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Association Between Executive Function, Physical Activity, and Physical Fitness in People with Type 2 Diabetes

A Thesis Presented

by

Joyce Ann Indelicato

to

Bouvé College of Health Sciences

in partial fulfillment of the requirement
for the degree of

Master of Science

in

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Northeastern University
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Thesis Approval Form

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ABSTRACT

INDELICATO, J.A. <u>The Association Between Executive Function, Physical Activity, and Physical Fitness in People with Type 2 Diabetes.</u> M.S. in Clinical Exercise Physiology, 2009, 57 p (W. Gillespie)

To investigate the association between executive function, physical activity, and physical fitness in people with type 2 diabetes, twenty participants (51-73 years, 50% female) with type 2 diabetes (mean HbA1C 7.9%) completed the Behavior Rating Inventory of Executive Function – Adult (BRIEF-A), the Diabetes Task of Executive Function (DTEF), the 7-day Physical Activity Recall (PAR), the Duke Activity Status Index (DASI), and the 6-Minute Walk Test (6MWT). Body Mass Index (BMI) and waist-to-hip ratio (WHR) were calculated, and percent body fat (BF%) and blood pressure (BP) measurements were obtained. Data were analyzed (SPSS 16.0) using Pearson's correlation and multiple linear regression. BRIEF-A working memory scores were significantly correlated with meters walked in six minutes (r= -0.49; p=0.03), but were not predictive of MET-hours per week, kilocalories per week, meters walked in six minutes, or estimated VO2peak. Significant correlation was found between DTEF blood glucose log scores, MET-hours per week (r=0.54; p=0.02), and kilocalories per week (r=.54; p=0.01), but DTEF blood glucose log scores did not predict MET-hours per week, kilocalories per week, meters walked in six minutes or estimated VO2peak. DTEF planning scores predicted meters walked in six minutes (b=.404; p=.007), as did DTEF total scores (b=.364; p=.034). Results demonstrated that intra-individual variations in working memory, planning, multitasking, and time management abilities are associated with weekly physical activity and physical fitness in people with type 2 diabetes.

The Association Between Executive Function, Physical Activity, and Physical Fitness in People with Type 2 Diabetes

Chapter I

Introduction

Diabetes now affects nearly 24 million people in the United States, an increase of more than 3 million in approximately two years. Diabetes is the seventh leading cause of mortality, the direct cause of 72,507 deaths annually in 2006, and the leading cause of visual impairment, blindness, renal failure, and non-traumatic amputations in the U.S. People with diabetes have a 2- to 4-fold increased risk of cardiovascular disease (CDC, 2008). As the prevalence of obesity and physical inactivity has grown, so too has the incidence of diabetes.

Physical activity plays a vital role in the prevention and management of type 2 diabetes. For people with type 2 diabetes, the risk of mortality is inversely related to physical fitness (Morrato et al., 2007), and this result has been seen in all BMI (body mass index) and body fatness groups (Church et al., 2004). However, despite the growing body of research showing the significant benefits of exercise in diabetes management, findings from the Medical Expenditure Panel Survey (MEPS) (Morrato et al., 2007) and the National Health and Nutrition Examination Survey (NHANES1999-2000) (CDC, 2008) suggest that no substantial improvement in physical activity has occurred over the past decade. Morrato et al. (2007), in a study of 23,283 people, found that just 39% of adults with type 2 diabetes were physically active, compared to 58% of those without diabetes.

Maintaining a program of physical activity that is performed at a high enough intensity, duration, and frequency to improve and maintain fitness requires motivation that is often short-lived. Although research investigating the effects of both home-based and structured exercise interventions on diabetes management has shown that these approaches can be effective in increasing physical activity levels and improving cardiovascular fitness and glycemic control during the intervention period, there is little evidence that these strategies have effects past six months post-intervention and that long term adherence is poor (Kirk et al., 2003).

Various explanations have been proposed as to why so many individuals fail to maintain healthy lifestyle behaviors, including exercise. One intriguing area of research suggests that there may be a brain-based explanation for health behavior motivation and adherence, at least in those with chronic illnesses like type 2 diabetes. Although the evidence is inconclusive (Hassing et al., 2004), some studies show that type 2 diabetes has been associated with cognitive impairment (Schillerstrom, 2005; Royall et al., 2002). There is also evidence that certain cognitive functions can be improved with exercise (Colcombe eta al, 2004). One of those cognitive domains is e*xecutive functioning*, the specific cognitive process that enables one to engage in independent, goal directed behavior. Executive functioning has not been shown to have a direct effect on the ability to begin and maintain an exercise program, however, there is evidence that executive function contributes to a person's ability to manage their diabetes (Munshi et al., 2006), which includes the decision to exercise or not. Previous research seldom report combinations of activity, fitness and cognition in a single study (Angevaren, 2008). Therefore, further research is warranted to investigate whether normal variations in executive function are associated with variations in physical activity and fitness. The present study proposed to determine whether a relationship exists between executive function, physical activity and physical fitness in people

with type 2 diabetes. Better understanding of the association between these variables could lead to the development of more effective targeted interventions designed to support exercise initiation and maintenance in people with type 2 diabetes.

Statement of the Problem

This study investigated the associations between executive function, physical activity and physical fitness in people with type 2 diabetes. More specifically, this study examined whether executive functioning in people with type 2 diabetes was associated with self-reported levels of physical activity (MET-hours per week and kilocalories per week) and objective measures of physical fitness (meters walked in six minutes and estimated VO2 peak).

Scope of the Study

This cross-sectional pilot study assessed 20 subjects age $\geq$ 50 years who have type 2 diabetes and are patients at the Joslin Diabetes Center/Joslin Clinic in Boston MA. Subjects were recruited through clinic outreach and clinician referrals. All data were collected using signed informed consent and followed the guidelines of the Joslin Diabetes center Institutional Review Board (IRB).

