosocial factor as mediators in the relationship between gender and functional health was constructed (Figure 4.2). The fit of the initial hypothetical model was poor, as shown by the significant chi-square and other practical fit indices. The significant association between the measurement errors of self-efficacy and depressive symptoms, and ADLs and IADLs as

indicated by the modification indices, suggested that further testing with the two sets of correlated measurement errors might generate a model that fit the data better.

An interim structural equation model allowing associations between measurement errors of self-efficacy and depressive symptoms, and ADLs and IADLs is shown in Figure 4.3. The test of the measurement model revealed good loadings for the indicators on the latent variables, and the overall model had an acceptable fit (RMSEA=.05, NFI=.91, RHO=.89, CFI=.92), thus justifying the explanation of the proposed relations among the latent variables. This model showed that being a woman was positively associated with higher biological indicators (e.g, HbA1c, blood pressure, BMI, and early complications) and lower behavioral (i.e., exercise) and psychosocial status (e.g., perceived control, self-efficacy, reverse of depressive symptoms, and coping status). In addition, the higher biological indicators and lower behavioral status were related to greater levels of limitations in physical function. However, the lack of significant associations from psychosocial factors to physical function, and the non-significant residual direct effect from gender to physical function suggest that further testing of pathways that omit the estimate of residual direct path from gender to physical function (a complete mediation model) and modeling paths between the three distinct but correlated mediators might be warranted.

Based on the widely accepted notion that glycemic control is key to avoiding adverse health outcomes, we tested an alternative model with behavioral and psychosocial mediators preceding the biological mediators between the link of gender and limitations in physical function, omitting the residual direct path from gender to limitations in physical function (Figure 4.4). The model fit indices suggested the model fit the data well (RMSEA=.05, NFI=.91, RHO=.90, CFI=.9). In this model, the significant paths from psychosocial mediators to

biological mediators and, in turn, to limitations in physical function support our hypothesis that the mediation role of psychosocial mediators is through biological mediators. However, this is not the case for the behavioral mediators. This model suggests that the behavioral mediators, like the biological mediators, have a direct effect on physical function. The last possibility—that the effect of psychosocial factors works not only through the biological factors, but also through the behavioral factors—was tested in the next model.

As shown in Figure 4.5, the fit of the model was similar to that in the last model (RMSEA=.05, NFI=.91, RHO=.90, CFI=.93), but all the paths in the model were significant at the .05 level. Moreover, the model explained a substantial amount of the variance (63%) in physical disability at the 1-year follow-up. Thus this model was chosen as the final model. This final model suggests that the total effect of gender (1=men, 2=women) on physical disability is 0.18, and that its effect is completely explained by four paths: (1) Directly mediated by biological factors: gender→biological→ physical disability ($\beta_{indirect}$= .07*.76=.053); (2) Directly mediated by behavioral factors: gender→behavioral→ physical disability ($\beta_{indirect}$= -.18*-.07=.013); (3) Indirectly mediated by psychosocial factors by way of biological factors: gender→ psychosocial→ biological→ physical disability ($\beta_{indirect}$= -.18*-.81*.76=.110); and (4) Indirectly mediated by psychosocial factors by way of behavioral factors: gender→ psychosocial→ behavioral→ physical disability ($\beta_{indirect}$= -.18*.33*-.07=.004).

DISCUSSION

This study used prospective data to test the mediation effect of biobehavioral and psychosocial factors in the gender-physical disability link in a heterogeneous sample of U.S. middle-aged and older adults living with type 2 diabetes. Drawing on prior research and

empirical evidence in gender-related factors, several hypothesized models were tested. The final model provided a good fit to the data and the relative importance of various mediating factors for explaining observed gender differences in physical disability were illuminated in the study.

Our results add to the literature on gender differences in several biological, behavioral, and psychosocial factors. In accordance with previously published investigations, our study revealed that women had worse levels in diabetes-related biological indicators (Legato et al., 2006; Nilsson et al., 2004; Shalev et al., 2005; Tang et al., 2008; Wexler et al., 2005). Mean HbA1c levels, blood pressure, BMI, and occurrence of early complications were higher in women than in men. We also found gender differences in a number of psychosocial variables. The findings on perceived control and diabetes-specific family support are consistent with previous research indicating men express stronger perceptions of control and family support for diet (Brown et al., 2000). Similarly, the finding of gender differences in depressive symptoms is also consistent with the findings in Canadian and Italian studies showing higher depressive symptoms in women with diabetes than in their men counterparts (Gucciardi et al., 2008; Ponzo et al., 2006). Although previous findings indicate that women with type 2 diabetes reported more barriers to regimen adherence than did men (Glasgow et al., 1986), we found women did better than men in diet and blood glucose self-monitoring behaviors, and there is no gender difference in mediation adherence. The result of exercise behavior is in line with a previous investigation reporting lower exercise behavior in women than men with type 2 diabetes (Barrett et al., 2007).

Results of our final structural equation model indicate that although there were notable gender differences in biological, behavioral, and psychosocial variables, only biological and behavioral factors directly mediated the relationship between gender and physical disability in adults with type 2 diabetes. Gender had a significant direct impact on biological and behavioral

factors, which themselves influenced physical disability. In particular, women with type 2 diabetes had poorer levels in biological indicators and reported less frequent exercise behavior than did men. Poorer biological factors and less frequent exercise behavior were related to greater levels of physical disability. Net of any effects of psychosocial factors, the biological factors independently explained 29.4%, and the behavioral factors 7.2% of the total relationship between gender and physical disability (0.053/0.18 and 0.013/0.18, respectively).

Although we found no evidence that psychosocial well-being directly explained the gender differences in physical disability, it played an important role as an indirect mediator in the gender-physical disability relationship by way of its strong association with biological (r=-.81, *P*<.001) and behavioral (r=.33, *P*<.001) factors. The magnitude of the influence of psychocial well-being through biological factors is especially noticeable. Women reported poorer psychosocial well-being than did men overall, and their poorer psychosocial status was related to worsening biological indicators, which, in turn, were associated with subsequent higher levels of physical disability. This path explained 61.1% of the observed gender disparity in physical disability in adults with type 2 diabetes (0.110/0.18). The poorer psychosocial well-being in women was also associated with lower levels of exercise, and, in turn, to greater levels of physical disability. The path accounted for 2.2% of the gender-physical disability link (0.004/0.18).

The importance of our findings is magnified by the fact that although biological, behavioral and psychosocial factors have been shown to be inter-correlated with each other (Eriksson & Rosenqvist, 1993; Rose, Fliege, Hildebrandt, Schirop, & Klapp, 2002), there are several plausible pathways explaining their relationship; in particular, paths from psychosocial well-being to biological and behavioral factors were found in the present study. By constructing

latent variables and examining all possible paths, our study identified that higher psychosocial well-being is predictive of lower levels in biological indicators and more positive health behaviors, and the effects of psychosocial well-being on physical disability were completely explained by biological and behavioral factors.

In summary, using a large, community-based sample of middle-aged and older adults living with type 2 diabetes, the present study confirmed that women with type 2 diabetes tend to have less favorable levels of biological, psychosocial and behavior factors than do men. The biological and behavioral factors directly explained the gender differences in physical disability. Psychosocial factors, on the other hand, made an indirect contribution in the link for its high explanatory effects in the gender differences in biological and behavioral factors. In addition, the residual direct effect from gender to physical disability was not significant when these mediation variables were included in the model, suggesting these factors completely explained the observed gender differences in physical function in adults living with type 2 diabetes.

Limitations and Future Research

Three potential limitations of our study must be addressed. One limitation involves the use of self-report measures on some of our study variables, particularly self-reporting diabetes-specific health behaviors and blood pressure as well as weight for BMI. Although a previous study found that the validity of self-reported exercise behavior was high among older adults (Harada, Chiu, King, & Stewart, 2001), literature indicates that women's responses to dietary questionnaires may be influenced more powerfully by social desirability than those of men (Hebert et al., 2008; Hebert et al., 1997). Thus, our results in the behavioral aspects may be undermined by possible bias from the gender differential in social desirability. In addition,

although the validity of self-reported blood pressure and weight were acceptable as an epidemiologic tool (Bowman & DeLucia, 1992; Colditz et al., 1986), it may be preferable for future research to adopt a measurement approach that uses both self-report and objective measures in assessing biomarkers.

Second, the findings reported here relied on latent factors of biological, behavioral, and psychosocial variables. It is possible that some indicators within those latent factors explain the gender-physical disability link more than others. Future studies with separate models examining the biological, behavioral, or psychosocial mediators may disentangle the specific effects of each indicator and their association, providing more specific direction for practical intervention.

Third, although the findings of this study reveal the paths between the inter-correlated biological, behavioral, and psychosocial factors, they cannot provide strong evidence for the direction of the causal influence they exert on each other due to the cross-sectional measures for these mediation variables. For example, our model indicated that the behavioral factors were influenced by the psychosocial factors, and they were not predicted by biological factors, nor do they have any impact on the biological variables. Although the ascertained relationships are likely to reflect dominant associations, we suggest further research to address the causal sequence, using longitudinal data.

Implications for Practice

In addition to research considerations, the findings of this investigation have practical implications for health care professionals working with adults with type 2 diabetes. First, it should be emphasized that, in general, the longitudinal outcomes of functional health are largely affected by biological and behavioral factors. Both men and women with type 2 diabetes need to

be concerned in their daily lives with getting sufficient exercise and achieving lower HbA1c levels, blood pressure and BMI to prevent early complications and thus avoid developing limitations in their physical function.

Second, although psychosocial factors did not directly influence physical function, our findings indicate that psychosocial well-being—including perceived control, coping, self-efficacy, and depressive symptoms—largely explained the gender differences in the biological and behavioral (mainly exercise) factors. This finding underscores the importance of the role of psychosocial well-being, which appears to have been overlooked in the current diabetes guidelines. For that reason, it would be important for health care professionals to pay more attention to the psychosocial well-being of adults with type 2 diabetes, and to empower them to develop improved perceptions of diabetes control, coping and self-efficacy, and to reduce depressive symptoms.

Third, the results of the present study shed light on the need for health professionals involved with diabetes care to address the unique needs of men and women. For men with type 2 diabetes, the needs are to better integrate the diabetes self-care objectives of diet and blood glucose self-monitoring into their daily lives. For women with type 2 diabetes, methods to increase and strengthen their coping strategies, diabetes self-efficacy, perceived control, positive mood, and exercise behaviors may be important in decreasing their blood pressure, HbA1c levels, body weight and early complications.

Table 4.1 Descriptive Data and Gender Differences

Measure	Total sample	Men	Women	p
Biological				
HbA1c (4.8-15.5)	7.24± 1.40	7.16± 1.30	7.31± 1.49	.085
Blood pressure (70-194)	133.05± 15.83	131.95± 15.92	134.16± 15.69	.029
BMI (15.2-58.4)	30.09± 6.03	29.63± 5.02	30.49± 6.78	.004
Early complications (1-20)	7.37± 3.47	6.94± 3.24	7.75± 3.62	<.0001
Behavioral				
Exercise (0-4)	1.14± 0.98	1.39±1.01	0.93± 0.89	<.0001
Diet (1-7)	5.05± 1.22	4.93± 1.22	5.16± 1.21	.0002
Medication adherence (1-7)	6.67± 1.14	6.71± 1.01	6.64± 1.25	.329
Blood glucose self-monitoring (1-7)	5.12± 2.18	5.38± 2.24	5.64± 2.12	.027
Psychosocial				
Coping (1-5)	4.27± 0.75	4.36± 0.70	4.19± 0.79	<.0001
Perceived control (1-5)	3.47± 0.64	3.52± 0.64	3.43± 0.64	.006
Self-efficacy (1-5)	3.17± 0.75	3.77± 0.76	3.66± 0.74	.006
Perceived support (1-5)	3.84± 0.81	3.89± 0.78	3.81± 0.84	.038
Depressive symptoms (0-8)	1.73± 2.10	1.31± 1.86	2.07± 2.22	<.0001
Physical Disability				
ADL (0-6)	0.62± 1.31	0.51± 1.16	0.73± 1.42	.0006
IADL (0-5)	0.51± 1.04	0.38± 0.93	0.62± 1.12	<.0001
Strengths and mobility (0-5)	2.13± 1.63	1.85± 1.59	2.38± 1.62	<.0001

Note: values are Means ± SD

Table4.2 Correlation Matrix for Variables in Model (N=1,619)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 Gender [a]	-													
2 HbA1c	.05[a]	-												
3 Blood pressure	.07*	.13***	-											
4 BMI	.07**	.04	.04	-										
5 Early complications	.12***	.13***	.08*	.19***	-									
6 Exercise	-.23***	-.05 [a]	-.04	-.15***	-.21***	-								
7 Coping	-.11***	-.18***	-.08*	-.14***	-.37***	.10***	-							
8 Perceived control	-.07**	-.07*	-.09**	-.06*	-.28***	.26***	.34***	-						
9 Self-efficacy	-.07**	-.04	-.05	-.21***	-.29***	.29***	.35***	.33***	-					
10 Depressive symptoms	.18***	.13***	.08*	.09***	.31***	-.19***	-.32***	-.40***	-.18***	-				
11 Perceived support	-.05*	-.04	-.05	-.05*	-.08**	.07**	.20***	.14***	.38***	.09***	-			
12 ADL	.08**	-.003	.08*	.11***	.29***	-.21***	-.20***	-.31***	-.20***	-.29***	.02	-		
13 IADL	.16***	.01	.04	-.004	.25***	-.20***	-.19***	-.33***	-.15***	-.28***	.04	.64***	-	
14 Strength and mobility	.16***	.08**	.07*	.19***	.04***	-.26***	-.23***	-.34***	-.21***	-.37***	.04	.49***	.39***	-

[a] 1=Men, 2=Women

*Denotes significance at the .05 level; ** Denote significance at the .01 level; *** Denote significant at the <.001 level

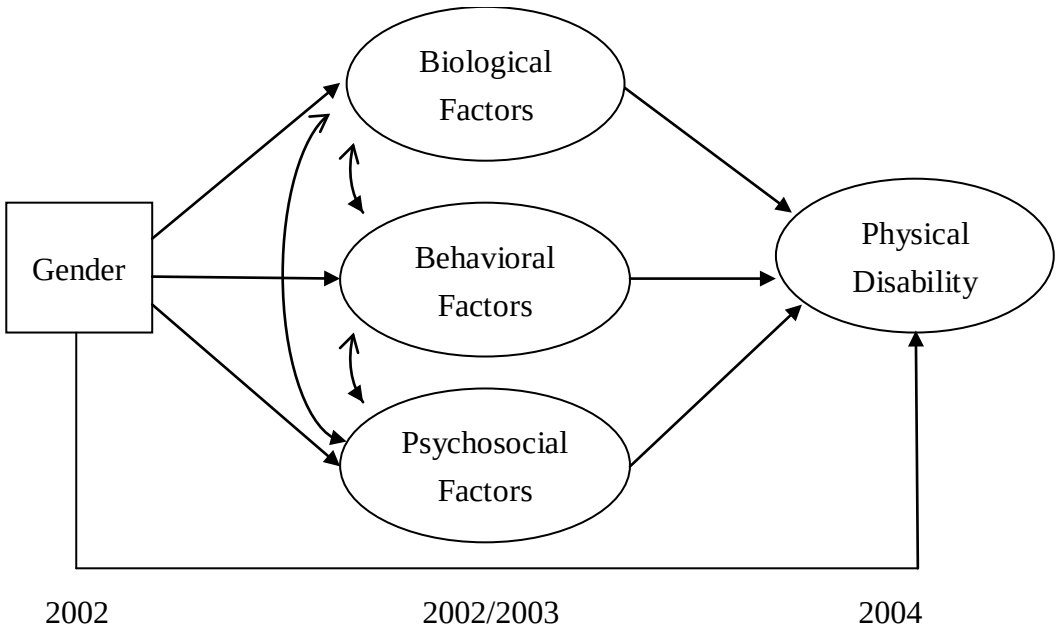

Figure 4.1 Hypothesized Model

Notes: Gender differences in physical disability observed in adults living with type 2 diabetes can be explained by inter-correlated biological, behavioral, and psychosocial factors.

x^2=531.34 (57), p=<.001
RMSEA=.07
NFI=.86
RHO=.82
CFI=.87

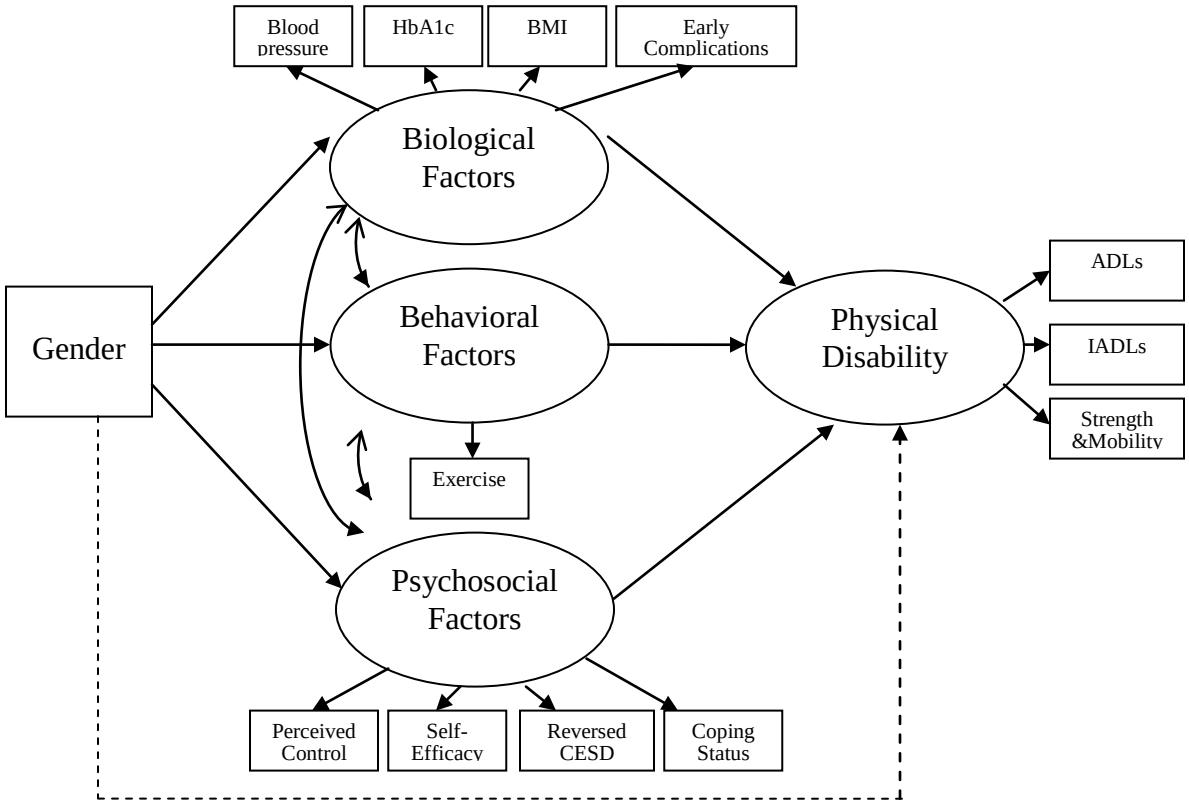

Figure 4.2 Initial Structural Equation Model

Notes: The indicators for each latent factor were based on gender-related variables found in the bivariate tests. All measurement errors were not correlated.

x^2=325.64 (55), p=<.001
RMSEA=.05
NFI=.91
RHO=.89
CFI=.92

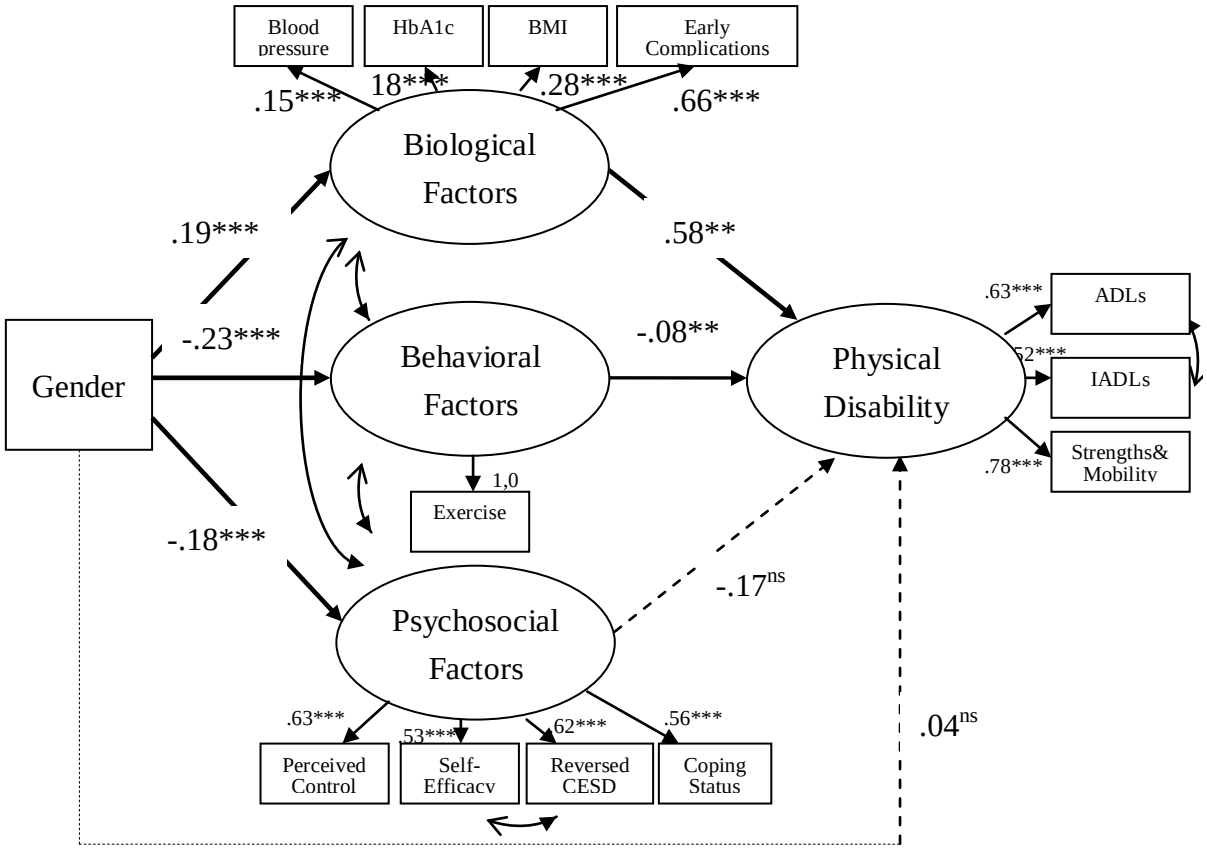

Figure 4.3 Interim Structural Equation Model

Notes: Correlations between measurement errors of self-efficacy and the reversed CESD, and between ADLs and IADLs, were estimated.

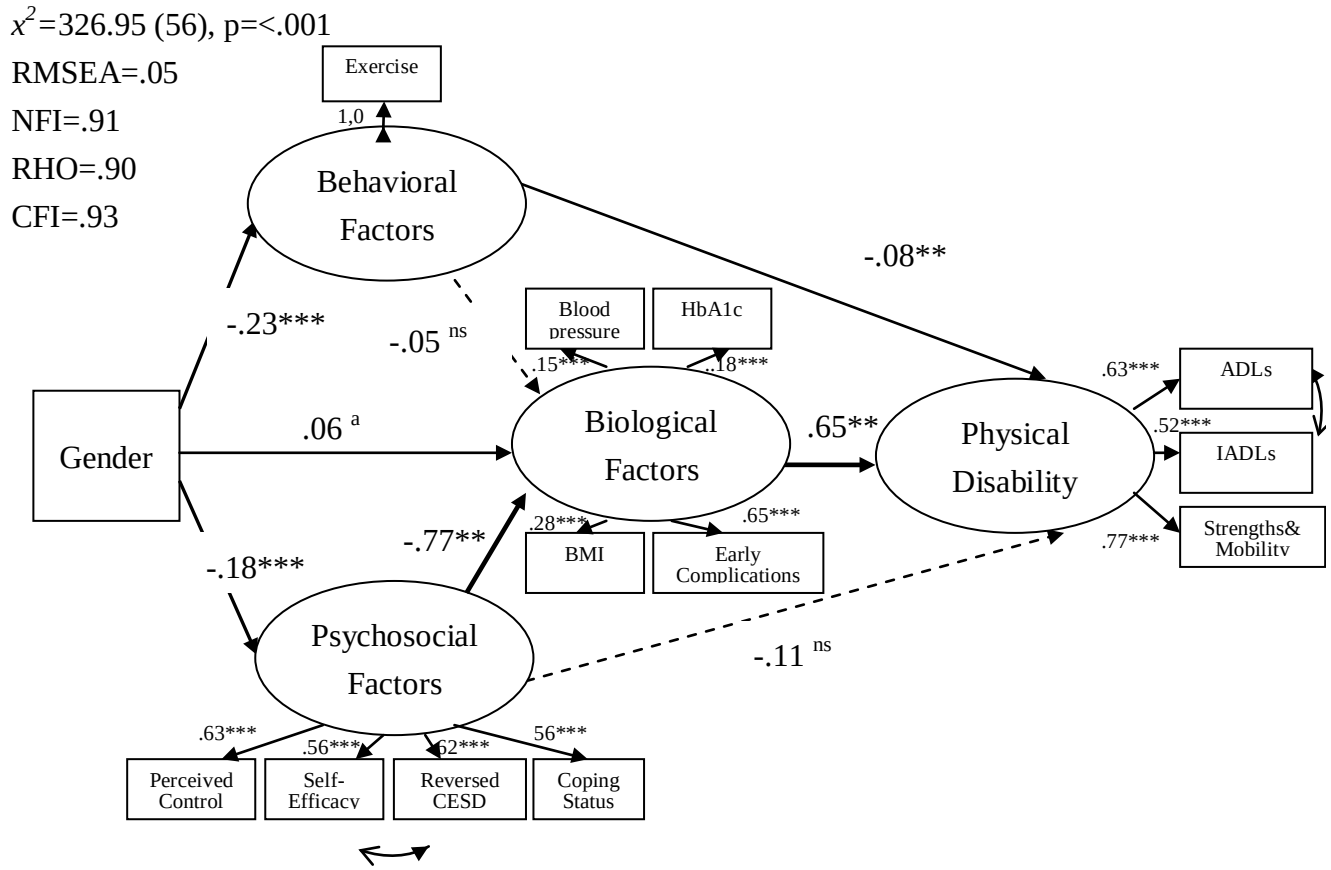

Figure 4.4 Interim Structural Equation Model (2)

Notes: The behavioral and psychosocial factors precede biological factors.
[a]: marginal significance t=1.74

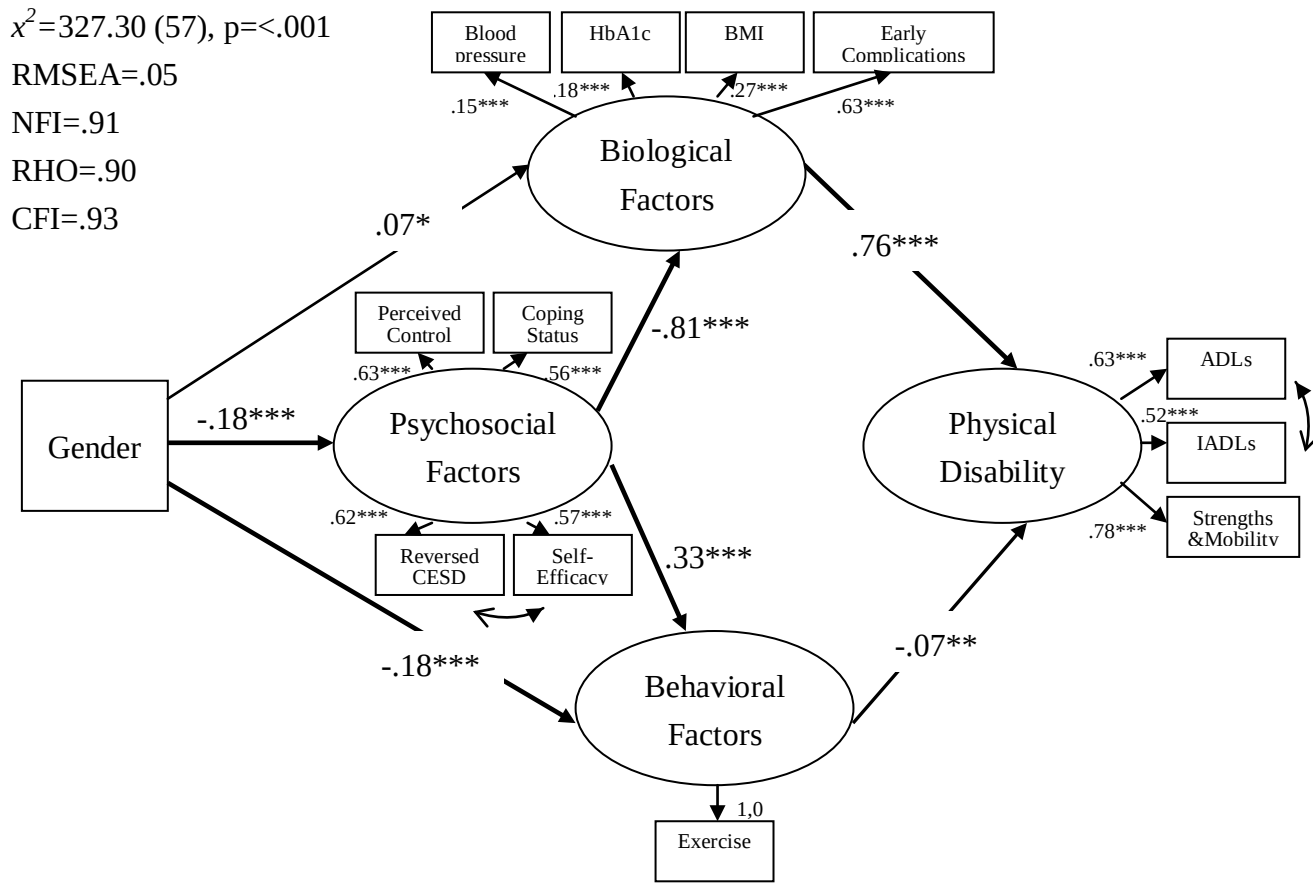

Figure 4.5 Final Structural Equation Model

Notes: The psychosocial mediator precedes the behavioral and psychosocial mediators.
Path 1: gender→biological→physical disability ($\beta_{indirect}$= .07*.76=.053)
Path 2: gender→behavioral→physical disability ($\beta_{indirect}$= -.18*-.07=.013)
Path 3: gender→psychosocial→biological→physical disability ($\beta_{indirect}$= -.18*-.81*.76=.110)
Path 4: gender→psychosocial→behavioral→physical disability ($\beta_{indirect}$= -.18*.33*-.07=.004)

Chapter 5

MANUSCRIPT 3:

BMI Trajectories in U.S. Middle-aged and Older Adults Living with Diabetes and Link with Future Disability Trajectories

Abstract

BACKGROUND: Inconsistent findings regarding weight change patterns in adults with diabetes are reported in diabetes research. Few studies have explored how patterns of change in body weight relate to patterns of change in disability across time. **OBJECTIVES:** The present study aims to: (1) discern the distinct weight and disability trajectories experienced by middle-aged and older adults living with diabetes; (2) identify the proportion of each trajectory in the population; and (3) reveal how weight trajectories are associated with disability trajectories later in life. **METHODS:** Data on 1,064 adults aged 51-61 who self-reported having diabetes in the 1992 U.S. Health and Retirement Study (HRS) were analyzed using dual-trajectory models based on a group-based trajectory modeling approach. **RESULTS:** We identified four distinct trajectories of body weight change in adults with diabetes from midlife to older age (stable normal weight, 29.0%; stable overweight, 46.5%; loss and regain obese, 17.6%; and weight cumulating morbidly obese, 6.9%) and three disability trajectories (little or low increase, 34.6%; moderate increase, 45.4%; and chronic high, 20.1%). Individuals in the stable normal weight group had the highest propensity for little/low increase disability, and individuals in the weight cumulating morbidly obese group had the highest probability for chronic high disability. However, one in five adults (19%) in the stable normal weight group transitioned into chronic high disability, suggesting the complexity of diabetes control in those with relatively normal

weight. **CONCLUSIONS**: Various relationships among these two sets of trajectories were found. Importantly, the recommendations for weight control in adults with diabetes in order to prevent future disability are strongly supported in the present study.

INTRODUCTION

The problem of overweight or obesity in adults with diabetes is widely recognized. The prevalence of overweight and obesity is much higher in people with diabetes than in those without diabetes (Mokdad et al., 2001). According to the U.S. National Health and Nutrition Examination Survey (NHANES III), about 85.2% of individuals with diabetes are overweight or obese (Centers for Disease Control and Prevention., 2004). Obesity is also associated with worse blood glucose level and other cardiovascular risk control, as well as lower active life expectancy and premature mortality (Anderson, Kendall, & Jenkins, 2003; Fontaine, Redden, Wang, Westfall, & Allison, 2003; Heo, Allison, Faith, Zhu, & Fontaine, 2003). Weight loss, on the other hand, can improve diabetes outcomes in adults who are overweight or obese (Anderson et al., 2003; Gregg, Gerzoff, Thompson, & Williamson, 2004; Lee & Aronne, 2007; Pi-Sunyer et al., 2007); thus, despite the acknowledged difficulties associated with losing weight and maintaining that weight loss, current clinical practice guidelines for diabetes (ADA., 2008) and diabetes researchers (Feldstein, Nichols, Smith, Stevens et al., 2008) continue to recommend weight loss as an important component of the treatment of overweight or obese patients with diabetes.

What percent of overweight or obese diabetes patients lose weight and maintain that loss over time? Research in both clinical and community settings has attempted to reveal the general weight change patterns in adults living with diabetes over time, yielding inconsistent findings.

For example, in the United Kingdom Prospective Diabetes Study (UKPDS), weight gain was seen in adults who participated in an intensive intervention and received at least some pharmacotherapies during the 10-year follow-up period, with the exception of individuals who were treated with metformin (U.K. Prospective Diabetes Study Group, 1998). Similarly, in an investigation of 205 men who attended a diabetes clinic in Minneapolis, increased body weight was observed for the group as a whole (0.23 kg/year) across a follow-up of a mean of 9.4 years (Chaudhry, Gannon, & Nuttall, 2006). Other evidence indicates, however, that a diagnosis of diabetes is linked with a greater probability of a 10-pound weight loss during 2 years of follow-up in relatively healthy, community-dwelling middle-aged adults (Wray, Blaum, Ofstedal, & Herzog, 2004), in both cross-sectional and longitudinal examinations of Pima Indians (Looker, Knowler, & Hanson, 2001), and in adults receiving structured individualized care over a 5-year follow-up period (de Fine Olivarius, Andreasen, Siersma, Richelsen, & Beck-Nielsen, 2006; Tuthill, McKenna, O'Shea, & McKenna, 2008).