Executive function was assessed via (1) the *Behavior Rating Inventory of Executive Function – Adult (BRIEF-A)*, which assesses the ability to plan and set goals, control impulses, move freely from one activity to another, solve problems, and self-monitor; and (2) the *Diabetes Task of Executive Function (DTEF)*, which assesses the ability to complete tasks related to diabetes management that tap executive functions.

Physical activity was assessed using the *Physical Activity Recall (PAR)*, a seven day self-report recall interview completed in person or by telephone. This yielded scores for MET-hours per week and kilocalories per week of energy expenditure.

Fitness capacity was estimated by (1) the *Duke Activity Status Index (DASI)*, a self-administered questionnaire that assesses functional capacity by providing a rough estimate of peak oxygen uptake, and (2) the *6-Minute Walk Test (6MWT)*, a submaximal test of aerobic capacity. Anthropometric measurements (body weight, waist circumference, waist-to-hip ratio, percent body fat, and body mass index) were also completed.

Limitations

Limitations to this study will restrict its generalizability. Study results showed the relationships between the measured variables in people with type 2 diabetes only and therefore cannot be generalized to people with other types of diabetes or people without the disease. All participants were patients of the Joslin Diabetes Center and therefore do not reflect the general population of all people with type 2 diabetes in terms of ethnicity, socioeconomic status, and educational attainment. The limited number of subjects (n=20) also prevents generalizability to the larger population of peoples with type 2 diabetes. In addition, since this study did not include a control group, only inter-individual differences were observed. Finally, the *Diabetes Task of Executive Functioning* is a newly developed executive functioning assessment tool and the psychometric properties are still being evaluated at this time.

Hypotheses

For the purposes of this study the following hypotheses were put forth:

1) In people with type 2 diabetes, measures of executive function (*BRIEF-A* and *DTEF*) will be positively correlated with measures of weekly physical activity (MET-hours per week and kilocalories per week).
2) In people with type 2 diabetes, measures of executive function (*BRIEF-A* and *DTEF*) will be positively correlated with measures of physical fitness (estimated VO2peak and meters walked in six minutes).

Definition of Terms

Aerobic or cardiovascular exercise refers specifically to activities that use large muscles groups, are rhythmic in nature, and are maintained continuously for at least 10 minutes, such as walking, aerobics, bicycling, and swimming. Aerobic exercise raises heart and respiratory rates above resting levels (ACSM, 2007).

Body composition included measurements of height, weight, waist circumference, hip circumference, and percent body fat and calculation of waist-to-hip ratio and body mass index.

Executive function refers to those operations of the brain that are involved in effortful or "top-down" control of behavior: the ability to plan, initiate, sequence, monitor and inhibit complex behavior (Norman & Shallice, 1986).

Exercise is a subcategory of physical activity. It is intentional, planned, structured and repetitive activity undertaken for the purpose of conditioning any part of the body. Examples include walking, running, swimming, and muscle strengthening and endurance.

Physical activity is any bodily movement produced by skeletal muscles resulting in energy expenditure. It is expressed as a rate: kilocalorie per unit of time. In this study, physical

activity was reported as MET-hours per week and kilocalories per week spent in activity of at least moderate intensity.

Physical fitness is a set of measureable attributes that are either health related, for example, cardiorespiratory endurance or body composition, or skill related, such as balance, or coordination. (Caspersen et al., 1985) In this study, physical fitness (or simply “fitness”) refers to functional capacity based on estimated VO2peak and meters walked in six minutes and body composition.

Chapter II

Review of Related Literature

Epidemiology of Type 2 Diabetes in the US

The number of Americans living with diabetes is increasing at an alarming rate, rising steadily from 5.6 million in 1980 to nearly 24 million in 2007 (ADA, 2008). The total prevalence of diabetes increased 13.5% from 2005-2007 alone, an increase of more than 3 million children and adults in just two years. The number of adults aged 18-79 years with newly diagnosed diabetes has almost tripled from 493,000 in 1980 to 1.4 million in 2005. This means that nearly 8 percent of the U.S. population has diabetes. The majority of these, an estimated 90-95%, have type 2 diabetes; the rest have type 1 diabetes. If the present trend continues, one in three Americans born in 2000 will develop diabetes in their lifetime (ADA, 2008).

In addition to the 24 million Americans living with diabetes, millions of Americans have risk factors for type 2 diabetes. Fifty-seven million people are estimated to have pre-diabetes (CDC, 2008), previously referred to as impaired glucose tolerance (IGT) or impaired fasting glucose (IFG), a risk factor for diabetes in which blood glucose levels that are higher than normal but not yet high enough to be diagnosed as diabetes (100 mg/dl – 126 mg/dl). People with pre-diabetes have a 1.5-fold risk of cardiovascular disease compared to people with normal blood glucose. According to the ADA, studies have shown that people with pre-diabetes can prevent or delay the development of type 2 diabetes by up to 58 percent through changes to their lifestyle that include modest weight loss and regular exercise. The ADA recommends that people

with pre-diabetes reduce their weight by 5-10 percent and participate in some type of modest physical activity for 30 minutes daily.

Diabetes has increased in both men and women and in all age groups, but disproportionately affects the elderly and minorities. Almost 25 percent of the population 60 years and older had diabetes in 2007. As in previous years, disparities exist among ethnic groups and minority populations. One in two minorities born in 2000 will develop diabetes in their lifetime. After adjusting for population age differences between the groups, the rate of diagnosed diabetes was highest among Native Americans and Alaska Natives (16.5 percent). This was followed by blacks (11.8 percent) and Hispanics (10.4 percent), which includes rates for Puerto Ricans (12.6 percent), Mexican Americans (11.9 percent), and Cubans (8.2 percent). By comparison, the rate for Asian Americans was 7.5 percent with whites at 6.6 percent. (CDC, 2008)