These findings underscore the fact that the longitudinal course of body weight in middle-aged and older adults with diabetes exhibits not only intra-individual but inter-individual variation. Distinct subgroups of weight change trajectories may exist in middle-aged and older adults after a diagnosis of diabetes, with each subgroup composed of adults who share common patterns of stability or change over time. However, little research has examined group-level patterns of weight change longitudinally in middle-aged and older adults with diabetes. Only recently have researchers begun to examine more explicitly distinct weight trajectories in adults with diabetes (Feldstein, Nichols, Smith, Rosales, & Perrin, 2008; Feldstein, Nichols, Smith, Stevens et al., 2008). Their work has identified four classes of weight trajectories for adults after a diagnosis of diabetes: higher stable weight, lower stable weight, weight gain, and weight loss.

Despite this valuable information, their studies were limited by relatively short periods of follow-up (1 and 3 years, respectively), use of medical records rather than population-based data, raw body weight rather than BMI, and a relatively wide age range (21-75 years old), leaving many important questions unanswered.

To identify longitudinal weight patterns in community-dwelling adults living with diabetes, it is necessary to follow both demographically- and geographically-heterogeneous adults with diabetes for longer periods of time so that weight regain, which often occurs in adults with diabetes (Guare, Wing, & Grant, 1995), can be detected, and to control for aging effects which may lead to a propensity to gain or lose weight during longitudinal follow up (Baltrus, Lynch, Everson-Rose, Raghunathan, & Kaplan, 2005; Barone et al., 2006; Clarke, O'Malley, Johnston, & Schulenberg, 2008; Himes, 2004; Jenkins, Fultz, Fonda, & Wray, 2003; Wray et al., 2004). It is also important to narrow the age range of research subjects and to remedy the flaw of using simple body weight, which is easily complicated by an individual's body size and has no comparing references or link to risk of illness. Additionally, although prior studies have examined weight change as a predictor of mortality, glycemic control, or blood pressure in adults with diabetes (Feldstein, Nichols, Smith, Rosales et al., 2008; Feldstein, Nichols, Smith, Stevens et al., 2008; Russell-Jones & Khan, 2007), little research has incorporated physical function, one of the most relevant predictors of quality of life (Gregg et al., 2002), as a key outcome of those weight trajectories of adults with diabetes. The interacting relationship between changes in BMI and disability is much less known.

Modeling the relationship between multiple, discrete patterns of body weight and disability trajectories over time may also enhance findings from prior work, which have revealed considerable heterogeneity of physical function in adults with diabetes. Although higher average

levels and faster rates of deterioration in physical function have been found in adults with diabetes compared to those without in many studies (Bruce et al., 2003; Chiu & Wray, 2009; Gregg et al., 2002a, 2002b; Kuo et al., 2005; Sinclair et al., 2008; Wray, Ofstedal et al., 2005), one study found that nearly 40% of individuals with diabetes aged 70 or older were free of functional limitations (Blaum et al., 2003). Recognition that trajectories of longitudinal weight and disability patterns exhibit variation at both the individual and group levels highlights the importance of identifying not only the extent to which longitudinal patterns of body weight change are associated with disability, but also how weight control in adults with diabetes may be related to stability or improvement in physical function over time.

The current study examined trajectories of BMI and disability in a representative sample of U.S. adults age 51-61 who were living with diabetes. Kahng and colleagues found that although obesity was associated with more functional disability in cross-sectional analyses, change in BMI was not related to change in physical function in older adults over time (Kahng, Dunkle, & Jackson, 2004). We argue that the limitations in their analytic methods—including the simultaneous measure of BMI and disability—may have obscured the real (or lagged) association between change in BMI and change in disability. Thus, we use a dual trajectory model within a group-based trajectory modeling approach (i.e., latent class growth model [LCGM]) to evaluate 10-year weight trajectory patterns from 1992 to 2002 and the patterns' association with disability trajectories in years 10-14 (2002-2006). Three research questions were posed in the present study:

(1) What are the main patterns of weight and disability trajectories experienced by middle-aged and older adults living with diabetes?

(2) What is the proportion of each trajectory in the population?

(3) How are weight trajectories associated with disability trajectories later in life?

METHODS

Data and Sample

Data for this study are based on the Health and Retirement Study (HRS), an ongoing population-based panel study that has been conducted in the United States since 1992. The HRS represents a wide range of data on one of the largest contemporary nationally representative samples of middle-aged and older adults. Data collection was sponsored by the National Institute of Aging (NIA) and performed by the Survey Research Center of the Institute for Social Research at the University of Michigan. The HRS first interviewed 9,760 adults age 51-61 in 1992 (born 1931-1941) with oversampling of blacks, Hispanics, and Florida residents, by telephone or in-person. Follow-up interviews have been conducted every two years since to collect updated information on a variety of health, economic and family variables, with good response rates. Further details of the HRS mission and administration are described elsewhere (Burkhauser & Gertler, 1995; Juster & Suzman, 1995).

For this study, we drew the full sample of participants who self-reported that they had been told by a doctor they have diabetes or high blood sugar in the 1992 baseline interview (N=1,064). In the sample of 1,064 adults, only one respondent disputed in 1994 that he/she did not have diabetes in 1992; however, since that same respondent reported that he/she had diabetes in 1996, we felt confident that his/her diabetes status reported in 1992 was, in fact, valid. Thus, all of the adults self-reported they had diabetes in 1992 were included in our analytic sample. These adults had an average age of 56.0 years (S*D*=3.2) and were 46.7% men; 66.4% self-identified as Caucasian, 28.0% as African American, and 5.6 % as Hispanic or other. The

majority (73.2%) reported their level of schooling as high school or less, and 26.8% some college or above. Mean BMI at baseline was 30.2 (*SD*=6.5). Mean years after diagnosis of diabetes was 8.7 (*SD*=8.9); nearly one in ten (9.2%) reported they had just recently been diagnosed with the disease in 1992. Treatment types were 34.2% diet alone, 39.7% oral therapy, and 26.1% insulin therapy. More than two in three adults (68.5%) had been diagnosed with diabetes at age 45 or above.

A total of 559 participants had complete data on all study variables at the last measurement point (i.e., Wave 8 in 2006). Those who completed the 2006 interview did not differ statistically from those who did not complete that interview on race/ethnicity, education level, years after diagnosis of diabetes, and late or early onset diabetes. However, they were significantly younger (55.7 vs. 56.4 years of age), more women (56.3% vs. 49.9%), had a higher mean BMI (30.7 vs. 29.7), and reported they were treated with diet alone (39.9% vs. 27.9%), and had lower disability (2.43 vs. 3.50) at baseline, than did adults who did not complete the 2006 interview.

Measures

This study investigated the association between weight and physical disability. Body Mass Index (BMI), based on self-reported height and weight at each wave of data collection from 1992 to 2002, was used in the present study to capture weight change in the participants. Thus, up to six waves of BMI—calculated by dividing a subject's weight in kilograms by the square of height in meters—were obtained.

Physical disability was measured with the modified Katz Activities of Daily Living (ADL) scale (Katz et al., 1963), the Lawton Instrumental Activities of Daily Living (IADL) scale

(Lawton & Brody, 1969), and Nagi strength and mobility activities (Nagi, 1964). In general, the Katz (ADL) scale concerns the most basic personal care tasks whereas the Lawton (IADL) and Nagi (strength and mobility) items require greater physical activity. Participants in the HRS studies were asked at each wave if they had any difficulty performing a certain task, avoided it, or needed help or equipment for its performance from among ADLs (bathing, dressing, eating, walking across a room, getting in/out of bed, and using a toilet independently), IADLs (preparing meals, shopping, managing money, using the telephone, and using a map or taking public transportations independently), and strength and mobility activities (walking several blocks, climbing several flights of stairs, stooping/ kneeling/ or crouching, reaching above the head, and lifting or carrying weights over 10 pounds like a heavy bag of groceries) (1=yes, 0=no). The sixteen items were summed to obtain a physical function disability score, with higher scores indicating more severe limitations (range 0-16). This composite measure captures a broad range of physical disability from early or ‘‘preclinical’’ disability to later personal care disability (Fried et al., 1994; Langlois et al., 1996; Siu et al., 1990; Wang et al., 2007; Wray, Ofstedal et al., 2005). In addition, using the scoring of overall limitations in physical function, rather than the commonly used able-disabled scoring for each functional domain, has the advantages of capturing finer graduations in limitations in physical function (Mendes de Leon et al., 2002) and reducing the chance of ceiling or flooring effects (Wang et al., 2007). The average internal consistency of the sixteen items from all waves was .90.

Several sociodemographic, clinical, behavioral, and diabetes-related variables associated with weight or weight change (Ambrosius, Newman, & Pratt, 2001; French, Jeffery, Folsom, Williamson, & Byers, 1995; Jeffery, McGuire, & French, 2002) were examined at baseline and treated as covariates. Sociodemographic variables included age (centered at the grand mean),

gender (1=men, 0=women), race/ethnicity (0=White, 1=Black, 2=Hispanic), and education level (1=at least some college, 0=high school or less). Clinical conditions included dichotomous measures (1=yes, 0= never) of self-reported cancer, lung disease, heart attack, arthritis, kidney/bladder problem, psychiatric disorder, high cholesterol, stroke, and fracture/break bone after 45. Behavioral factors included exercise (1= 3 or more times a week, 2= one to two times a week, 3= one to three times a month, 4=less than once a month, 5= never), being a current smoker (1=yes, 0=no), and drinker (1=yes, 0=never). Diabetes-related factors included diabetes duration (i.e., years after diagnosis of diabetes), diabetes onset type (1=late onset diabetes, 0=age at diagnosis of diabetes earlier than 45), and diabetes treatment type (1=diet alone, 2=oral therapy, 3=insulin therapy).

Statistical Analysis

Given our interest in detecting heterogeneity in the pattern of body weight and disability in middle-aged adults living with diabetes over time, we used a group-based semi-parametric mixture modeling approach (Nagin, 1999, 2005), also known as latent class growth model (LCGM) (Muthen & Muthen, 2000). This statistical technique for modeling trajectories is different from traditional latent growth curve modeling in that different from the latter which assumes all individuals belong to a single trajectory which varies continuously on a latent trait, the group-based method assumes a number of discrete classes, each having a specific intercept and slope. In additions, the proportion of the population belonging to each group can be estimated (Nagin & Tremblay, 2001).

The analysis proceeded in three steps. First, distinct classes (i.e., groups) of trajectories were identified separately for BMI and disability. Considering the distribution of BMI and

disability, a censored normal model was used for BMI, and a Poisson-based model to adjust for its non-normal distribution was used for disability. Following the suggestions of Jones and Nagin (2007), we selected the best fitting model, that is, the model with the optimal number of classes and shapes (e.g., linear, quadratic, cubic) of the growth trajectories, with the consideration of the maximum Bayesian Information Criterion (BIC) and the substantive importance of the groups (e.g., parsimony, group size, and standard errors).

In the second step, we examined the association between BMI trajectory groups and several sociodemographic, clinical, behavioral, and diabetes-related variables. Variables significantly associated with BMI trajectories were treated as covariates in the dual trajectory model tested in Step 3 so that the relationship of BMI and disability was not confounded with effects from these covariates.

Dual trajectory modeling (Jones & Nagin, 2007; Nagin & Tremblay, 2001), which linked conditional probabilities of membership across the trajectory groups, was employed in the third and final step. Specifically, we estimated the probability of membership in each of the classes for disability, conditional on membership in a given trajectory for body weight. In this step, we adjusted individual trajectories for empirically evident baseline covariates, as suggested in the second stage, to control for potential confounding effects. All the above models were performed by using the SAS TRAJ procedure in SAS Version 9.1 (SAS Institute, Cary, NC).

RESULTS

Trajectory Models for BMI and Disability

A four-group model best fit the data for middle-aged adults' longitudinal BMI during the 10-year follow-up. Figure 5.1 displays the form of each trajectory. The largest group of adults

(46.5% of the sample) comprised those who were consistently overweight across the 10 years, with a mean BMI of 29.6 kg/m^2 and without significant weight loss or weight gain detected throughout; this group was classified as "stable overweight." The second largest group (29.0% of the sample), classified as "stable normal weight," was characterized by a BMI of 24.1 kg/m^2 and their weights were largely maintained during the entire follow-up period. The "loss and regain obese" group (17.6% of the sample) began at a mean weight of 36.4 kg/m^2 , lost weight during the first 5 years to reach a mean of 35.4 kg/m^2 ($36.4-0.4*5+0.04*5^2=35.4$), and then regained weight in the second half of the period, ending with a mean weight near that measured at baseline. The remaining 6.9% of the sample demonstrated a linear increase in BMI over time ("weight cumulating morbidly obese"). This group of adults started off with a BMI of 43.2 kg/m^2 and gained weight at the rate of 0.2 kg/m^2 per year over the 10-year period.

A three-group model best fit the data for disability from 2002-2006. Figure 5.2 presents the trajectories of the three-group model, with each trajectory representing the mean number of physical limitations experienced by the participants assigned to that group. The two largest trajectory groups, which accounted for nearly 80% of the sample, were characterized by low or slightly increasing rates of disability ("little/low increase," 34.6%), or modest levels of disability following a pattern of rising disability over time ("moderate increase," 45.4%), respectively. The third group, which accounted for 20.1% of the sample, represented those adults with high levels of disability over the entire period ("chronic high").

Demographic, Health and Diabetes-related Variables in Association with BMI Trajectories

As shown in Table 5.1, the four weight trajectory groups were significantly different with respect to gender, race/ethnicity, heart attack, arthritis, kidney/bladder problem, psychiatric

disorder, exercise, diabetes duration, diabetes onset type, and antidiabetic treatment type. Compared to the other groups, the weight cumulating morbidly obese group had higher proportions of women ($p<.001$), members of minority groups ($p<.001$), and reports of heart attack ($p=.008$), arthritis ($p<.001$), kidney/bladder problem ($p=.005$), psychiatric disorder ($p<.001$), and use of insulin ($p<.001$) at baseline. The stable normal weight group comprised the lowest percent of individuals with late onset diabetes ($p=.001$) and were associated with longer duration of diabetes ($p<.001$). Since these variables may also affect physical function, they were treated as covariates in the dual trajectory model analyses.

Examining Membership in Disability Trajectory Groups as a Function of BMI Trajectory Group Membership

Table 5.2 reports results from analyses examining the conditional probabilities of membership in each disability trajectory group given membership in the BMI groups. Covariates which may link BMI and disability were controlled in this stage; as a result, independent associations of BMI and disability were captured in the analyses. Examination of the stable normal weight group showed that nearly half (49%) of the members of this group belonged to the little or low increase disability group, whereas one in three (32%) belonged to the moderate increase disability group, and one in five (19%) to the chronic high disability group. Nearly half (46%) of the stable overweight group was also in the moderate increase disability group, followed by 40% in the little or low increase disability group, with the remaining 14% experiencing chronic high disability. A substantial majority (64%) in the loss and regain obese group belonged to the moderate increase disability group, 26% in the chronic high disability group, and 9% in the little or low increase group. Finally, nearly all those in the weight

cumulating morbidly obese group belonged to either the chronic high disability group (51%) or the moderate increase disability group (48%); only 1% fell into the little or low increase disability group.

DISCUSSION

Previous work examining body weight in adults with diabetes has focused on the effects of diabetes medicine on short-term weight change, or tracing weight change in a specified clinical or community cohort. Furthermore, despite evidence suggesting that weight loss has a beneficial impact on glycemic control in adults with diabetes, very little research has evaluated the associations among different trajectories of weight and disability across multiple time periods. The present study examined intra-individually and inter-individually a 10-year BMI record in a U.S. nationally representative cohort of 51-61 year-old adults with diabetes and their disability during the 10th to 14th follow-up and revealed several important findings.

First, our examination of six biennially measures of BMI data over a 10-year period reveals that the majority (75.5%) of adults with diabetes from age 51-61 to age 61-71 did not change their weight. This result is consistent with past research indicating that 76.1% of adults who received a new diagnosis of type 2 diabetes maintained a stable weight in kilograms over the 3-year follow-up period (Feldstein, Nichols, Smith, Stevens et al., 2008). The current study also extends the previous understanding by providing evidence that the probability of stable weight maintenance in adults with diabetes over ten years is highest among those who were initially of normal weight (29.0%) or overweight (46.5%).

Second, results from the present study highlight the challenges of both losing and regaining weight in obese adults as well as accumulating weight in morbidly obese adults, two

groups that account for one in four (24.5%) adults living with diabetes. Similar to studies of weight management programs for adults with diabetes (Guare et al., 1995; Hensrud, 2001) that demonstrate that weight regain was common during a 1-year follow-up period, we found that weight loss and regain was also common in the general adult diabetes population over a longer period of time. Approximately one of six middle-aged adults with diabetes in our sample experienced the weight loss and regain pattern during the 10-year period. In the UKPDS, weight gain was higher in patients who were already more than 120% of their ideal body weight (U.K. Prospective Diabetes Study Group, 1998). Our results are in line with the finding that individuals whose BMI was over 40 at baseline (6.9%) tended to experience a pattern of weight accumulation, instead of weight loss, during a 10-year follow-up. In addition, we found that there was a higher proportion of individuals using insulin in this group than in other weight trajectory groups, a finding that supports previous research linking insulin use and weight accumulation (Chaudhry et al., 2006; Russell-Jones & Khan, 2007).