Along with its enormous impact on health and quality of life, diabetes also presents an enormous economic burden in the U.S. The total annual economic cost of diabetes in 2007 was estimated to be $174 billion. Medical expenditures totaled $116 billion and were comprised of $27 billion for diabetes care, $58 billion for chronic diabetes-related complications, and $31 billion for excess general medical costs. Indirect costs resulting from increased absenteeism, reduced productivity, disease-related unemployment disability, and loss of productive capacity due to early mortality totaled $58 billion. This is an increase of $42 billion since 2002. This 32% increase means the dollar amount has risen over $8 billion more each year. The 2007 per capita annual costs of health care for people with diabetes is $11,744 a year, of which $6,649 (57%) is attributed to diabetes. One out of every five health care dollars is spent caring for someone with diagnosed diabetes, while one in ten health care dollars is attributed to diabetes. (Stagnitti, 2001)

Physical Activity, Exercise, and Type 2 Diabetes

Physical activity (including exercise) plays a vital role in the management of type 2 diabetes. Regular moderate intensity exercise decreases the likelihood of cardiovascular and microvascular complications associated with hyperglycemia. The research is unequivocal that exercise is critical in the maintenance of glycemic control, but many research questions remain regarding optimal mode, intensity, and duration of endurance (aerobic) and resistance training. Overall, the benefits of exercise include lower resting and submaximal heart rate, increased stroke volume and cardiac output, enhanced oxygen extraction, lower resting and exercise blood pressures, improved insulin sensitivity, lower medication requirements, reduced vascular inflammation, improved endothelial function, reduction in body fat with preferential mobilization of visceral adipose tissue (abdominal obesity), psychological improvements (such as decreased depression and reduced stress) and increased adherence to nutritional advice (Durstine, 2003).

Boule et al. (2001, 2003) performed two meta-analyses investigating the effects of exercise on various parameters related to glycemic control and cardiovascular fitness. In a meta-analysis of fourteen controlled clinical trials investigating the effects of exercise on glycemic control and body mass, Boule et al. (2001) reviewed eleven randomized and three non-randomized studies of twelve aerobic training and two resistance training trials. Subjects (n=504) had type 2 diabetes, with no significant baseline differences in HbA1C, a mean age of 55 years, and a mean duration of diabetes of 4.3 years and 50% female. The aerobic exercise interventions were at least eight weeks in duration, typically three times per week, with a mean duration of 53 $\pm$17 minutes and of moderate intensity walking or cycling. The resistance exercise interventions had either no intensity specified or consisted of two to three sets of ten to twenty repetitions at

50-55% 1 RM, or the resistance was progressively increased for the duration of the intervention. Post-intervention HbA1C was significantly lower in the exercise vs. the control groups (7.65 vs. 8.31), or 0.66% lower. There were no significant post intervention differences in body mass and body weight. The average change in body weight was -0.9 kg in the exercise groups, -3.4 kg in combined groups, -2.5 kg in diet group, and an increase of 0.8 kg in the control groups. This meta-analysis showed that exercise training reduced HbA1C by an amount that should decrease the risk of diabetic complications; however, no significantly greater change in body mass was found when exercise groups were compared to the controls. Based on this analysis, it appears that exercise does not need to change body weight to impact glycemic control, and confers important benefits regardless of weight loss.

In the second analysis, Boule et al. (2003) examined seven randomized controlled trials that investigated the effects of structured exercise training on cardiovascular fitness in 266 adults with type 2 diabetes, a mean age of 55.7 years, mean duration of diabetes of 4.1 years, and 40% female. Studies were only included if interventions involved structured aerobic activities; those with large resistance training components were excluded. All interventions were at least eight weeks in duration, with a mean of 3.4 sessions per week, 49 minutes per session, and twenty weeks duration. Intensity ranged from 50% to 75% VO2max. These seven trials showed an 11.8% increase in VO2max in the exercise group compared to 1.0% decrease in the control group. Higher intensity interventions were shown to lead to larger improvements in VO2max, for example at an intensity of 75% VO2max, there was a VO2max increase of 40.9%. The weighted average was a 9.5% increase in VO2max in studies with lower intensity. In this analysis, intensity predicted mean difference in HbA1C to a larger extent than did volume. This analysis showed that regular exercise has a statistically and clinically significant effect on VO2max and

that higher intensity exercise could have additional benefits on cardiorespiratory fitness and HbA1C. The researchers also noted that exercise training stimulus must be sustained in order to maintain the risk reduction benefits.

In 2007, the LookAHEAD Research Group conducted an NIH-funded 16 center clinical trial investigating the long-term health impact of an intensive lifestyle intervention compared with a diabetes support and education group. Subjects (n= 5,145) were overweight or obese adults with type 2 diabetes, 45-74 yrs, BMI >25 (>27 if taking insulin), A1C <11%, SBP<160 mmHg, DBP <100 mmHg, triglycerides <600 mg/dl. All participants were able to achieve a minimum18 RPE and 4 METS on a baseline exercise tolerance test. Diet modification involved caloric restriction, including liquid meal replacements with a macronutrient breakdown of 55% carbohydrate, 30% fat and 15% protein. The exercise intervention included home- based exercise; walking was encouraged, but other modes were allowed. Exercise progressed gradually to a goal of 175 minutes of moderate intensity physical activity per week. The goal of this lifestyle intervention was a 7% loss of initial body weight, based on previous studies that show that this percentage of weight loss can improve various metabolic parameters in overweight and obese people with type 2 diabetes. At year one, subjects receiving intensive lifestyle intervention (ILI) achieved an average loss of 8.6% of initial body weight compared to 0.7% in the diabetes support and education group (DSE). There was a 20.9 % improvement in VO2max in ILI vs. 5.8% in DSE. A1C dropped from 7.3% to 6.6% in ILI vs. 7.3% to 7.2% in DSE; there was an increase from 46% to 73% in participants meeting the American Diabetes Association goal of HbA1C <7. The intervention groups also showed significantly greater improvements in systolic and diastolic BP, triglycerides, HDL, urine albumin-to-creatinine ratio compared to DSE. At year one, ILI resulted in significant weight loss in people with type 2 diabetes. This was associated

with improved diabetes control and cardiovascular disease risk factors and reduced medicine use. (LookAHEAD, 2007)

Despite this growing body of research showing the significant benefits of exercise in diabetes management, findings from the Medical Expenditure Panel Survey (Morrato et al., 2006) and the National Health and Nutrition Examination Survey 1999-2000 suggest that no substantial improvement in physical activity has occurred in the general population over the past decade. Since these two reports were published, the CDC has reported that in 2001 the national average for the prevalence of recommended physical activity was 45.3%; in 2007 it rose to 48.8 %. People with type 2 diabetes are far less active than people without the disease. Morrato et al. (2007) in a study of 23, 283 people, found that just 39% of adults with type 2 diabetes were physically active, compared to 58% of those without diabetes.