In addition, as prior studies have pointed out that anti-hyperglycemic therapies (Chaudhry et al., 2006; de Fine Olivarius et al., 2006; Nichols, Hillier, & Brown, 2007), duration of diabetes (Looker et al., 2001), and gender (Tuthill et al., 2008) may have a substantial effect on weight change, results from the present study support and extend previous findings. In particular, this study found that different weight trajectory groups were significantly different not only by treatment type, duration of diabetes, and gender, but also by race/ethnicity, diabetes onset type, and the occurrence of heart attack, arthritis, kidney/bladder problem, psychiatric disorder, as well as frequency of exercise. The weight cumulating morbidly obese group had a higher proportion of women, members of minority groups, and comorbid health conditions (heart attack, arthritis, kidney/bladder problem, psychiatric disorder), as well as insulin treatment type than did other

groups. In contrast, the stable normal weight group comprised a relatively high percentage of adults with a longer duration of diabetes.

Further, analyses of the conditional probabilities of belonging to the disability trajectory groups given membership in the various BMI trajectory groups, controlling for the aforementioned weight change associated covariates, provide conservative estimates of effects of longitudinal weight change on future disability. Results indicate that individuals in the stable normal weight group have the highest propensity to go into the group of little or low increase disability. Conversely, individuals in the weight cumulating morbidly obese group were most likely to be in the chronic high disability group. This set of results is in line with the findings from previous work that in general, optimizing weight in normal BMI range may serve a protective function and guard against a pattern of progressive functioning disability, supporting general diabetes guidelines (ADA, 2008).

Nevertheless, despite the fact that the majority of members in the stable normal weight group also had the highest probability of being in the little or low increase disability group, nearly one in five adults in the stable normal weight group progressed into chronic high disability, a higher proportion than for those in the stable overweight. Three possible reasons may explain the link between stable normal weight and chronic high disability. First, stable normal weight may actually mask disease burden: Previous studies have shown that normal or low BMI, and especially in older adults, may be associated with greater disease burden (Sairenchi et al., 2008), which, in turn, may lead to moderate or higher levels of disability. Another possible reason for the finding, based on studies linking diabetes medication to weight gain (Purnell et al., 1998; Russell-Jones & Khan, 2007), is that differential adherence to medication could be a source of body weight change. Specifically, maybe people who don’t gain

weight are the ones who are not adhering to diabetic medications. Third, for some individuals, such as older persons with long diabetes duration, increase in weight, as opposed to loss of weight, could be a better indicator for diabetes control (Jacob, Salinas, Adams-Huet, & Raskin, 2007; Shoff, Klein, Moss, Klein, & Cruickshanks, 1998; Zamboni et al., 2005).

Surprising results also emerged from the link between the stable overweight group and the little or low increase disability group—despite their longitudinal overweight pattern, 40% of these individuals with diabetes enjoyed little or no disability, only 9% lower than for those in the normal weight group. The association may be analogous to the "effects of life-threatening disease on behavioral change" which has been found in the link of heart attack and smoking cessation behavior (Wray, Herzog, Willis, & Wallace, 1998). For instance, overweight individuals may be more conscious about their health outcome and thus may pay more attention to health information and be willing to adopt a healthy lifestyle, resulting in maintenance of good physical function.

In summary, the findings in this study suggest that neither BMI nor disability in middle-aged and older adults with diabetes follows fixed patterns of change over time. Four distinct weight trajectories (table normal weight, 29.0%; stable overweight, 46.5%; loss and regain obese, 17.6%; and weight cumulating morbidly obese, 6.9%) and three disability trajectories (little or low increase, 34.6%; moderate increase, 45.4%; and chronic high, 20.1%) might best characterize long-term patterns of change in BMI and disability. In addition, although the beneficial impacts of optimizing weight in adults with diabetes and displaying disability later in life were supported in the present study, the evidence that there were various ways in which the two variables were linked further implies the possible value in tailoring treatments and interventions at the individual level for adults with diabetes to achieve long-term health.

Limitations of the Study

Three key limitations of the study should be addressed. First, as in all longitudinal studies, there was attrition in the sample over time. Although comparison of individuals who did and did not participate in all eight waves of the study revealed no significant differences in race/ethnicity, education level, years after diagnosis of diabetes, and late or early onset diabetes, those who did complete all eight waves were younger in age, more women, had higher mean BMI, and those who used diet alone to manage their diabetes, and reported lower disability. Thus, the results may not generalize to older men, those with lower mean BMI, users of more intensive diabetic therapies, or those who presented with higher disability at baseline.

Second, it should be noted that although BMI is a good indicator for evaluating weight by adjusting height and has practical implications for linking disease and risk, decreasing bone and muscle mass and increasing fatness around the abdominal area may not be captured by BMI in older age (Baumgartner, Stauber, McHugh, Koehler, & Garry, 1995). Because some studies have suggested that waist circumference may be a more effective measure of obesity for older adults (Molarius, Seidell, Visscher, & Hofman, 2000), future work examining weight and disability change might benefit from comparing the use of both anthropometric and self-report measures.

Third, although the link between BMI and future disability shown in the present study carefully controlled for sociodemographic (age, gender, race/ethnicity, education), clinical (cancer, lung disease, heart attack, arthritis, kidney problem, psychiatric disorder, high cholesterol, stroke, fracture), behavioral (exercise, smoke, drink), and diabetes-related (diabetes duration, diabetes onset type, diabetes treatment type) variables, other variables such as medication adherence and socioeconomic factors (e.g., income, wealth, and occupational status)

were not controlled in the present study. It is known that medication adherence is an important predictor for diabetes prognosis (Donnan, MacDonald, & Morris, 2002; Evans, Donnan, & Morris, 2002; Schectman, Nadkarni, & Voss, 2002) and that socioeconomic factors moderate many diseases and health outcomes (Alwin & Wray, 2005). Future research is encouraged to incorporate these variables.

Implications for Practice

Four important implications emerged from the present study. First, the results of the present study may inform the evaluation of middle-aged and older adults who are at risk of disability. The fact that, compared to overweight and obese groups, the normal weight group has the highest probability for little or no increase in disability in the 10-14th-year follow-up suggests that optimizing weight may help to alleviate future disability.

Second, findings from this study highlight the possible value in tailoring treatments and interventions at the individual level. The various ways in which patterns of longitudinal BMI trajectories are associated with disability trajectories later in life as ascertained in the present study suggests that although body weight is predictive of future disability, it is important to recognize that no one intervention will be uniformly effective across all individuals. Other factors such as nutrition, lifestyle behaviors, and other physical (e.g., disease burden) and psychological factors (e.g., depressive symptoms) should be taken into consideration when evaluating the needs of adults with diabetes.

Third, our results highlight the importance of developing creative strategies to improve long-term weight loss and weight maintenance in overweight or obese adults with diabetes. Of the adults in the study, 17.6% had lost weight, but eventually regained their weight to the

baseline level, thus leaving little beneficial weight loss impact on physical function. The reasons for the weight regain were not examined by the present study. Future studies are encouraged to reveal the mechanisms to follow up on this topic and current diabetes practitioners are encouraged to focus more attention on preventing weight regain in adults who have lost weight to ensure the beneficial impact of weight loss.

Fourth, the present study found that those who had morbid obese weight at baseline tend to follow a weight cumulating pattern during longitudinal follow-up. In addition, members of this BMI trajectory have a higher proportion reporting insulin use. Since obesity and weight gain are risk factors for diabetes prognosis, and insulin-associated weight gain in diabetes has long been identified (Russell-Jones & Khan, 2007), more focus should be placed on constructing coping strategies to counteract insulin-related weight gain, especially in obese adults with diabetes.

Table 5.1 Baseline Sociodemographic, Clinical, Behavioral and Diabetes-related Factors by BMI Trajectory Groups

	Stable normal weight	Stable overweight	Loss & regain obese	Weight cumulating morbid obese	*p*
n (%)	308 (29.0)	495 (46.5)	187 (17.6)	74 (6.9)	
Age (years)	56.1 ± 3.2	56.1 ± 3.2	55.7 ± 3.2	55.6 ± 3.4	.21
Women	50.2	48.8	58.8	81.6	<.001
Race/ethnicity					<.001
White	66.6	70.9	59.4	52.6	
Black	25.1	23.9	36.9	44.7	
Hispanic/others	8.4	5.2	3.7	2.6	
Education (at least some college)	27.8	27.9	23.0	25.0	.58
Cancer	8.4	6.6	4.8	9.2	.40
Lung disease (exclude asthma)	12.0	11.2	13.9	15.8	.59
Heart attack	25.4	21.9	27.8	39.5	.008
Arthritis	39.8	49.4	63.1	73.7	<.001
Kidney/bladder problem	21.1	15.7	25.1	29.0	.005
High cholesterol	29.4	29.3	26.7	38.2	.33
Ever had Stroke	9.7	6.8	4.8	7.9	.21
Fracture/break bone after 45	16.4	12.2	15.0	11.8	.35
Psychiatric disorder	13.7	14.7	9.6	28.9	<.001
Exercise	2.0 ± 1.4	2.3 ± 1.5	2.7 ± 1.7	2.7 ± 1.7	<.001
Diabetes duration	10.7± 10.4	7.8± 7.5	7.8± 7.6	8.8± 7.8	<.001
Late onset diabetes	59.9	73.5	69.3	67.6	.001
Treatment type					<.001
Diet alone	41.1	35.1	25.7	22.4	
Oral therapy	31.8	44.4	40.1	38.2	
Insulin therapy	27.1	20.5	34.2	39.5	

Note: Data are means ± SD or % unless otherwise indicated.
Source: Health and Retirement Study 1992-2002

Table 5.2 Probability of 2002-2006 Disability Group Membership Conditional on 1992-2002 BMI Group Membership, HRS 1992-2006

BMI Group	(I, S, C)	Disability Group (I, S)		
		Little or low increaser (0.8^{*}, 1.0^{a})	Moderate increaser (3.2^{***}, 1.1^{***})	Chronic high (8.8^{***}, 1.0^{ns})
Stable normal weight	(24.1^{***}, ------, ------)	$.49^{***}$	$.32^{***}$	$.19^{***}$
Stable overweight	(29.6^{***}, ------, ------)	$.40^{***}$	$.46^{***}$	$.14^{***}$
Loss and regain obese	(36.4^{***}, -0.4^{***}, 0.04^{**})	$.09^{**}$	$.64^{***}$	$.26^{***}$
Weight cumulating morbid obese	(43.2^{***}, 0.2^{**}, ------)	$.01^{a}$	$.48^{***}$	$.51^{***}$

Note: I=intercept; S=slope; C=curvature; * $p<.05$; ** $p<.01$; *** $p<.001$; --- not significant from zero ; [a] $p=.05$
Source: Health and Retirement Study 1992-2006

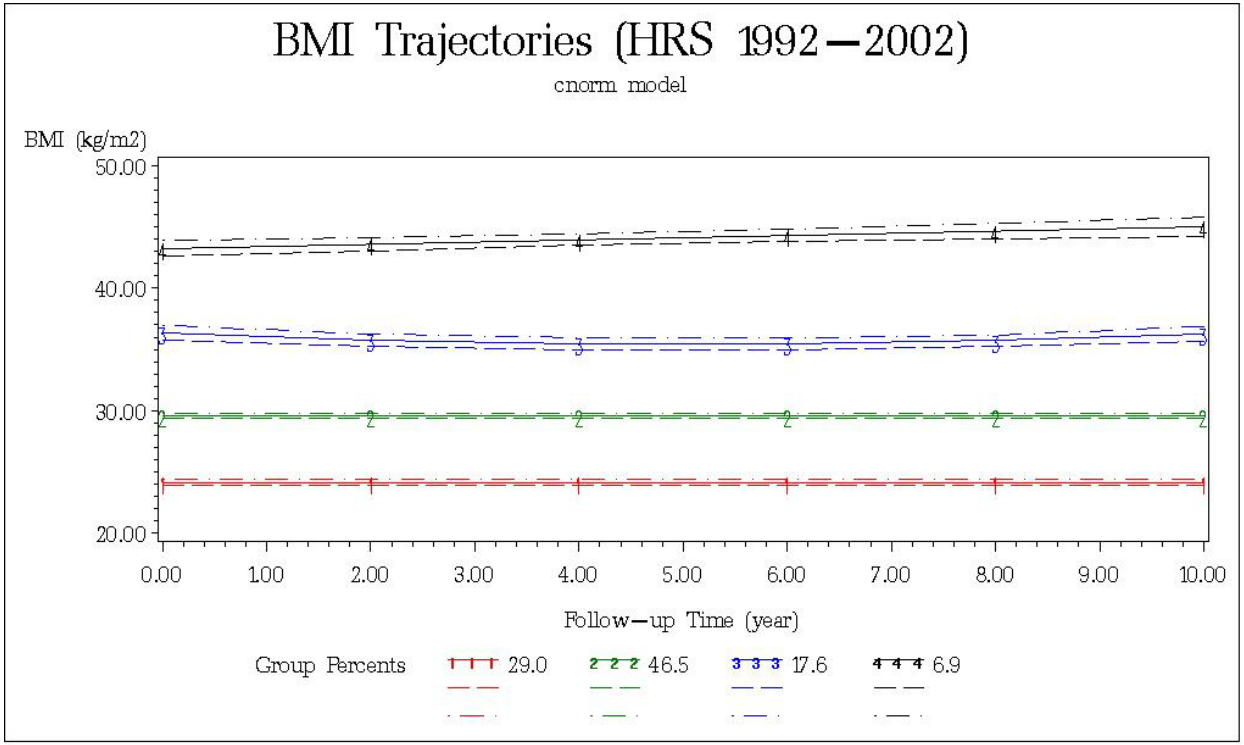

Figure 5.1 Ten-year BMI Trajectories in U.S. Middle-Aged Adults with Diabetes (HRS 1992-2002).
Note:
1. Participants were aged 51-61 at baseline.
2. The solid lines are the mean value of BMI for members in that class. Dashed lines represent 95% confidence intervals.

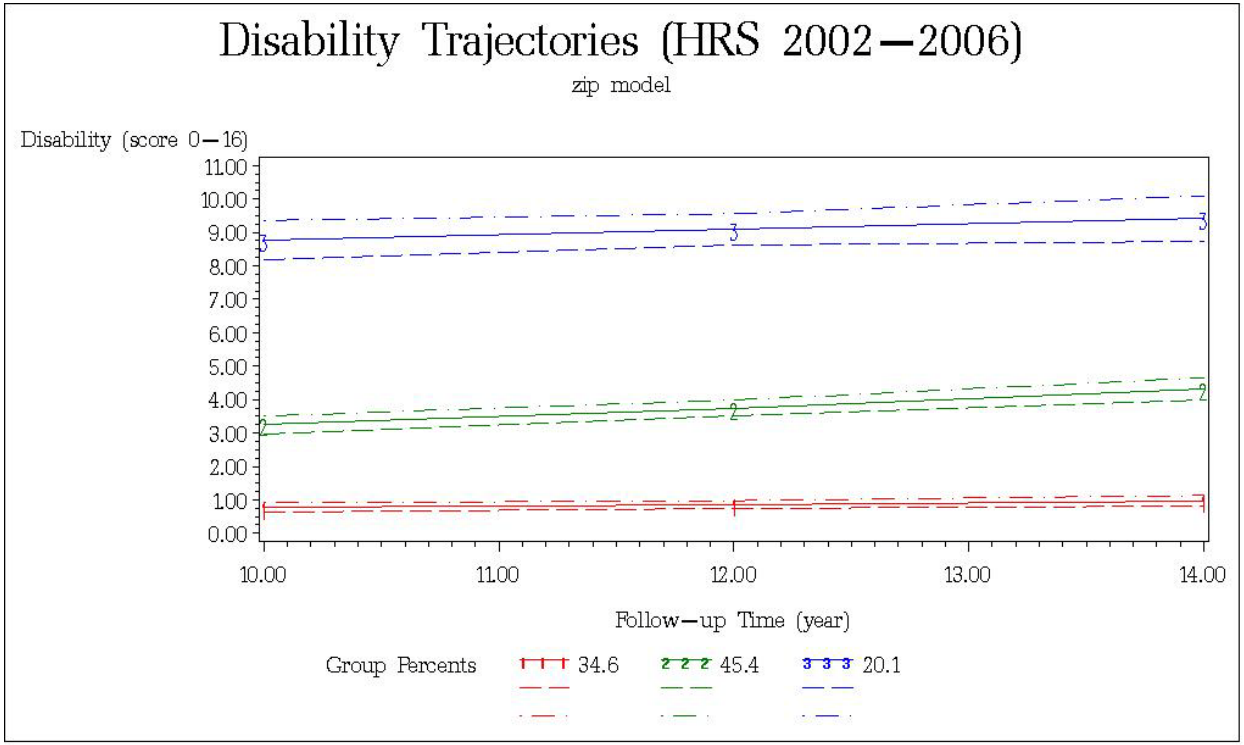

Figure 5.2 Disability Trajectories in U.S. Middle-Aged Adults with Diabetes during the 10th -14th Year Follow-up (HRS 2002-2006)

Note:

1. Participants were 51-61 years old at baseline.
2. The solid lines are the mean value of BMI for members in that class. Dashed lines represent 95% confidence interval

Chapter 6

DISCUSSION AND IMPLICATIONS

The impact of diabetes on physical function from midlife to older adulthood is intuitively important but not well defined (Gregg et al., 2002). As the number and proportion of older adults with diabetes grows within populations (Wild & Forouhi, 2007; Zimmet et al., 2001), there is an increasing need to understand the difficulties faced by these adults beyond the basic measure of mortality. The purpose of this thesis was to illuminate the impact of diabetes on physical function for adults after age 50. Unlike much of the extant literature on physical function in the oldest old (Romoren & Blekeseaune, 2003) or in the years before death (Covinsky et al., 2003), the studies described here were informed by the Life-Span Developmental (LSD) framework (Alwin & Wray, 2005) and focused instead on changes in physical function spanning from midlife to older age may provide a useful way to capture the burden of diabetes in contemporary middle-aged and older adults. Further, as suggested by the Mandala of Health Model (Hancock, 1985), the present investigations explored whether the physical function trajectories identified for adults with and without diabetes are predominantly the same for men and women, for adults with different education levels and racial/ethnic backgrounds, or for populations in different countries. In addition, the thesis also addressed the role of the potential mechanisms that may underlie these relationships, such as biobehavioral and psychosocial processes. In the following sections we summarize the key results from the three studies, the strengths and limitations of these studies, and the practical implications and future directions of this line of research.