Physical Fitness and Type 2 Diabetes

Due to hyperglycemia, low capillary density, alterations in oxygen delivery, increased blood viscosity, and vascular and neuropathic abnormalities, people with type 2 diabetes achieve lower VO2max levels (<6 METS) compared with healthy age matched controls. People with diabetes age 60 years or older are two to three times more likely to report an inability to walk one-quarter of a mile, climb stairs, or do housework, compared to those of the same age without diabetes (CDC).The risk of mortality among people with type 2 diabetes is inversely related to their physical fitness (Morrato et al., 2007). The Aerobics Center Longitudinal Study (ACLS), a prospective epidemiologic investigation of 2,196 men with type 2 diabetes, found that fitness had a strong and independent inverse association with mortality, and this result was seen in all BMI

and body fatness groups (Church et al., 2004). Earlier studies by these researchers showed that the inverse gradient of mortality across fitness groups is similar for both sexes.

A long-term follow-up study presented at the recent Endocrine Society 90th Annual Meeting (Jacob-Issac, 2008), examined whether physical fitness decreases the potential mortality risks posed by obesity in people with type 2 diabetes. The study involved 2690 men with type 2 diabetes and showed that higher levels of physical fitness confer a survival advantage for men with type 2 diabetes, whether the individual is obese, overweight, or normal weight. Participants in each BMI group were also classified by peak workload performance in routine exercise tolerance testing, as expressed in metabolic equivalents (METS). In this study, highly fit participants achieved more than 8 METS, moderately fit participants achieved 5.1 to 8 METS, and low fit participants achieved fewer than 5 METS. All-cause mortality was examined during a follow up period of 7.1 ± 4.7 years, during which 172 deaths occurred in the normal weight group, 334 in the overweight group, and 256 in the obese group. When mortality risk was compared with fitness level, the researchers identified an inverse, graded association between the two. Specifically, each 1-MET increase in exercise capacity conferred a 14% reduction in mortality risk. In addition, the relationship was consistent across all three weight categories. Jacob-Issac summarized the study's findings by stating "What we found was that after controlling for [cardiovascular disease] risk factors, we see that those having moderate to high fitness had higher survival rates when compared to those who were lower fit. The reason this is important is that we often focus on weight loss as a way to improve mortality in those who are overweight or obese, but that may not be the key issue here. Being physically active is just as important".

Barriers to Exercise in People with Type 2 Diabetes

Findings from the Diabetes Attitudes, Wishes, and Needs (DAWN) Study (Alberti, 2001) a cross-national psychosocial study of 5,426 adults with diabetes, showed adherence rates for exercise for those with type 2 diabetes was only 35%. Given the benefits, why don't more peoples with type 2 diabetes start and maintain programs of regular exercise? One explanation is that adherence to self-care regimens involves a variety of psychosocial and physical factors that interact in complex ways. Adopting new lifestyle habits that include changing eating and exercise patterns can be challenging. People with type 2 diabetes face the same motivational barriers to exercise that their healthy peers do, such as lack of interest, not enough time, and difficulty finding an enjoyable activity (Morrato et al., 2007), but they may also have physical conditions that can act as additional barriers to exercise.

For example, overweight and obesity can be potent barriers to exercise. Analysis of data collected in 2001 by the Medical Expenditure Panel Survey, a set of large-scale surveys of families and individuals, their medical providers, and employers across the United States, showed that 79% of people with diabetes, compared with 57.8 % of non-diabetics, had a BMI that placed them in the extremely obese, obese, or overweight categories (Stagnitti, 2001). In a study using minute-by-minute accelerometry to assess the compliance of overweight/obese and normal weight adults with the Centers for Disease Control and Prevention and American College of Sports Medicine recommendations for 30 minutes of moderate-intensity activity per day, Davis et al. (2006) found that overweight/obese adults spent 21 minutes less per day engaged in moderate or greater intensity activity than their normal-weight counterparts.

In addition, adults with diabetes are more likely than those without the disease to report a number of other chronic health conditions. People with diabetes are more likely to have asthma

than adult non-diabetics (13.6% vs. 8.9%), nearly three times as likely to have hypertension (62.7% vs.21.4%), over three times as likely to have heart disease (30.7% vs. 8.9%), and over four times as likely to have ever had a stroke (9.9% vs. 2.2%). MEPS showed that the likelihood of being active among individuals with diabetes was reduced by half when physical limitations were present. (Stagnitti, 2001) A study released by the CDC (Behavioral Risk Factor Surveillance System, 2005, 2007) on arthritis and diabetes suggests that the presence of co-occurring arthritis acts as an under-recognized additional barrier to physical activity among those with diabetes. This analysis of combined data indicated that arthritis prevalence was 52% among adults with diagnosed diabetes. The study found that 29.8 % of adults with diabetes and arthritis were inactive, compared to 21% with diabetes alone.

Executive Function and Type 2 Diabetes

In addition to the psychosocial and physical barriers discussed above, some people with type 2 diabetes may have variations in cognitive functioning that could potentially interfere with their ability to initiate or maintain an exercise program. Thus far, determining the association between cognitive function and type 2 diabetes has been problematic because of the complexity of conducting longitudinal research, the lack of consistency in the choice of appropriate psychometric tests, and the small magnitude of change observed in studies conducted to date (Allen et al., 2004). The research in this area has been inconclusive: some studies have found that type 2 diabetes is associated with cognitive impairment while others show a weak or non-existent association (Royall et al., 2002; Hassing et al., 2004; Schillerstrom, 2005; Yeung et al., 2009). The results vary depending on several factors, including the neurocognitive tests used, the

age ranges of the subjects, and the presence of comorbidities often found in this population that can also contribute to cognitive deficits.

In those studies that do report cognitive deficits in participants with type 2 diabetes, the specific type of deficits and explanations of their causes also vary. In a report from the Committee on Research of the American Neuropsychiatric Association, Royall et al. (2002) showed that some people with diabetes demonstrate impairment in the areas of verbal fluency and abstract reasoning and go on to suggest that the potential cause of this impairment may include subcortical vascular disease, polypharmacy, hypoglycemia, and/or concurrent major depression. In a 2005 review of the literature, Schillerstrom et al. found that type 2 diabetes has been associated with cognitive impairment in some people and that hypertension, vascular disease, renal failure, and cardiac illnesses, all co-morbidities or complications of type 2 diabetes, may contribute to these impairments. Age is also a factor; a recent study by Yeung et al. (2009) observed differences in cognitive performance between the young-old (53-70 years old) and the old-old (71-90 years old), with and without type 2 diabetes.

Although the exact domains of cognitive function most affected in those with type 2 diabetes remains unclear, it appears that one area, *executive function*, may play a role in health behavior motivation and treatment adherence. Executive function refers to those operations of the brain that are involved in effortful or "top-down" control of behavior: the ability to plan, initiate, sequence, monitor and inhibit complex behavior (Norman & Shallice, 1986). Lezak et al. (2004) conceptualized executive function as having four components: volition, planning, purposive action, and effective performance. Gioia, Isquith, and Steven (2001) emphasize that executive functions are especially called upon when one engages in actively solving novel problems versus during the performance of routine, well-learned behaviors. Since these planning

and organizational abilities allow one to conceptualize goals, start and complete tasks related to those goals, persevere in the face of challenges, and make alternative plans quickly when unusual events interfere with normal routines, it would appear that adequate executive functioning would be necessary to successfully plan and maintain a program of regular exercise.

Exercise and Executive Function

The seat of executive function is the prefrontal cortex and related sub-cortical structures and appears to be fundamentally connected to the operation of the anterior cingulate cortex (Hall, 2008). The literature indicates that aerobic exercise may protect individuals from age-related atrophy of these structures and to improve frontal metabolism. While an objective decline in cognitive performance accelerates around the age of fifty (Salthouse, 2003, Verhaeghen, 1997), with the exception of cognitive skills with a large knowledge component, research has shown that a regular exercise program can slow or prevent this functional decline (Kramer, Erikson, & Colcombe, 2006). Research using animal models has shown that increased aerobic fitness is found to increase cerebral blood flow, oxygen extraction and glucose utilization at the tissue level, as well as activation of growth factors which mediate structural changes such as capillary density. Research on humans suggests that the same possible physiological mechanisms may explain the association between physical activity and improvement or maintenance of cognitive function (Churchill 2002).

Further evidence for a link between physical activity, cardiovascular fitness and cognitive function, especially in older individuals, is provided by longitudinal studies and randomized controlled trials of both healthy and impaired adults. Several randomized controlled studies, as described in a meta-analysis by Colcombe and Kramer (2003), concluded that aerobic fitness

training enhances the cognitive capacity of healthy older adults. A meta-analysis by Etnier et al. (1997) that also included several non-randomized clinical trials showed similar results. A meta-analysis by Heyn et al. (2004) found a similar effect of physical activity on cognitive function in people with dementia and cognitively impaired older adults (Angevaren et al., 2008). It should be noted, however that not all studies have shown associations between cognitive function and exercise, for example, results from training studies performed by Hill et al. (1993) and Blumenthal et al. (1991) failed to correlate changes in VO2max with changes in cognitive measures.

The literature is also inconclusive when it comes to determining which aspects of cognitive functioning are most affected by cardiovascular exercise, to what extent, and in which age groups. In a review of the literature by Angevaren et al. (2008) eleven studies of aerobic physical activity programs for healthy people over the age of 55 years were reviewed. Eight of these eleven studies reported that aerobic exercise interventions resulted in an improvement in at least one aspect of cognitive function. The cognitive functions which improved were not the same in each study although the largest effects were on cognitive speed, and auditory and visual attention. The authors of this review concluded that there is evidence that aerobic physical activities which improve cardiorespiratory fitness are beneficial for cognitive function in healthy older adults. However, the data were insufficient to show that the improvements in cognitive function which can be attributed to physical exercise are due solely to improvements in cardiovascular fitness. It would be informative to understand why some cognitive functions seem to improve with aerobic/physical exercise while other functions seem to be insensitive to physical exercise.

It does appear that physical activity has an effect specifically on executive function; a meta-analysis of the exercise literature (Colcombe et al., 2003) showed that the effect of exercise on cognition is limited solely to executive function. At the same time, it also appears that executive function plays a role in adopting a physically activate lifestyle; Hall et al. (2008) report that recent studies have provided evidence to suggest that neurocognitive factors may indeed be implicated in patterns of health behavior over the lifespan and that executive functions may be especially central. These studies suggest that while the ability to plan and carry out an exercise program requires adequate executive functioning; exercise is the very thing that has been shown to improve executive function. Paradoxically, while the *act* of exercise appears to improve executive function, the *decision* to exercise depends on that very same function.

Chapter III

Methods and Procedures

This chapter presents the methods and procedures employed in the study including subject selection, tests used to assess executive function, physical activity, and physical fitness, and data analysis.