Summary of Findings

The first study, entitled "Physical Disability Trajectories for Adults With and Without Diabetes from Midlife to Older Adulthood: A Cross-national Comparison between the U.S. and Taiwan," employed accelerated longitudinal design and multilevel modeling growth curve models to analyze data from the 1996–2003 Survey of Health and Living Status of the Elderly in Taiwan and 1998–2006 Health and Retirement Study (HRS) in the United States. This study examined the average forms of the physical function trajectories from midlife to older adulthood in two national samples of middle-aged and older adults, and focused on testing the independent effects of diabetes on the trajectories over time and whether these patterns are the same by gender, race/ethnicity, and education levels. Results from both the U.S. and Taiwan samples demonstrated that adults living with diabetes experienced more physical limitations and faster rates of change from midlife to older adulthood than did those without diabetes. This study also echoed the life-span development (LSD) perspective, as illustrated by Alwin and Wray (2005) suggesting that people of different ascribed (e.g., gender, race/ethnicity, age) and achieved social statuses (e.g., educational and other socioeconomic differences) may have different health outcomes: Women, those of lower education, and members of minority groups suffered more adverse impacts of diabetes than did men, those of higher education and White adults. In addition, corresponding to the Mandala of Health Model (MHM) (Hancock, 1985), the moderating effects of cultural differences on diabetes outcomes was also supported in the study. Compared to U.S. adults, Taiwanese adults increased disability levels more rapidly over time, and the impact of diabetes on their physical disability did not differ by sociodemographic background (e.g., gender, education and ethnicity) as it did in U.S. adults.

The second study, entitled "Gender Differences in Physical Disability in Adults Living with Type 2 Diabetes: BioBehavioral and Psychosocial Mediators," used data from the 2002 and 2004 HRS and its 2003 diabetes-specific mail survey to test if gender differences in physical disability can be attributed to biomarkers (blood pressure, BMI, HbA1c, and early complications), self-care behaviors (medication, blood sugar test, diet and exercise), or psychosocial well-being (perceived diabetes control, perceived diabetes-specific family/friends support, coping, and mood). Results in this study add to the literature on gender differences in biological, behavioral, and psychosocial factors. In accordance with previously published investigations (Brown et al., 2000; Gucciardi et al., 2008; Legato et al., 2006; Nilsson et al., 2004; Ponzo et al., 2006; Shalev et al., 2005; Tang et al., 2008; Wexler et al., 2005), this study revealed that women had worse levels in diabetes-related biological indicators (e,g., HbA1c levels, blood pressure, BMI, and occurrence of early complications), psychosocial well-being (e.g., perceived control, diabetes-specific family support, depressive symptoms) (Gucciardi et al., 2008; Ponzo et al., 2006), and exercise behavior (Barrett et al., 2007). In contrast to previous studies indicating that women with type 2 diabetes reported more barriers to regimen adherence than did men (Glasgow et al., 1986), we found women performed better than did men in diet and blood glucose self-monitoring behaviors and no gender difference in medication adherence. In addition, although there were notable gender differences in biological, behavioral, and psychosocial variables in this study, only biological and behavioral factors directly mediated the relationship between gender and disability in adults with type 2 diabetes. Psychosocial well-being, on the other hand, played an important role as an indirect mediator in the gender-disability relationship by way of its strong association with biological and behavioral factors. The complex relationships in among the gender-disability link revealed in the study underscores the

importance of biological and behavioral factors in diabetes control, and the highlighted the role of psychosocial well-being, a factor that is often overlooked in current diabetes guidelines.

The third study, entitled “BMI Trajectories in U.S. Middle-aged and Older Adults Living with Diabetes and Link with Future Disability Trajectories,” employed the group-based trajectory modeling approach (i.e., latent class growth analyses, LCGM) and HRS data to identify the distinct trajectories experienced by U.S. middle-aged adults living with diabetes and to reveal how those trajectories were shaped by body weight trajectories earlier in life. In particular, this study examined patterns of body mass index from 1992–2002 and their associations with disability patterns from 2002–2006 in 1,064 adults who self-reported diabetes in 1992. The results identified four distinct body weight trajectories (stable normal weight, 29.0%; stable overweight, 46.5%; loss and regain obese, 17.6%; and weight cumulating morbidly obese, 6.9%) and three disability trajectories (little or low increase, 34.6%; moderate increase, 45.4%; and chronic high, 20.1%) in the sample. Compared to previous studies looking at weight change in adults with diabetes, this study adds to other findings that the majority of adults with diabetes from age 51-61 to age 61-71 did not change their weight (Feldstein, Nichols, Smith, Stevens et al., 2008) and highlights the challenges of losing and regaining weight in obese adults (Guare et al., 1995; Hensrud, 2001) as well as weight accumulation patterns in morbidly obese adults (U.K. Prospective Diabetes Study Group, 1998). In addition, various relationships among these two sets of trajectories (i.e., body weight and disability) were found. Importantly, the recommendations for weight control in adults with diabetes in order to prevent future disability were strongly supported in the present study. However, 19% of adults in the stable normal weight group went into chronic high disability, suggesting the complexity of diabetes control among those of relatively normal weight.

In sum, the three studies in this thesis, which were designed to gain a better understanding and explicate the experiences of adults with diabetes in two large-scale population-based panel studies, documented the significant burden of diabetes on physical function. The results highlighted the heterogeneity in the population of adults living with diabetes and underscored the importance of taking a multidimensional approach to providing diabetes care. Such care should focus not only on encouraging control of relevant biological factors (e.g., HbA1c, blood pressure, body weight) and adoption of behavioral modifications (e.g., exercise), but also on enhancing psychosocial well-being (e.g., coping strategy, depressive symptoms, social support, and perceived diabetes control).

Practical Implications

The three studies in this thesis focusing on middle-aged and older adults with diabetes identified the burden of diabetes on physical function in middle-aged and older adults and underscored the heterogeneity in their experience and the opportunities that might mitigate the burden. From an applied point of view, several practical implications emerged from these studies.

Results from the first study, a cross-national comparison of aging populations in the U.S. and Taiwan, indicated that adults with diabetes have more physical limitations and endure greater rates of deterioration over time. These results point to the need for current diabetes care guidelines that focus not only on the prevention of traditional diabetes comorbidities, but also on preventing the negative impact of diabetes on physical function to ensure a higher quality of life for adults with diabetes. The consistent findings for the U.S. and Taiwan support the generalizability of concepts designed to prevent the negative impacts of diabetes on physical function for middle-aged and older adults across diverse cultural and geographic settings.

The finding in the first study that several high risk groups in the U.S. adults were more likely to experience greater levels and faster rates of change in disability also has important implications. Specifically, middle-aged women and adults with lower levels of education suffered more adverse impacts of diabetes than did men and those of higher education support the need to develop diabetes care that specifically targets the needs of women and adults with lower education in the U.S. Previous research has suggested that reasons for education on adverse health outcome may be explained by factors such as health literacy (Schillinger et al., 2006; Tang et al., 2008) and sense of personal control (Alwin & Wray, 2005). To reduce education-related disparities, it is important for diabetes care system to tailoring health education instruction, and design activities to promote sense of personal control in adults with diabetes, especially among those of lower education level.

With regard to the gender differences in physical disability, findings from the second study provided important practical implications. The study emphasized the importance of more targeted prevention and intervention initiatives in diabetes care to address the unique needs of men and women with diabetes in the U.S. For example, for men with type 2 diabetes, the needs are to better integrate diabetes self-care via diet and blood glucose self-monitoring into their daily lives. For women with type 2 diabetes, methods to increase their coping strategies, diabetes self-efficacy, perceived control, and exercise behaviors, as well as to decrease their depressive symptoms may be important in controlling their blood pressure, HbA1c levels, body weight and early complications, which in turn may mitigate future functional deterioration.

In addition, results from the second study, which identified the path of gender→ psychosocial →biological→ physical disability explaining nearly two-thirds (61.2%) of the gender differences in physical disability, underscore the role of psychosocial well-being in

affecting diabetes outcomes, which has often been overlooked in current diabetes guidelines. It is recommended in the present study that health care professionals should consider the psychosocial well-being of adults with type 2 diabetes, and work to enhance their perceived diabetes control, coping, self-efficacy, and positive mood to improve their diabetes management and, in turn, diabetes-related health outcomes, such as physical function.

Findings from the third study demonstrated variation in the relationship between physical function and body mass index for U.S. adults with diabetes. First, the result that overweight or obese groups are disproportionately represented in the follow-up chronic high disability group suggests that BMI is a predictive factor for future disability. Thus, evaluations of middle-aged adults with diabetes who are already at higher risk for disability may take weight into greater consideration in order to prevent more severe future disability. Second, although BMI predicts future disability, it is important to recognize that no one intervention will be uniformly effective across individuals. In other words, this study highlighted the possible value of tailoring treatments and interventions at the individual level. Other factors such as nutrition, lifestyle behaviors, and other physical and psychological disease burden should also be taken into consideration when evaluating the needs of adults with diabetes.

The third study also highlighted the importance of identifying creative strategies to foster long-term weight loss or weight maintenance in overweight or obese adults with diabetes, especially as they age (Sierra, Hadley, Suzman, & Hodes, 2008). Nearly one in five adults with diabetes (17.6%) lost weight from 1992–2002, but subsequently returned to their baseline levels and thereafter gained few of the health benefits of weight loss on physical function. The reasons for the weight regain were not explored in the present study. Future studies are encouraged to examine the mechanisms underlying and consequences of such weight gain, and current diabetes

practitioners are encouraged to discern more effective methods for preventing weight regain in adults who lost weight to reap health benefits.

In addition, the third study highlighted the challenges faced by diabetes care about the effect of diabetes medication on weight management, and in turn diabetes control. Specifically, using insulin as directed, might actually add to weight gain (Jacobson et al., 2007; Purnell et al., 1998; Russell-Jones & Khan, 2007), which could add disease burden, and in turn, further higher dose of insulin. The speculation was supported from result in the present study identifying that those who had morbid obese weight at baseline tend to follow a weight cumulating pattern during longitudinal follow-up. In addition, members of this BMI trajectory have a higher proportion reporting insulin use. Since obesity and weight gain are risk factors for diabetes prognosis, and insulin-associated weight gain in diabetes has long been identified (Russell-Jones & Khan, 2007), more focus should be placed on constructing coping strategies to counteract insulin-related weight gain, especially in obese adults with diabetes.

On the other hand, the third study also sheds light on the importance of more careful monitoring of medication adherence in normal weight adults with diabetes. It was found in our study that almost one in five adults with normal weight group went into chronic high disability. That proportion is higher than those in stable overweight to go to chronic high disability. Based on the link between medication and weight change (Jacobson et al., 2007; Purnell et al., 1998; Russell-Jones & Khan, 2007), it is possibility that people who don’t gain weight are the ones who are not adhering to medications, and therefore greater chronic high disability in person with stable normal weight than in stable overweight. The finding suggests that differential adherence to medication could be a source of body weight change and should be carefully evaluated in diabetes care.

Strengths and Limitations

Several of the methodological and research design aspects of these studies strengthened our ability to examine the link between diabetes and physical function as well as its complex mediators in middle-aged and older adults. A major strength was the quality analysis of the longitudinal population-based data. We know of no previous studies to utilize the accelerated longitudinal nature (cohort-sequential design) of the HRS and HLSES by linking adjacent and overlapping segments of available longitudinal data from different age cohorts to approximate a longer-term change, such as from midlife to older adulthood. This technique enables us to examine trajectories of functional health among adults aged 50–105 without having to follow adults currently aged 50 for 55 years.

The exploration of the dynamic relationship between diabetes and functional health is also unique and fills an empirical void in the literature. Few studies have examined whether diabetes shapes functional health trajectories, including levels of and rates of change from midlife to older age. By modeling age (longitudinal) and age cohort (cross-sectional) effects as major within-individual change in functional health over time, the study teased out effects confounded with natural aging processes and facilitated the simultaneous testing of cross-sectional and longitudinal relationships between diabetes and functional health. Specifically, the growth parameter of age provided longitudinal evidence of change in functional health; by connecting the intercept (medium age of each cohort) of each cohort, functional limitations in each 5-year lag of age were revealed with cross-sectional data.

Further, the study is unique in providing evidence based on two large national samples from eastern and western populations, which are seldom presented in one study. Not only do the heterogeneous samples in the two data sets allow us to report precise and accurate estimates, but

the investigation of individual differences in moderating the relationship between diabetes and functional health in two countries may also inform policy-relevant recommendations in diabetes care for both western and non-western countries.

Study limitations also warrant comment. First, the results shared the well-known limitations of research based on secondary data analysis. For example, although the validity of self-report diabetes was proven to be highly accurate in the U.S. (Goldman et al., 2003), the accuracy of self-reports of diabetes in eastern countries was not clear. In addition, a comparison of limitations in physical function in eastern and western countries may also confound with differential cultural tendencies to report difficulties. In the second study, although individual evaluation of diet, medication, and blood glucose self-monitoring behaviors were believed to be close to actual behavior, future research should adopt a measurement approach that uses both self-report and objective measures in measuring diabetes self-management behaviors. Similarly, although measure of body mass index using self-reported height and weight were found to be of high validity and were widely accepted for epidemiological analysis (Alwin, 2007; Bowman & DeLucia, 1992; Wallace & Herzog, 1995), potential cognitive deterioration, which is especially common in old age, may possibly bias the self-reported weight and height in the data.

Another limitation related to period and cohort effects. The study results reported here were based on middle-aged and older Americans and Taiwanese born in 1891–1947, 1898–1945 and their data during 1996–2003 in Taiwan and 1998–2006 in the U.S.; thus, it is not clear whether the results found here are generalizable to other, more recently born middle-aged and older adults. For example, contemporary older adults in Taiwan experienced tremendous social changes during the early 1900s compared to more recently born adults (Lin et al., 1989;

Thornton, Chang, & Sun, 1984), which may lead to differential relationships between sociodemographic backgrounds and diabetes-functional health outcomes.

In addition, although link between BMI and future disability shown in the third study was carefully controlled for sociodemographic (age, gender, race/ethnicity, education), clinical (cancer, lung disease, heart attack, arthritis, kidney problem, psychiatric disorder, high cholesterol, stroke, fracture), behavioral (exercise, smoke, drink), and diabetes-related (diabetes duration, diabetes onset type, diabetes treatment type) variables, medication adherence behavior, however, was not available in the data and was not controlled. It is known that medication adherence is an important predictor for diabetes prognosis (Donnan et al., 2002; Evans et al., 2002; Schectman et al., 2002), future research was encouraged to incorporate the variable.

Future Directions

As many researchers often note about their research findings, this investigation raised as many questions as it answered—a phenomenon that allows the field of study to progress and innovative ideas to develop. As such, two types of future directions are discussed here. First, a discussion of future directions for the questions raised by the present study is offered, followed by potential directions with regard to the data utilized in this thesis.

The first study revealed that differences in physical function for adults with and without diabetes were greater in adults with fewer years of education than in those with more education. Limited by the scope of this thesis, the mechanisms underlying educational differences were not known and thus should be addressed in future research. Further, while scoring overall limitations in physical function has the advantage of capturing finer gradations in limitations, the decision to aggregate the physical function items also limited our ability to identify which domain of

physical function was more sensitive to the effects of diabetes. Future studies are also encouraged to investigate each domain of functional health separately.

The second study relied on latent factors of biological, behavioral, and psychosocial variables. It is possible that some indicators within those latent factors explain the gender-physical disability link better than do others. Future studies with separate models examining biological, behavioral, or psychosocial mediators may disentangle the specific effects of each indicator and their association, thereby providing more specific directions for practical intervention. In addition, although the findings from the second study revealed the paths between the inter-correlated biological, behavioral, and psychosocial factors, they were not able to provide strong evidence for the direction of intra-causal influence due to the cross-sectional measures for these mediation variables. Further research should be conducted to address the causal sequence with longitudinal data.

The third study found that nearly one in five adults with diabetes lost weight during ten years of observation, but subsequently regained weight to their baseline levels. The reasons for the weight regain were not explored in this thesis. Future studies are encouraged to reveal the mechanisms underlying and consequences of such weight regain.