Subject Selection

This cross-sectional pilot study assessed 20 subjects age 50 years and older who have type 2 diabetes and are patients at the Joslin Diabetes Center/Joslin Clinic in Boston MA. Participants were recruited through mailings, flyers posted on Joslin bulletin boards, clinic outreach, clinician referrals, and referrals from other researchers. Recruiting material included a telephone number to call for more information about the study and to determine eligibility. The study was explained in detail by the researcher and a telephone screening interview was completed. With patients' approval, medical records were reviewed to ensure that inclusion and exclusion criteria were met. Interested individuals who met the inclusion criteria were scheduled to come in to the Joslin Diabetes Center to meet with the researcher to complete the assessments of executive function, physical activity and fitness. All data were collected using signed informed consent and followed the guidelines of the Joslin and Northeastern University Institutional Review Boards (IRB).

Demographic Data

Demographic information was collected, including age, gender, ethnicity, and race. A health history was conducted including number of years since diagnosis of type 2 diabetes,

medications, and any comorbidities were noted. HbA1C at last medical visit was determined through patient medical records.

Inclusion and Exclusion Criteria

Inclusion Criteria. The following are inclusion criteria employed in the study:

1. Age 50 years and older
2. Diagnosis of type 2 diabetes mellitus
3. Ability to read and speak English.

Exclusion Criteria. The following are exclusion criteria employed in the study:

1. Severe complications of diabetes including renal disease, severe peripheral diabetic neuropathy and/or severe peripheral vascular disease
2. Inability to ambulate
3. Proliferative diabetic retinopathy based on dilated eye examination within one year of study entry. Patients whose eye disease is successfully treated will be included
4. A history of severe, unstable myocardial infarction, congestive heart failure or other severe cardiac disease, or hypertension (systolic ≥160 mmHg or diastolic ≥ 90 mmHg)
5. A diagnosis of bipolar disorder, schizophrenia, mental retardation, organic mental disorder, and severe alcohol or drug abuse

Assessment of Executive Function

Adhering to an exercise plan requires the ability to set goals, make plans, act on those plans, adapt to changing circumstances, stick with and complete the task, and assess the outcome of the planned behavior. For the purposes of this study, tests that tap into these specific executive functions were used. All subjects were asked to complete two assessments of executive function.

(1) Behavior Rating Inventory of Executive Function – Adult Version (BRIEF A-) (Gioia, Isquith & Steven, 2001): The *BRIEF-A* is a standardized measure that assesses executive functions or self-regulation in adults in their everyday environment. The *BRIEF-A* was standardized and validated for use with men and women from ages 18-90 years. The normative sample includes adults from a wide range of racial/ethnic and educational backgrounds, as well as geographic regions that are matched to U.S. Census data (U.S. Bureau of the Census, 2002). The *BRIEF-A* has demonstrated evidence of reliability, validity, and clinical utility as an ecologically sensitive measure of executive functioning in individuals with a range of conditions across a wide age range. The *BRIEF-A* is composed of 75 items within nine non-overlapping theoretically and empirically derived clinical scales that measure various aspects of executive functioning, categorized as follows:

Clinical Scales: 1) *Inhibit* – the ability to control impulses, stop behaviors; 2) S*hift* – the ability to move freely from one activity or situation to another, transition, problem-solve flexibly; 3) *Emotional Control* – the ability to modulate emotional responses appropriately; 4) *Self-monitor* – the ability to assess one's own performance; 5) *Initiate* – the ability to begin an activity, generate ideas; 6) *Working Memory* – the ability to hold information in mind for the purpose of completing a task; 7) *Plan/Organize* – the ability to anticipate future events, set goals, develop steps; 8) *Task Monitor* – the ability to keep track of problem-solving success or failure; 9) *Organization of materials* – the ability to maintain order in the everyday work and home environment.

Indexes and Summary Scores: The clinical scales form two broader indexes: 1) Behavioral Regulation and 2) Metacognition, and these indexes form the overall summary score, the Global

Executive Composite (GEC). The *BRIEF-A* also includes three validity scales (Negativity, Inconsistency, and Infrequency).

This test can be administered individually or in a group setting and takes 10-15 minutes to administer and 15-20 minutes to score (Roth et al., 2005).

(2) Diabetes Task of Executive Functioning (DTEF)) (Beverly, 2008*)*: The Diabetes Task of Executive Functioning *(DTEF)* is a newly developed test that assesses time management, multi-tasking and planning abilities in real life diabetes activities. Using specific rules, the *DTEF* assesses the ability to complete at least part of five tasks related to the care of diabetes: 1) classifying foods according to carbohydrate content, 2) checking blood glucose level at specified times, 3) planning exercise for a week, 4) organizing a week's supply of 8 medications with different times and doses, 5) checking a glucose log for high and low glucose levels, and identifying patterns. Participants are allowed 10 minutes to complete all of the tasks, although the actual time needed for completion is longer. In addition to the five individual tasks, participants are scored on Planning, the ability to articulate a plan for completing the five tasks, doing some of each activity, and looking at the clock at least one time. The task is also scored for Total Processing, which includes overall planning and multi-tasking strategies and time management, where a high score represents more planning and organizational strategies, and also on Inaccuracy where a high score indicates more mistakes or omissions. Of particular interest for the purposes of this study, the exercise task directs the subject to incorporate into a written weekly schedule of a variety of specific daily activities (work, carpooling, children's activities, leisure activities, grocery shopping , medical appointments), up to 60 minutes of combined

aerobic, strength, and flexibility exercise on at least five days. The psychometric properties of the *DTEF* are currently being validated in a study at the Joslin Diabetes Center.

Assessment of Physical Activity

Physical activity was evaluated via the *Seven-Day Physical Activity Recall Questionnaire (PAR)* (Sallis, Haskell, Wood, et al., 1985*).* The *PAR* is a self-report recall instrument to assess physical activity. The instrument was designed for use in a community health survey on prevention of heart disease. Respondents are asked about the number of hours spent in sleep, moderate, hard, and very hard activities during the preceding week. Examples of the types of activities in each category are provided, and the week is separated into weekend days and weekdays. The remaining amount of time is presumed to have been spent in light activities. The amount of energy expenditure for each activity is quantified in terms of metabolic equivalents (METS) for each activity. Data are reported in MET-hours per week, derived by multiplying the amount of time spent performing an activity by the MET value of the activity. A formula is available for the calculation of daily energy expenditure in kilocalories, and norms are available from the Stanford Heart Disease Prevention Program. Test-retest reliability over a two week interval has been found to be good, and validity testing of the instrument versus a one-week physical activity log shows a trend for under-reporting of both hours and events in recall. However, estimates of mean daily energy expenditure were not significantly different using the two methods (Blair et al., 1985).

Assessment of Physical Fitness

Physical fitness and exercise capacity were determined by anthropometric measurements, the Duke Activity Status Index (DASI), the 6-Minute Walk Test (6MWT).

(1) (1) Anthropometric Measurements: Body weight was determined on a digital Tanita scale in light clothing. Height was measured without shoes by a measuring tape against a wall. Body Mass Index (BMI) was calculated using the formula BMI (kg/m^2) = weight in kilograms/ (height in meters x height in meters). Waist circumference was measured at the midpoint between the iliac crest and the lowest rib, and hip circumference was measured at the widest part of the pelvis. Waist-to-hip ratio (WHR) was calculated as waist divided by hip. Percent body fat was measured using the Tanita BF-350 Body Composition Analyzer/Scale (Tanita Corporation of America, Arlington Heights, ILL) which uses leg-to-leg bioelectric impedance to measure resistance to an electrical signal as it travels through the water present in muscle and fat. The subject steps onto the scale without shoes and socks and electrodes in the foot sensor pads send a low, safe electrical signal through the body. Imbedded computer software allows the subject's age, gender, height, and fitness level to be entered into the system to determine body fat percentage based on equation formulas. Since hydration levels and exercise can influence results, subjects were asked when they last ate, drank, and exercised to enable a more accurate interpretation of the measurements.

(2) Duke Activity Status Index (DASI) (Hltaky, Boineau, et al., 1989): Current cardiovascular fitness levels was ascertained through the Duke Activity Status Index (DASI) a self-administered questionnaire which assesses functional capacity by providing a rough estimate of peak oxygen uptake. The DASI is a self-reported measure of ability to do twelve personal,

household, and recreational activities, each of which is assigned a metabolic equivalent (MET) used to assess cardiovascular capacity. A higher score indicates greater functional capacity.

(3) 6-Minute Walk Test (6MWT) (American Thoracic Society, 2002): Submaximal level of functional capacity was measured by the 6MWT, a practical, simple walking test that reflects the capacity to perform activities of daily living. This test evaluates the global and integrated responses of all the systems involved during exercise, including the pulmonary and cardiovascular system, systemic and peripheral circulation, blood, neuromuscular units, and muscle metabolism. The 6MWT was used in this study because it is safer than a maximal exercise test for older, overweight and obese type 2 diabetes populations who are at risk for heart disease and is appropriate for individuals who are on beta blockers. The test was conducted on a flat, straight corridor of at least 50 feet in length (with a marked start and end line) at the Joslin Diabetes Center. The subject rested for 10 minutes prior to the test, then heart rate, blood pressure, oxygen saturation, and exertion using the Borg Rate of Perceived Exertion (RPE) scale of 6-20 was recorded. The subject was instructed to stand at the marked start line and complete as many laps as possible down and back to the end mark in six minutes. Slowing down, stopping, and resting were allowed, as necessary. Post-test heart rate, blood pressure, oxygen saturation, RPE, and number of laps completed were recorded. Total meters completed in six minutes were calculated.

Analysis of Data

A sample size of 20 was used for this cross sectional pilot study. Statistical analysis was performed using SPSS 16.0 for Windows (SPSS, Inc. Evanston, IL). Data are reported as mean and standard deviation (SD) for continuous variables and number and percentage for categorical

variables. Data were inspected for normality and considered statistically significant when the two-tailed p value was ≤ 0.05. Difference in baseline characteristics between men and women for demographic and health variables were determined by independent t-test. Pearson's correlation coefficient was used to determine the relationship between study variables including executive function (measured by the *BRIEF-A* questionnaire and the *DTEF* task), physical fitness (6MWT, DASI, and body composition), and physical activity (PAR). Multiple linear regression using executive function as the main predictor variables and physical fitness and physical activity as the dependent variables. Other variables tested in the model as confounding variables included age, gender, and HbA1C.

Chapter IV

Results and Discussion

This chapter is a presentation and discussion of the results of the statistical analysis performed to investigate whether there is an association between executive function, physical fitness, and physical activity in people with type 2 diabetes.

Results

Twenty participants (n=20) completed the demographic survey and tests of executive function, physical activity, and physical fitness. The *Behavior Rating Inventory of Executive Function – Adult (BRIEF-A)* yielded a composite score, nine clinical scale scores and two indices, and the *Diabetes Task of Executive Function (DTEF)* activity yielded a total score, a planning score, and five individual task scores. Peak VO2 was calculated from the *Duke Activity Status Index (DASI),* MET-hours per week and kilocalories per week were obtained from the *7-day Physical Activity Recall (PAR)* interview, and meters completed were calculated from the *6-Minute Walk Test (6MWT)*. BMI was calculated from weight and height measurements. Waist to hip ratio (WHR) was calculated from waist and hip circumferences. Percent body fat was obtained from a Tanita BF-250 and blood pressure was obtained from an automated blood pressure machine. Results from the various assessments and activities were coded, entered into Excel spreadsheets, and checked by a third party. All statistics were analyzed using SPSS 16.0. Data were inspected for normality and considered statistically significant when the two-tailed p value was ≤ 0.05. Differences in baseline characteristics between men and women for

demographic and health variables were determined by independent t-test and Chi-square. These demographic and health characteristics were analyzed to determine correlation with physical activity and physical fitness. Data were analyzed using bivariate Pearson's correlation to determine the direction and strength of any linear relationship between summary scores of executive function (the *BRIEF-A* Global Executive Composite (GEC) score and the *DTEF* Total score) and fitness (meters completed from the 6MWT and VO2 peak predicted from the DASI). A second bivariate Pearson correlation analysis was performed using the *BRIEF-A* and *DTEF* sub-scores, meters walked in six minutes, MET-hours per week, kilocalories per week, and VO2 peak as variables. Once correlation was estimated between variables, multiple linear regression analysis was used to determine to what extent executive function predicted fitness and physical activity levels in people with type 2 diabetes. In all of the regression models age, gender, and hemoglobin A1C were entered as confounders.