The data currently available from the core interviews of the Health and Retirement Study and the Survey of Health and Living Status of the Elderly in Taiwan offer many interesting future research possibilities. First, there would be great value in determining the effect of diabetes on other outcomes in both middle-aged and older adults, including depressive symptoms, progression to diabetes-related comorbidities, participation in engaged lifestyle behaviors, and cognitive function. In addition to studying outcomes, differential effects by lifestyle behaviors or disease self-management behaviors may also be explored.

In summary, recent advances in longitudinal modeling methodology are enabling researchers to investigate questions following a life-span developmental scheme, thereby adding innovative and informative information to the literature and practice. These types of investigations permit public health professionals and research scientists alike to better understand the pathways toward delineating the needs of the targeted population, such as the diabetes population, and toward developing interventions to help improve care for such groups.

Epilogue

Diabetes has become an increasingly common chronic disease that imposes great individual and social burdens in countries across the word, which makes efforts to understand both antecedents and consequences of the disease imperative. This thesis aimed to add important new information to that understanding. By using large empirical data sets in two countries and statistical methods which were developed for longitudinal data analyses, this thesis filled many gaps in the current literature which most often includes studies that are limited by small sample sizes and short-term follow-ups. Due to recent advances in statistical methods and increasingly available large datasets, a greater understanding of the links between diabetes and biobehavioral and psychosocial factors can be achieved by replicating the methods utilized in this thesis with different data sets, or cross-validating the findings in the same data sets with different statistical methods. It is also hoped that clinical researchers can design case-control experiments to further test the findings in this thesis.

REFERENCES

ADA (2008). Standards of medical care in diabetes--2008. *Diabetes Care, 31 Suppl 1*, S12-54.

ADA (2003). Standards of medical care for patients with diabetes mellitus. *Diabetes Care, 26 Suppl 1*, S33-50.

ADA (1997). Report of the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. *Diabetes Care, 20*(7), 1183-1197.

Albert, S. M., Alam, M., & Nizamuddin, M. (2005). Comparative study of functional limitation and disability in old age: Delhi and New York City. *J Cross Cult Gerontol, 20*(3), 231-241.

Alberti, K. G., & Zimmet, P. Z. (1998). Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus provisional report of a WHO consultation. *Diabet Med, 15*(7), 539-553.

Alwin, D. F. (2007). *Margins of Error: A Study of Reliability in Survey Measurement*. Hoboken, New Jersey: John Wiley & Sons, Inc.

Alwin, D. F., & Wray, L. A. (2005). A life-span developmental perspective on social status and health. *J Gerontol B Psychol Sci Soc Sci, 60 Spec No 2*, 7-14.

Ambrosius, W. T., Newman, S. A., & Pratt, J. H. (2001). Rates of change in measures of body size vary by ethnicity and gender. *Ethn Dis, 11*(2), 303-310.

Anderson, J. C., & Gerbing, D. W. (1984). The effect of sampling error on convergence, improper solutions, and goodness-of-fit indices for maximum likelihood confirmatiory factor analysis. *Psychometrika, 49*, 155-173.

Anderson, J. W., Kendall, C. W., & Jenkins, D. J. (2003). Importance of weight management in type 2 diabetes: review with meta-analysis of clinical studies. *J Am Coll Nutr, 22*(5), 331-339.

Anderson, R. J., Freedland, K. E., Clouse, R. E., & Lustman, P. J. (2001). The prevalence of comorbid depression in adults with diabetes: a meta-analysis. *Diabetes Care, 24*(6), 1069-1078.

Baltrus, P. T., Lynch, J. W., Everson-Rose, S., Raghunathan, T. E., & Kaplan, G. A. (2005). Race/ethnicity, life-course socioeconomic position, and body weight trajectories over 34 years: the Alameda County Study. *Am J Public Health, 95*(9), 1595-1601.

Barberger-Gateau, P., Rainville, C., Letenneur, L., & Dartigues, J. F. (2000). A hierarchical model of domains of disablement in the elderly: a longitudinal approach. *Disabil Rehabil, 22*(7), 308-317.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinciton in social psychological research: conceptual, strategic, and statistical considerations. *J Pers Soc Psychol, 51*, 1173-1182.

Barone, B. B., Clark, J. M., Wang, N. Y., Meoni, L. A., Klag, M. J., & Brancati, F. L. (2006). Lifetime weight patterns in male physicians: the effects of cohort and selective survival. *Obesity (Silver Spring), 14*(5), 902-908.

Barrett, J. E., Plotnikoff, R. C., Courneya, K. S., & Raine, K. D. (2007). Physical activity and type 2 diabetes: exploring the role of gender and income. *Diabetes Educ, 33*(1), 128-143.

Basit, A., Hydrie, M. Z., Hakeem, R., Ahmedani, M. Y., & Masood, Q. (2004). Frequency of chronic complications of type II diabetes. *J Coll Physicians Surg Pak, 14*(2), 79-83.

Baumgartner, R. N., Stauber, P. M., McHugh, D., Koehler, K. M., & Garry, P. J. (1995). Cross-sectional age differences in body composition in persons 60+ years of age. *J Gerontol A Biol Sci Med Sci, 50*(6), M307-316.

Beckett, L. A., Brock, D. B., Lemke, J. H., Mendes de Leon, C. F., Guralnik, J. M., Fillenbaum, G. G., et al. (1996). Analysis of change in self-reported physical function among older persons in four population studies. *Am J Epidemiol, 143*(8), 766-778.

Beckett, M., Goldman, N., Weinstein, M., Lin, I. F., & Chuang, Y. L. (2002). Social environment, life challenge, and health among the elderly in Taiwan. *Soc Sci Med, 55*(2), 191-209.

Beverly, E. A., Miller, C. K., & Wray, L. A. (2008). Spousal support and food-related behavior change in middle-aged and older adults living with type 2 diabetes. *Health Educ Behav, 35*(5), 707-720.

Bijl, J. V., Poelgeest-Eeltink, A. V., & Shortridge-Baggett, L. (1999). The psychometric properties of the diabetes management self-efficacy scale for patients with type 2 diabetes mellitus. *J Adv Nurs, 30*(2), 352-359.

Blaum, C. S., Ofstedal, M. B., Langa, K. M., & Wray, L. A. (2003). Functional status and health outcomes in older americans with diabetes mellitus. *J Am Geriatr Soc, 51*(6), 745-753.

Bowman, R. L., & DeLucia, J. L. (1992). Accuracy of self-reported weight: a meta-analysis. *Behavior Therapy, 23*, 637-655.

Boyd, C. M., Darer, J., Boult, C., Fried, L. P., Boult, L., & Wu, A. W. (2005). Clinical practice guidelines and quality of care for older patients with multiple comorbid diseases: implications for pay for performance. *JAMA, 294*(6), 716-724.

Boyle, J. P., Honeycutt, A. A., Narayan, K. M., Hoerger, T. J., Geiss, L. S., Chen, H., et al. (2001). Projection of diabetes burden through 2050: impact of changing demography and disease prevalence in the U.S. *Diabetes Care, 24*(11), 1936-1940.

Brown, A. F., Mangione, C. M., Saliba, D., & Sarkisian, C. A. (2003). Guidelines for improving the care of the older person with diabetes mellitus. *J Am Geriatr Soc, 51*(5 Suppl Guidelines), S265-280.

Brown, S. A., Harrist, R. B., Villagomez, E. T., Segura, M., Barton, S. A., & Hanis, C. L. (2000). Gender and treatment differences in knowledge, health beliefs, and metabolic control in Mexican Americans with type 2 diabetes. *Diabetes Educ, 26*(3), 425-438.

Bruce, D. G., Casey, G. P., Grange, V., Clarnette, R. C., Almeida, O. P., Foster, J. K., et al. (2003). Cognitive impairment, physical disability and depressive symptoms in older diabetic patients: the Fremantle Cognition in Diabetes Study. *Diabetes Res Clin Pract, 61*(1), 59-67.

Bryk, A. S., & Raudenbush, S. W. (1987). Application of Hierarchical Linear Modeling to Assessing Change. *Psychological Bulletin, 101*, 147-158.

Burkhauser, R. V., & Gertler, P. J. (1995). The Health and Retirement Study: data quality and early results. *Journal of Human Resources, 30*(supp), S1-S318.

Centers for Disease Control and Prevention. (2005). National diabetes fact sheet. *article online, Available from http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2005.pdf*.

Centers for Disease Control and Prevention. (2004). Prevalence of overweight and obesity among adults with diagnosed diabetes--United States, 1988-1994 and 1999-2002. *MMWR Morb Mortal Wkly Rep., 53*(45), 1066-1068.

Chang, C., Lu, F., Yang, Y. C., Wu, J. S., Wu, T. J., Chen, M. S., et al. (2000). Epidemiologic study of type 2 diabetes in Taiwan. *Diabetes Res Clin Pract, 50 Suppl 2*, S49-59.

Chaudhry, Z. W., Gannon, M. C., & Nuttall, F. Q. (2006). Stability of body weight in type 2 diabetes. *Diabetes Care, 29*(3), 493-497.

Chen, K. T., Chen, C. J., Gregg, E. W., Engelgau, M. M., & Narayan, K. M. (2001). Prevalence of type 2 diabetes mellitus in Taiwan: ethnic variation and risk factors. *Diabetes Res Clin Pract, 51*(1), 59-66.

Chen, K. T., Chen, C. J., Gregg, E. W., Williamson, D. F., & Narayan, K. M. (1999). High prevalence of impaired fasting glucose and type 2 diabetes mellitus in Penghu Islets, Taiwan: evidence of a rapidly emerging epidemic? *Diabetes Res Clin Pract, 44*(1), 59-69.

Chen, M. Y., James, K., & Wang, E. K. (2007). Comparison of health-promoting behavior between Taiwanese and American adolescents: a cross-sectional questionnaire survey. *Int J Nurs Stud, 44*(1), 59-69.

Cheng, S. H., & Chiang, T. L. (1997). The effect of universal health insurance on health care utilization in Taiwan. Results from a natural experiment. *JAMA, 278*(2), 89-93.

Cheng, S. H., & Chiang, T. L. (1997). The effect of universal health insurance on health care utilization in Taiwan: Results from a natural experiment. *Journal of the American Medical Association, 278*, 89-93.

Cheng, S. H., & Chiang, T. L. (1998). Disparity of medical care utilization among different health insurance schemes in Taiwan. *Soc Sci Med, 47*(5), 613-620.

Chia, L. R., Schlenk, E. A., & Dunbar-Jacob, J. (2006). Effect of personal and cultural beliefs on medication adherence in the elderly. *Drugs Aging, 23*(3), 191-202.

Chiu, C. J., & Wray, L. A. (2009). Does diabetes change functional health trajectory from midlife to older adulthood? Findings from U.S. and Taiwan national samples. *Dissertation*.

Chiu, C. J., Wray, L. A., Beverly, E. A., & Dominic, O. G. (2009, in press). The role of health behaviors in mediating the relationship between depressive symptoms and glycemic control in type 2 diabetes: a structural equation modeling approach. *Social Psychiatry and Psychiatric Epidemiology*.

Chou, K. L., & Chi, I. (2005). Functional disability related to diabetes mellitus in older Hong Kong Chinese adults. *Gerontology, 51*(5), 334-339.

Chuang, L. M., Tsai, S. T., Huang, B. Y., & Tai, T. Y. (2001). The current state of diabetes management in Taiwan. *Diabetes Res Clin Pract, 54 Suppl 1*, S55-65.

Clarke, P., O'Malley, P. M., Johnston, L. D., & Schulenberg, J. E. (2008). Social disparities in BMI trajectories across adulthood by gender, race/ethnicity and lifetime socio-economic position: 1986-2004. *Int J Epidemiol*.

Colagiuri, S., Borch-Johnsen, K., Glumer, C., & Vistisen, D. (2005). There really is an epidemic of type 2 diabetes. *Diabetologia, 48*(8), 1459-1463.

Colditz, G. A., Martin, P., Stampfer, M. J., Willett, W. C., Sampson, L., Rosner, B., et al. (1986). Validation of questionnaire information on risk factors and disease outcomes in a prospective cohort study of women. *Am J Epidemiol, 123*(5), 894-900.

Covinsky, K. E., Eng, C., Lui, L. Y., Sands, L. P., & Yaffe, K. (2003). The last 2 years of life: functional trajectories of frail older people. *J Am Geriatr Soc, 51*(4), 492-498.

Cowie, C. C., Rust, K. F., Byrd-Holt, D. D., Eberhardt, M. S., Flegal, K. M., Engelgau, M. M., et al. (2006). Prevalence of diabetes and impaired fasting glucose in adults in the U.S. population: National Health And Nutrition Examination Survey 1999-2002. *Diabetes Care, 29*(6), 1263-1268.

Crystal, S., & Shea, D. (1990). Cumulative advantage, cumulative disadvantage, and inequality among elderly people. *Gerontologist, 30*(4), 437-443.

Cummings, S. R., Nevitt, M. C., Browner, W. S., Stone, K., Fox, K. M., Ensrud, K. E., et al. (1995). Risk factors for hip fracture in white women. Study of Osteoporotic Fractures Research Group. *N Engl J Med, 332*(12), 767-773.

Dannefer, D. (2003). Cumulative advantage/disadvantage and the life course: cross-fertilizing age and social science theory. *J Gerontol B Psychol Sci Soc Sci, 58*(6), S327-337.

Davis, K., & Huang, A. T. (2008). Learning from Taiwan: experience with universal health insurance. *Ann Intern Med, 148*(4), 313-314.

de Fine Olivarius, N., Andreasen, A. H., Siersma, V., Richelsen, B., & Beck-Nielsen, H. (2006). Changes in patient weight and the impact of antidiabetic therapy during the first 5 years after diagnosis of diabetes mellitus. *Diabetologia, 49*(9), 2058-2067.

De Rekeneire, N., Resnick, H. E., Schwartz, A. V., Shorr, R. I., Kuller, L. H., Simonsick, E. M., et al. (2003). Diabetes is associated with subclinical functional limitation in nondisabled older individuals: the Health, Aging, and Body Composition study. *Diabetes Care, 26*(12), 3257-3263.

Deurenberg, P., Deurenberg-Yap, M., & Guricci, S. (2002). Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. *Obes Rev, 3*(3), 141-146.

Donnan, P. T., MacDonald, T. M., & Morris, A. D. (2002). Adherence to prescribed oral hypoglycaemic medication in a population of patients with Type 2 diabetes: a retrospective cohort study. *Diabet Med, 19*(4), 279-284.

Drevets, W. C., Price, J. L., Bardgett, M. E., Reich, T., Todd, R. D., & Raichle, M. E. (2002). Glucose metabolism in the amygdala in depression: relationship to diagnostic subtype and plasma cortisol levels. *Pharmacol Biochem Behav, 71*(3), 431-447.

Duncan, S. C., Duncan, T. E., & Hops, H. (1996). Analysis of longitudinal data within accelerated longitudinal designs. *Psychological Methods, 1*, 236-248.

Enders, C. K., & Bandalos, D. L. (2001). The relative performance of full information maximum likelihood estimation for missing data in structural equation models. *Structural Equation Modeling, 8*, 430-457.

Enders, C. K., & Peugh, J. L. (2004). Using an EM Covariance Matrix to Estimate Structural Equation Models With Missing Data: Choosing an Adjusted Sample Size to Improve the Accuracy of Inferences. *Structural Equation Modeling, 11*(2), 1-19.

Engelgau, M. M., Geiss, L. S., Saaddine, J. B., Boyle, J. P., Benjamin, S. M., Gregg, E. W., et al. (2004). The evolving diabetes burden in the United States. *Ann Intern Med, 140*(11), 945-950.

Eriksson, B. S., & Rosenqvist, U. (1993). Social support and glycemic control in non-insulin dependent diabetes mellitus patients: gender differences. *Women Health, 20*(4), 59-70.

Evans, J. M., Donnan, P. T., & Morris, A. D. (2002). Adherence to oral hypoglycaemic agents prior to insulin therapy in Type 2 diabetes. *Diabet Med, 19*(8), 685-688.

Feldstein, A. C., Nichols, G. A., Smith, D. H., Rosales, A. G., & Perrin, N. (2008). Weight change and glycemic control after diagnosis of type 2 diabetes. *J Gen Intern Med, 23*(9), 1339-1345.

Feldstein, A. C., Nichols, G. A., Smith, D. H., Stevens, V. J., Bachman, K., Rosales, A. G., et al. (2008). Weight change in diabetes and glycemic and blood pressure control. *Diabetes Care, 31*(10), 1960-1965.

Figaro, M. K., Kritchevsky, S. B., Resnick, H. E., Shorr, R. I., Butler, J., Shintani, A., et al. (2006). Diabetes, inflammation, and functional decline in older adults: findings from the Health, Aging and Body Composition (ABC) study. *Diabetes Care, 29*(9), 2039-2045.

Fisher, L., & Glasgow, R. E. (2007). A call for more effectively integrating behavioral and social science principles into comprehensive diabetes care. *Diabetes Care, 30*(10), 2746-2749.

Fitzgerald, J. T., Anderson, R. M., & Davis, W. K. (1995). Gender differences in diabetes attitudes and adherence. *Diabetes Educ, 21*(6), 523-529.

Fontaine, K. R., Redden, D. T., Wang, C., Westfall, A. O., & Allison, D. B. (2003). Years of life lost due to obesity. *JAMA, 289*(2), 187-193.

Freedman, V. A., Crimmins, E., Schoeni, R. F., Spillman, B. C., Aykan, H., Kramarow, E., et al. (2004). Resolving inconsistencies in trends in old-age disability: report from a technical working group. *Demography, 41*(3), 417-441.

French, S. A., Jeffery, R. W., Folsom, A. R., Williamson, D. F., & Byers, T. (1995). Weight variability in a population-based sample of older women: reliability and intercorrelation of measures. *Int J Obes Relat Metab Disord, 19*(1), 22-29.

Fried, L. P., Ettinger, W. H., Lind, B., Newman, A. B., & Gardin, J. (1994). Physical disability in older adults: a physiological approach. Cardiovascular Health Study Research Group. *J Clin Epidemiol, 47*(7), 747-760.

Fultz, N. H., Ofstedal, M. B., Herzog, A. R., & Wallace, R. B. (2003). Additive and interactive effects of comorbid physical and mental conditions on functional health. *J Aging Health, 15*(3), 465-481.

Gary, T. L., McGuire, M., McCauley, J., & Brancati, F. L. (2004). Racial comparisons of health care and glycemic control for African American and white diabetic adults in an urban managed care organization. *Dis Manag, 7*(1), 25-34.

Glasgow, R. E., McCaul, K. D., & Schafer, L. C. (1986). Barriers to regimen adherence among persons with insulin-dependent diabetes. *J Behav Med, 9*(1), 65-77.

Goldman, N., Lin, I. F., Weinstein, M., & Lin, Y. H. (2003). Evaluating the quality of self-reports of hypertension and diabetes. *J Clin Epidemiol, 56*(2), 148-154.

Gorman, B. K., & Read, J. G. (2006). Gender disparities in adult health: an examination of three measures of morbidity. *J Health Soc Behav, 47*(2), 95-110.

Graham, J. W., & Hofer, S. M. (2000). *Multiple imputation in multivariate research.* NJ: Erlbaum: Hillsdale.

Gregg, E. W., Beckles, G. L., Williamson, D. F., Leveille, S. G., Langlois, J. A., Engelgau, M. M., et al. (2000). Diabetes and physical disability among older U.S. adults. *Diabetes Care, 23*(9), 1272-1277.

Gregg, E. W., Engelgau, M. M., & Narayan, V. (2002). Complications of diabetes in elderly people: underappreciated problems include cognitive decline and physical disability. *British Medical Journal, 325*(7370), 916-917.

Gregg, E. W., Gerzoff, R. B., Thompson, T. J., & Williamson, D. F. (2004). Trying to lose weight, losing weight, and 9-year mortality in overweight U.S. adults with diabetes. *Diabetes Care, 27*(3), 657-662.

Gregg, E. W., Mangione, C. M., Cauley, J. A., Thompson, T. J., Schwartz, A. V., Ensrud, K. E., et al. (2002). Diabetes and incidence of functional disability in older women. *Diabetes Care, 25*(1), 61-67.

Gregg, E. W., Yaffe, K., Cauley, J. A., Rolka, D. B., Blackwell, T. L., Narayan, V., et al. (2000). Is diabetes associated with cognitive impairment and cognitive decline among older women? *Archives of Internal Medicine, 160*, 174-180.

Guare, J. C., Wing, R. R., & Grant, A. (1995). Comparison of obese NIDDM and nondiabetic women: short- and long-term weight loss. *Obes Res, 3*(4), 329-335.

Gucciardi, E., Wang, S. C., DeMelo, M., Amaral, L., & Stewart, D. E. (2008). Characteristics of men and women with diabetes: observations during patients' initial visit to a diabetes education centre. *Can Fam Physician, 54*(2), 219-227.

Hancock, T. (1985). The mandala of health: a model of the human ecosystem. *Fam Community Health, 8*(3), 1-10.

Harada, N. D., Chiu, V., King, A. C., & Stewart, A. L. (2001). An evaluation of three self-report physical activity instruments for older adults. *Med Sci Sports Exerc, 33*(6), 962-970.

Harris, M. I. (2001). Racial and ethnic differences in health care access and health outcomes for adults with type 2 diabetes. *Diabetes Care, 24*(3), 454-459.

Hebert, J. R., Hurley, T. G., Peterson, K. E., Resnicow, K., Thompson, F. E., Yaroch, A. L., et al. (2008). Social desirability trait influences on self-reported dietary measures among diverse participants in a multicenter multiple risk factor trial. *J Nutr, 138*(1), 226S-234S.

Hebert, J. R., Ma, Y., Clemow, L., Ockene, I. S., Saperia, G., Stanek, E. J., 3rd, et al. (1997). Gender differences in social desirability and social approval bias in dietary self-report. *Am J Epidemiol, 146*(12), 1046-1055.

Heisler, M., Faul, J. D., Hayward, R. A., Langa, K. M., Blaum, C., & Weir, D. (2007). Mechanisms for racial and ethnic disparities in glycemic control in middle-aged and older Americans in the Health and Retirement Study. *Arch Intern Med, 167*(17), 1853-1860.

Hensrud, D. D. (2001). Dietary treatment and long-term weight loss and maintenance in type 2 diabetes. *Obes Res, 9 Suppl 4*, 348S-353S.

Heo, M., Allison, D. B., Faith, M. S., Zhu, S., & Fontaine, K. R. (2003). Obesity and quality of life: mediating effects of pain and comorbidities. *Obes Res, 11*(2), 209-216.

Herd, P. (2006). Do functional health inequalities decrease in old age? Educational status and functional decline among the 1931-1941 birth cohort. *Research on Aging, 28*(3), 375-392.

Hertz, R. P., Unger, A. N., & Ferrario, C. M. (2006). Diabetes, hypertension, and dyslipidemia in Mexican Americans and non-Hispanic whites. *Am J Prev Med, 30*(2), 103-110.

Himes, C. L. (2004). Obesity in later life: An overview of the issues. *Research on Aging, 26*(1), 3-12.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indices in covariance structure analysis: Conventional versus new alternatives. *Structural Equation Modeling, 6*, 1-55.

Huang, E. S., Gorawara-Bhat, R., & Chin, M. H. (2004). Practical challenges of individualizing diabetes care in older patients. *Diabetes Educ, 30*(4), 558, 560, 562 passim.

Huxley, R., James, W. P., Barzi, F., Patel, J. V., Lear, S. A., Suriyawongpaisal, P., et al. (2008). Ethnic comparisons of the cross-sectional relationships between measures of body size with diabetes and hypertension. *Obes Rev, 9 Suppl 1*, 53-61.

International Diabetes Federation. (2000). Diabetes Atlas 2000. *Brussels, International Diabetes Federation*.

Jacob, A. N., Salinas, K., Adams-Huet, B., & Raskin, P. (2007). Weight gain in type 2 diabetes mellitus. *Diabetes Obes Metab, 9*(3), 386-393.

Jacobson, A. M., Musen, G., Ryan, C. M., Silvers, N., Cleary, P., Waberski, B., et al. (2007). Long-term effect of diabetes and its treatment on cognitive function. *N Engl J Med, 356*(18), 1842-1852.

Jeffery, R. W., McGuire, M. T., & French, S. A. (2002). Prevalence and correlates of large weight gains and losses. *Int J Obes Relat Metab Disord, 26*(7), 969-972.

Jenkins, K. R., Fultz, N. H., Fonda, S. J., & Wray, L. A. (2003). Patterns of body weight in middle-aged and older Americans, by gender and race, 1993-2000. *Soz Praventivmed, 48*(4), 257-268.

Jones, B. L., & Nagin, D. S. (2007). Advances in group-based trajectory modeling and an SAS procedure for estimating them. *Sociological Methods & Research, 35*(4), 542-571.

Joreskog, K. G. (1977). Structural equation models in the social sciences: Specification estimation and testing. In P. R. Krishnaiah (Ed.), *Applications of Statistics* (pp. 265-287). Amsterdam: North Holland.

Joreskog, K. G., & Sorbom, D. (1999). *LISREL 8: User's reference guide*. Lincolnwood, IL: Scientific Software International, Inc.

Joreskog, K. G., & Sorbom, D. (2001). *LISREL 8.5*. Chicago: Scientific Software International.

Juster, F. T., & Suzman, R. (1995). An overview of the Health and Retirement Study. *The Journal of Human Resources, 30*(Special Issue on the Health and Retirement Study: Data Quality and Early Results), S7-S56.

Jylha, M., Guralnik, J. M., Ferrucci, L., Jokela, J., & Heikkinen, E. (1998). Is self-rated health comparable across cultures and genders? *J Gerontol B Psychol Sci Soc Sci*, 53(3), S144-152.

Kahng, S. K., Dunkle, R. E., & Jackson, J. S. (2004). The relationship between the trajectory of body mass index and health trajectory among older adults. *Research on Aging, 26*(1), 31-61.

Kannel, W. B. (2000a). Elevated systolic blood pressure as a cardiovascular risk factor. *Am J Cardiol, 85*(2), 251-255.

Kannel, W. B. (2000b). Fifty years of Framingham Study contributions to understanding hypertension. *J Hum Hypertens, 14*(2), 83-90.

Katz, S., Ford, A. B., Moskowitz, R. W., Jackson, B. A., & Jaffe, M. W. (1963). Studies of illness in the aged. The index of ADL: A standardized measure of biological and psychosocial function. *JAMA, 185*, 914-919.

Kimbro, R. T., Bzostek, S., Goldman, N., & Rodriguez, G. (2008). Race, ethnicity, and the education gradient in health. *Health Aff (Millwood), 27*(2), 361-372.

King, H., Aubert, R. E., & Herman, W. H. (1998). Global burden of diabetes, 1995-2025: prevalence, numerical estimates, and projections. *Diabetes Care, 21*(9), 1414-1431.

Krieger, N. (2003). Genders, sexes, and health: what are the connections--and why does it matter? *Int J Epidemiol, 32*(4), 652-657.

Kuo, H. K., Jones, R. N., Milberg, W. P., Tennstedt, S., Talbot, L., Morris, J. N., et al. (2005). Effect of blood pressure and diabetes mellitus on cognitive and physical functions in older adults: A longitudinal analysis of the advanced cognitive training for independent and vital elderly cohort. *J Am Geriatr Soc, 53*(7), 1154-1161.

Lai, W. A., Chie, W. C., & Lew-Ting, C. Y. (2007). How diabetic patients' ideas of illness course affect non-adherent behaviour: a qualitative study. *Br J Gen Pract, 57*(537), 296-302.

Lai, W. A., Lew-Ting, C. Y., & Chie, W. C. (2005). How diabetic patients think about and manage their illness in Taiwan. *Diabet Med, 22*(3), 286-292.

Langlois, J. A., Maggi, S., Harris, T., Simonsick, E. M., Ferrucci, L., Pavan, M., et al. (1996). Self-report of difficulty in performing functional activities identifies a broad range of disability in old age. *J Am Geriatr Soc, 44*(12), 1421-1428.

Lawton, M. P., & Brody, E. (1969). Assessment of older people: Self-maintaining and Instrumental Activities of Daily Living. *The Gerontologist, 9*, 179-186.

Lee, M., & Aronne, L. J. (2007). Weight management for type 2 diabetes mellitus: Global cardiovascular risk reduction. *Am J Cardiol, 99*(4A), 68B-79B.

Legato, M. J., Gelzer, A., Goland, R., Ebner, S. A., Rajan, S., Villagra, V., et al. (2006). Gender-specific care of the patient with diabetes: Review and recommendations. *Gend Med, 3*(2), 131-158.

LeMaster, J. W., Chanetsa, F., Kapp, J. M., & Waterman, B. M. (2006). Racial disparities in diabetes-related preventive care: Results from the Missouri Behavioral Risk Factor Surveillance System. *Prev Chronic Dis, 3*(3), A86.

Li, L. W. (2005). Predictors of ADL disability trajectories among low-income frail elders in the community. *Research on Aging, 27*(6), 615-642.

Lin, T. Y., Chu, H. M., Rin, H., Hsu, C. C., Yeh, E. K., & Chen, C. C. (1989). Effects of social change on mental disorders in Taiwan: observations based on a 15-year follow-up survey of general populations in three communities. *Acta Psychiatr Scand Suppl, 348*, 11-33; discussion 167-178.

Looker, H. C., Knowler, W. C., & Hanson, R. L. (2001). Changes in BMI and weight before and after the development of type 2 diabetes. *Diabetes Care, 24*(11), 1917-1922.

Mainous, A. G., 3rd, Baker, R., Koopman, R. J., Saxena, S., Diaz, V. A., Everett, C. J., et al. (2007). Impact of the population at risk of diabetes on projections of diabetes burden in the United States: An epidemic on the way. *Diabetologia, 50*(5), 934-940.

Marsh, H. W., Bajaj, J. R., & MacDonald, R. P. (1988). Goodness-of-fit indexes in confirmatory factor analysis: The effect of sample size. *Psychological Bulletin, 103*, 391-410.

Marsh, H. W., Hau, K., & Wen, Z. (2004). In search of golden rules: Comment on hypothesis-testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's findings. *Structural Equation Modeling, 11*, 320-341.

Marshall, S. M., & Flyvbjerg, A. (2006). Prevention and early detection of vascular complications of diabetes. *BMJ, 333*(7566), 475-480.

Maser, R. E., Mitchell, B. D., Vinik, A. I., & Freeman, R. (2003). The association between cardiovascular autonomic neuropathy and mortality in individuals with diabetes: A meta-analysis. *Diabetes Care, 26*(6), 1895-1901.

Maty, S. C., Everson-Rose, S. A., Haan, M. N., Raghunathan, T. E., & Kaplan, G. A. (2005). Education, income, occupation, and the 34-year incidence (1965-99) of type 2 diabetes in the Alameda County Study. *Int J Epidemiol, 34*(6), 1274-1281.

McCollum, M., Hansen, L. B., Ghushchyan, V., & Sullivan, P. W. (2007). Inconsistent health perceptions for US women and men with diabetes. *J Womens Health (Larchmt), 16*(10), 1421-1428.

McCollum, M., Hansen, L. S., Lu, L., & Sullivan, P. W. (2005). Gender differences in diabetes mellitus and effects on self-care activity. *Gend Med, 2*(4), 246-254.

Mendes de Leon, C. F., Guralnik, J. M., & Bandeen-Roche, K. (2002). Short-term change in physical function and disability: The Women's Health and Aging Study. *J Gerontol B Psychol Sci Soc Sci, 57*(6), S355-365.

Merton, R. K. (1968). The Matthew effect in science. The reward and communication systems of science are considered. *Science, 159*(810), 56-63.

Miyazaki, Y., & Raudenbush, S. W. (2000). Tests for linkage of multiple cohorts in an accelerated longitudinal design. *Psychol Methods, 5*(1), 44-63.

Mokdad, A. H., Bowman, B. A., Ford, E. S., Vinicor, F., Marks, J. S., & Koplan, J. P. (2001). The continuing epidemics of obesity and diabetes in the United States. *JAMA, 286*(10), 1195-1200.

Molarius, A., Seidell, J. C., Visscher, T. L., & Hofman, A. (2000). Misclassification of high-risk older subjects using waist action levels established for young and middle-aged adults--results from the Rotterdam Study. *J Am Geriatr Soc, 48*(12), 1638-1645.

Muthen, B., & Muthen, L. K. (2000). Integrating person-centered and variable-centered analyses: Growth mixture modeling with latent trajectory classes. *Alcohol Clin Exp Res, 24*(6), 882-891.

Nagi, S. Z. (1964). A study in the evaluation of disability and rehabilitation potential: Concepts, methods, and procedures. *Am J Public Health Nations Health, 54*, 1568-1579.

Nagi, S. Z. (1969). Congruency in medical and self-assessment of disability. *IMS Ind Med Surg, 38*(3), 27-36.

Nagi, S. Z. (1976). An epidemiology of disability among adults in the United States. *Milbank Mem Fund Q Health Soc, 54*(4), 439-467.

Nagin, D. S. (1999). Analyzing developmental trajectories: a semiparametric group-based approach. *Pschol Methods, 4*, 139-157.

Nagin, D. S. (2005). *Group-Based Modeling of Development*. Harvard University Press, Cambridge, Massachusetts London, England: Cambridge.

Nagin, D. S., & Tremblay, R. E. (2001). Analyzing developmental trajectories of distinct but related behaviors: A group-based method. *Psychol Methods, 6*(1), 18-34.

Nakagami, T., Qiao, Q., Carstensen, B., Nhr-Hansen, C., Hu, G., Tuomilehto, J., et al. (2003). Age, body mass index and Type 2 diabetes-associations modified by ethnicity. *Diabetologia, 46*(8), 1063-1070.

Nichols, G. A., Hillier, T. A., & Brown, J. B. (2007). Progression from newly acquired impaired fasting glusose to type 2 diabetes. *Diabetes Care, 30*(2), 228-233.

Nilsson, P. M., Theobald, H., Journath, G., & Fritz, T. (2004). Gender differences in risk factor control and treatment profile in diabetes: A study in 229 Swedish primary health care centres. *Scand J Prim Health Care, 22*(1), 27-31.

Norris, S. L., Kansagara, D., Bougatsos, C., & Fu, R. (2008). Screening adults for type 2 diabetes: A review of the evidence for the U.S. Preventive Services Task Force. *Ann Intern Med, 148*(11), 855-868.

O'Rand, A. M. (1996). The precious and the precocious: Understanding cumulative disadvantage and cumulative advantage over the life course. *Gerontologist, 36*(2), 230-238.

Ofstedal, M. B., Zimmer, Z., Hermalin, A. I., Chan, A., Chuang, Y. L., Natividad, J., et al. (2007). Short-term trends in functional limitation and disability among older Asians: A comparison of five Asian settings. *J Cross Cult Gerontol, 22*(3), 243-261.

Ofstedal, M. B., Zimmer, Z. S., & Lin, H. S. (1999). A comparison of correlates of cognitive functioning in older persons in Taiwan and the United States. *J Gerontol B Psychol Sci Soc Sci, 54*(5), S291-301.

Osgood, D. W., & Smith, G. L. (1995). Applying hierarchical linear modeling to extended longitudinal evaluations: The Boys Town follow-up study. *Evaluation Review, 19*, 3-38.

Pan, W. H., Flegal, K. M., Chang, H. Y., Yeh, W. T., Yeh, C. J., & Lee, W. C. (2004). Body mass index and obesity-related metabolic disorders in Taiwanese and US whites and blacks: Implications for definitions of overweight and obesity for Asians. *Am J Clin Nutr, 79*(1), 31-39.

Payette, H., Kergoat, M. J., Shatenstein, B., Boutier, V., & Nadon, S. (2000). Validity of self-reported height and weight estimates in cognitively-intact and impaired elderly individuals. *J Nutr Health Aging, 4*(4), 223-228.

Pi-Sunyer, X., Blackburn, G., Brancati, F. L., Bray, G. A., Bright, R., Clark, J. M., et al. (2007). Reduction in weight and cardiovascular disease risk factors in individuals with type 2 diabetes: One-year results of the Look AHEAD trial. *Diabetes Care, 30*(6), 1374-1383.

Pinn, V. W. (2003). Sex and gender factors in medical studies: Implications for health and clinical practice. *JAMA, 289*(4), 397-400.

Pinn, V. W. (2006). Past and future: Sex and gender in health research, the aging experience, and implications for musculoskeletal health. *Orthop Clin North Am, 37*(4), 513-521.

Ponzo, M. G., Gucciardi, E., Weiland, M., Masi, R., Lee, R., & Grace, S. L. (2006). Gender, ethnocultural, and psychosocial barriers to diabetes self-management in Italian women and men with type 2 diabetes. *Behav Med, 31*(4), 153-160.

Purnell, J. Q., Hokanson, J. E., Marcovina, S. M., Steffes, M. W., Cleary, P. A., & Brunzell, J. D. (1998). Effect of excessive weight gain with intensive therapy of type 1 diabetes on lipid levels and blood pressure: Results from the DCCT. Diabetes Control and Complications Trial. *JAMA, 280*(2), 140-146.

Quandt, S. A., Bell, R. A., Snively, B. M., Smith, S. L., Stafford, J. M., Wetmore, L. K., et al. (2005). Ethnic disparities in glycemic control among rural older adults with type 2 diabetes. *Ethn Dis, 15*(4), 656-663.

Radloff, L. (1977). The CES-D Scale. *Applied Psychological Measurement, 1*(3), 385-401.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical Linear Models: Applications and Data Analysis Methods*. Newbury Park: Sage.

Romoren, T. I., & Blekeseaune, M. (2003). Trajectories of disability among the oldest old. *J Aging Health, 15*(3), 548-566.

Rose, M., Fliege, H., Hildebrandt, M., Schirop, T., & Klapp, B. F. (2002). The network of psychological variables in patients with diabetes and their importance for quality of life and metabolic control. *Diabetes Care, 25*(1), 35-42.

Ross, C. E., & Wu, C. L. (1996). Education, age, and the cumulative advantage in health. *J Health Soc Behav, 37*(1), 104-120.

Russell-Jones, D., & Khan, R. (2007). Insulin-associated weight gain in diabetes--causes, effects and coping strategies. *Diabetes Obes Metab, 9*(6), 799-812.

Ryerson, B., Tierney, E. F., Thompson, T. J., Engelgau, M. M., Wang, J., Gregg, E. W., et al. (2003). Excess physical limitations among adults with diabetes in the U.S. population, 1997-1999. *Diabetes Care, 26*(1), 206-210.

Sabolsi, M., Solomon, C. G., & Manson, J. E. (2001). The middle years. In G. L. Beckles & P. E. Thompson-Reid (Eds.), *Diabetes & Women's Health Across the Life Stages: A Public Health Perspective* (pp. 105-145). Atlanta: U.S. Department of Health and Human Services, Center for Disease Control and Prevention.

Sairenchi, T., Iso, H., Irie, F., Fukasawa, N., Ota, H., & Muto, T. (2008). Underweight as a predictor of diabetes in older adults: A large cohort study. *Diabetes Care, 31*(3), 583-584.

Schafer, L. C., McCaul, K. D., & Glasgow, R. E. (1986). Supportive and nonsupportive family behaviors: Relationships to adherence and metabolic control in persons with type I diabetes. *Diabetes Care, 9*(2), 179-185.

Schaie, K. W. (1965). A general model for the study of developmental problems. *Psychol Bull, 64*, 92-107.

Schectman, J. M., Nadkarni, M. M., & Voss, J. D. (2002). The association between diabetes metabolic control and drug adherence in an indigent population. *Diabetes Care, 25*(6), 1015-1021.

Schillinger, D., Barton, L. R., Karter, A. J., Wang, F., & Adler, N. (2006). Does literacy mediate the relationship between education and health outcomes? A study of a low-income population with diabetes. *Public Health Rep, 121*(3), 245-254.

Shalev, V., Chodick, G., Heymann, A. D., & Kokia, E. (2005). Gender differences in healthcare utilization and medical indicators among patients with diabetes. *Public Health, 119*(1), 45-49.

Shoff, S. M., Klein, R., Moss, S. E., Klein, B. E., & Cruickshanks, K. J. (1998). Weight change and glycemic control in a population-based sample of adults with older-onset diabetes. *J Gerontol A Biol Sci Med Sci, 53*(1), M27-32.

Shumway-Cook, A., Ciol, M. A., Yorkston, K. M., Hoffman, J. M., & Chan, L. (2005). Mobility limitations in the Medicare population: Prevalence and sociodemographic and clinical correlates. *J Am Geriatr Soc, 53*(7), 1217-1221.

Sierra, F., Hadley, E., Suzman, R., & Hodes, R. (2008). Prospects for life span extension. *Annu Rev Med*. 60, 457-469.

Sinclair, A. J., Conroy, S. P., & Bayer, A. J. (2008). Impact of diabetes on physical function in older people. *Diabetes Care, 31*(2), 233-235.

Siu, A. L., Reuben, D. B., & Hays, R. D. (1990). Hierarchical measures of physical function in ambulatory geriatrics. *J Am Geriatr Soc, 38*(10), 1113-1119.

Soldo, B. J., Hurd, M. D., Rodgers, W. L., & Wallace, R. B. (1997). Asset and Health Dynamics among the Oldest Old: An overview of the AHEAD study. *Journal of Gerontology, 52b*, 1-20.

Songer, T. J. (1995). Disability in diabetes. In M. Harris, C. C. Gowie, M. Stern, E. J. Boyko, R. G.E. & P. H. Bennett (Eds.), *Diabetes in America* (2nd ed., pp. 429-448). Washington DC: U.S. Govt. Printing Office: NIH publ. no. 95-1468.

Standl, E. (2002). International Diabetes Federation European Policy Group standards for diabetes. *Endocr Pract, suppl 1*, 37-40.

Strawbridge, W. J., Camacho, T. C., Cohen, R. D., & Kaplan, G. A. (1993). Gender differences in factors associated with change in physical functioning in old age: A 6-year longitudinal study. *Gerontologist, 33*(5), 603-609.

Szalat, A., & Raz, I. (2007). Gender-specific care of diabetes. *Women's Health, 3*(6), 735-764.

Tang, Y. H., Pang, S. M., Chan, M. F., Yeung, G. S., & Yeung, V. T. (2008). Health literacy, complication awareness, and diabetic control in patients with type 2 diabetes mellitus. *J Adv Nurs, 62*(1), 74-83.

Thornton, A., Chang, M. C., & Sun, T. H. (1984). Social and economic change, intergenerational relationships, and family formation in Taiwan. *Demography, 21*(4), 475-499.

Tomlinson, B., Deng, H. B., & Thomas, G. N. (2008). Prevalence of obesity amongst Chinese populations revisited. *Future Medicine, 3*(2), 139-152.

Tonry, M., Ohlin, L. E., & Farrington, D. P. (1991). *Human development and criminal behavior: New ways of advancing knowledge*. New York: Springer-Verlag.

Tseng, C. H., Tseng, C. P., Chong, C. K., Huang, T. P., Song, Y. M., Chou, C. W., et al. (2006). Increasing incidence of diagnosed type 2 diabetes in Taiwan: Analysis of data from a national cohort. *Diabetologia, 49*(8), 1755-1760.

Tuthill, A., McKenna, M. J., O'Shea, D., & McKenna, T. J. (2008). Weight changes in type 2 diabetes and the impact of gender. *Diabetes Obes Metab, 10*(9), 726-732.

U.K. Prospective Diabetes Study Group. (1998). Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). UK Prospective Diabetes Study (UKPDS) Group. *Lancet, 352*(9131), 837-853.

U.S. Preventive Services Task Force. (2008). Screening for type 2 diabetes mellitus in adults: U.S. Preventive Services Task Force recommendation statement. *Ann Intern Med, 148*(11), 846-854.

Ueda, T., Tamaki, M., Kageyama, S., Yoshimura, N., & Yoshida, O. (2000). Urinary incontinence among community-dwelling people aged 40 years or older in Japan: Prevalence, risk factors, knowledge and self-perception. *Int J Urol, 7*(3), 95-103.

Umberson, D. (1992). Gender, marital status, and the social control of health behavior. *Social Science and Medicine, 34,* 907-917.

Verbrugge, L. M., & Jette, A. M. (1994). The disablement process. *Soc Sci Med, 38*(1), 1-14.

Verbrugge, L. M., Merrill, S. S., & Liu, X. (1999). Measuring disability with parsimony. *Disabil Rehabil, 21*(5-6), 295-306.

Vinik, A. I. (2003). Management of neuropathy and foot problems in diabetic patients. *Clin Cornerstone, 5*(2), 38-55.

Vinik, A. I., & Vinik, E. (2003). Prevention of the complications of diabetes. *Am J Manag Care, 9*(3 Suppl), S63-80; quiz S81-64.

Wallace, R. B., & Herzog, A. R. (1995). Overview of the health measures in the Health and Retirement Study. *Journal of Human Resources, 30,* s84-s107.

Wallhagen, M. I., & Lacson, M. (1999). Perceived control and psychosocial/physiological functioning in African American elders with type 2 diabetes. *Diabetes Educ, 25*(4), 568-575.

Wang, C. Y., Sheu, C. F., & Protas, E. (2007). Construct validity and physical performance of older adults in different hierarchical physical-disability level. *J Aging Phys Act, 15*(1), 75-89.

Wang, L., van Belle, G., Kukull, W. B., & Larson, E. B. (2002). Predictors of functional change: a longitudinal study of nondemented people aged 65 and older. *J Am Geriatr Soc, 50*(9), 1525-1534.

Welch, G. W., Jacobson, A. M., & Polonsky, W. H. (1997). The Problem Areas in Diabetes Scale. An evaluation of its clinical utility. *Diabetes Care, 20*(5), 760-766.

Wen, C. P., Tsai, S. P., & Chung, W. S. (2008). A 10-year experience with universal health insurance in Taiwan: measuring changes in health and health disparity. *Ann Intern Med, 148*(4), 258-267.

Wexler, D. J., Grant, R. W., Meigs, J. B., Nathan, D. M., & Cagliero, E. (2005). Sex disparities in treatment of cardiac risk factors in patients with type 2 diabetes. *Diabetes Care, 28*(3), 514-520.

Wild, S., Roglic, G., Green, A., Sicree, R., & King, H. (2004). Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care, 27*(5), 1047-1053.

Wild, S. H., & Forouhi, N. G. (2007). What is the scale of the future diabetes epidemic, and how certain are we about it? *Diabetologia, 50*(5), 903-905.

World Health Organization. (1980). *The International Classification of Impairments, Disabilities, and Handicaps: A Manual Relating to the Consequences of Disease.* Geneva: WHO.

Wray, L. A., Alwin, D. F., & McCammon, R. J. (2005). Social status and risky health behaviors: results from the health and retirement study. *J Gerontol B Psychol Sci Soc Sci, 60 Spec No 2*, 85-92.

Wray, L. A., Alwin, D. F., McCammon, R. J., Manning, T., & Best, L. E. (2006). Social status, risky health behaviors, and diabetes in middle-aged and older adults. *J Gerontol B Psychol Sci Soc Sci, 61*(6), S290-298.

Wray, L. A., Blaum, C., Ofstedal, M. B., & Herzog, R. (2004). Diabetes diagnosis and weight loss in middle-aged adults. *Research on Aging, 26*(1), 62-81.

Wray, L. A., Herzog, A. R., Willis, R. J., & Wallace, R. B. (1998). The impact of education and heart attack on smoking cessation among middle-aged adults. *J Health Soc Behav, 39*(4), 271-294.

Wray, L. A., Ofstedal, M. B., Langa, K. M., & Blaum, C. S. (2005). The effect of diabetes on disability in middle-aged and older adults. *J Gerontol A Biol Sci Med Sci, 60*(9), 1206-1211.

Wu, J. H., Haan, M. N., Liang, J., Ghosh, D., Gonzalez, H. M., & Herman, W. H. (2003). Diabetes as a predictor of change in functional status among older Mexican Americans: A population-based cohort study. *Diabetes Care, 26*(2), 314-319.

Yoon, K. H., Lee, J. H., Kim, J. W., Cho, J. H., Choi, Y. H., Ko, S. H., et al. (2006). Epidemic obesity and type 2 diabetes in Asia. *Lancet, 368*(9548), 1681-1688.

Zamboni, M., Mazzali, G., Zoico, E., Harris, T. B., Meigs, J. B., Di Francesco, V., et al. (2005). Health consequences of obesity in the elderly: A review of four unresolved questions. *Int J Obes (Lond), 29*(9), 1011-1029.

Zimmer, Z., & Lin, H. S. (1996). Leisure activity and well-being among the elderly in Taiwan: Testing hypotheses in an Asian setting *J of Cross-Cultural Gerontology, 11*(2), 167-186.

Zimmet, P. (2003). The burden of type 2 diabetes: Are we doing enough? *Diabetes Metab, 29*(4 Pt 2), 6S9-18.

Zimmet, P., Alberti, K. G., & Shaw, J. (2001). Global and societal implications of the diabetes epidemic. *Nature, 414*(6865), 782-787.

Ching-Ju Chiu

Vita

EDUCATION

2009	Ph.D. Biobehavioral Health, Pennsylvania State University Minor: Statistics
2003	M.S., Health Policy and Management, National Taiwan University
2001	B.S.Ed., Health Education, National Taiwan Normal University

PROFESSIONAL EMPLOYMENT

Research

2009-	Research Associate, The Role of Social Relationships and Self-Efficacy in Diabetes Management, National Institute on Diabetes and Digestive and Kidney Disorders, R21-DK078894 (Linda A. Wray, PI)
2008-09	Research Assistant, Trajectories of Diabetes and Physical Function in Older Age in the United States and Taiwan, Seed grant, Center on Population Health and Aging; parent, National Institute on Aging, P30-AG024395 (Linda A. Wray, PI)
2008-09	Research Assistant, Latent Growth Curve Models of Cognitive Aging, National Institute on Aging, R01-AG021203 (Duane F. Alwin, PI)
2001-03	Research Assistant, National Health Research Institutes (NHRI), Taiwan
1999-01	Research Assistant, National Taiwan Normal University, Taiwan

Teaching

2006-08	Teaching Assistant and Lecturer, Department of Biobehavioral Health, The Pennsylvania State University BBH 119- Behavior, Health & Disease BBH 316- Foundations and Principles of Health Promotion BBH 416- Health Promotion II: Planning, Implementation, and Evaluation)
2003-06	Health Education Teacher, Taipei Long-Men Junior High School, Taiwan

PUBLICATIONS

1. **Chiu, C.-J.**, Wray L.A., Beverly E.A., Dominic O.G. (2009, in press) The Role of Health Behaviors in Mediating the Relationship between Depressive Symptoms and Glycemic Control in Type 2 Diabetes: A Structural Equation Modeling Approach. *Social Psychiatry and Psychiatric Epidemiology*. First published on April 3, 2009 as e-publication:DOI10.1007/s00127-009-0043-3.
2. **Chiu, C.-J.**, Wray L.A. (2009, in press) Factors Predicting Glycemic Control in Middle-aged and Older Adults Living with Type 2 Diabetes: Evidence from the U.S. Health and Retirement Study and the Diabetes Survey. *Preventing Chronic Disease*. Accepted for publication March 30, 2009.
3. Yen L.-L., **Chiu C.-J.,** Wu W.-C., Pan L.-Y. (2006). Aggregation of Health Behaviors among Fourth Graders in Northern Taiwan. *Journal of Adolescent Health* 39(3): 435-442.
4. **Chiu C.-J.**, Liu G.-Y. (2003). Health Lifestyle and Needs Assessment for Health Promotion in Employees Working in Manusfacture Factories. *Journal of Health Promotion & Health Education (Taiwan)* 23:29-42.
5. Guo J.-L., Huang C.-M., Su F.-C., **Chiu C.-J**., et al. (2003) The Meta-Analysis of the Effects of Intervention Studies Using Health Education and Behavioral Modification. *Journal of Health Education (Taiwan)* 20:71-88.