Presentation of data

The mean age of participants was 62.6±5.9 years. Fifty percent of the participants were female and the overwhelming majority of informants were White (80%; 20% Black). Participants were, on average, college-educated (15.7±2.4 years) and married (50%; 30% single; 20% divorced). Average HbA1C was 7.9%±1.5 with a mean duration of diabetes of 14.9±8.7 years. Ninety-five percent of participants were classified as overweight or obese. The average systolic and diastolic blood pressure measurement was 131±14 mmHg and 71±8 mmHg, respectively.

Table 1 presents general demographic and health characteristics of participants by gender.

Table 1. Demographic and Health Characteristics of Participants by Gender

	Women	Men	
	Mean ± SD (n=10)	Mean ± SD (n=10)	p
Age (years)	63.0 ± 4.2	63.1 ± 4.2	0.100
White (%)	(7) 70	(9) 90	0.119
Married (%)	30	70	0.195
Education (years)	15.3 ± 2.7	16.2 ± 2.2	0.900
Diabetes duration (years)	13.6 ± 9.3	16.8 ± 9.3	0.431
HbA1C	8.1 ± 2.0	7.6 ± .85	0.513
Systolic blood pressure (mmHg)	129.2 ± 15.6	134.0 ± 13.4	0.486
Diastolic blood pressure (mmHg)	66.8 ± 6.9	76.5 ± 5.8	0.004
Body Mass Index (kg/m$^{2)}$	34.0 ± 4.3	31.8 ± 4.8	0.288
Waist (inches)	43.0 ± 3.6	43.0 ± 3.6	0.413
Waist-to-hip ratio	0.90 ± .06	0.96 ± .06	0.158
Body fat (%)	44.2 ± 2.7	30.8 ± 9.6	0.011
Resting heart rate (bpm)	75.7 ± 13.3	69.3 ± 10.6	0.251

The majority of women ((7; 70%) and men (9; 90%) were White. Thirty percent of women (3) and 70% percent of men (7) were married. On average, both women and men were college educated (15.3 ± 2.7 years and 16.2 ± 2.2 years, respectively). Women had shorter mean duration of diabetes compared to men (13.6 ± 9.3 years vs. 16.8 ± 9.3 years) and higher average HbA1C levels compared to men (8.1 ± 2.0% vs.7.6 ± .85%). Average systolic blood pressure was 129.2 ± 15.6 for women and 134.0 ± 13.4 for men. There was a statistically significant difference (p= 0.004) in average diastolic blood pressure between women (66.8 ± 6.9 mmHg) and men (76.5 ± 5.8 mmHg). Mean BMI was higher for women (34.0 ± 4.3 kg/m^2) than men (31.8 ± 4.8 kg/m^2). Waist circumference was 43.0 ± 3.6 inches for women and 44.7 ± 5.2 inches for men. There was a statistically significant difference (p= 0.01) in body fat percentage between

women and men (44.2 ± 2.7 % vs. 30.8 ± 9.6). Heart rate at rest was 75.7 ± 13.3 for women and 69.3 ± 10.6 for men.

Table 2 shows gender differences between mean summary scores of executive function (*BRIEF-A* GEC and *DTEF* Total scores), physical activity (MET-hrs/week and kilocalories/week), and physical fitness (meters walked in six minutes and estimated VO2peak. There were no significant gender differences between mean summary scores of executive function or physical activity. However, differences in meters walked in six minutes and estimated VO2peak were significant (p< 0.001; p=0.034, respectively).

Table 2. Mean Summary Scores of Executive Function and Measures of Physical Activity and Physical Fitness by Gender

	Women	Men	
	Mean ± SD (n=10)	Mean ± SD (n=10)	p
BRIEF-A Global Executive Composite Score	55.3 ± 11.3	49.6 ± 11.0	0.268
DTEF Total Score	13.4 ± 5.3	15.0 ± 4.2	0.463
MET-hrs/week	17.9 ± 15.9	26.6 ± 27.6	0.401
Kilocalories/week	1596.9 ± 1451.1	2375.6 ± 2450.5	0.399
Meters walked in 6 minutes	401.0 ± 72.2	563.4 ± 77.1	0.000
Estimated VO2peak	25.0 ± 5.5	30.5 ± 5.2	0.034

Pearson's correlation coefficient was used to examine the relationship between selected demographic and health characteristics, and various measures of fitness and of physical activity, shown in **Table 3.** Age was inversely correlated with both MET-hours per week (r=-.52; p=0.02) and kilocalories per week (r=-.50; p=0.02), indicating that as age increased physical activity decreased. Diastolic blood pressure (DBP) showed strong significant positive correlation with meters walked in six minutes (r=.73;p <0.001) and estimated VO2peak (r=.47; p=0.04),

indicating that resting DBP was higher in those who walked more meters in six minutes and reported higher functional capacity. This correlation may be explained by gender differences in DBP and fitness (Table 1). DBP was on average higher in men (76.5 ± 5.8 mmHg) than women (66.8 ± 6.9 mmHg), and men walked more meter in six minutes and had higher estimated VO2peak (i.e. were more fit) compared to women.

Table 3. Pearson's Correlation Coefficients of Health Characteristics, Physical Activity, and Physical Fitness (n=20)

	Age (yrs)	HbA1C (%)	SBP (mm Hg)	DBP (mmHg)	Waist (in)	WHR	BMI (kg/m2)	BF (%)	HR (bpm)
	(n=20)	(n=20)	(n=20)	(n=20)	(n=20)	(n=11)	(n=20)	(n=11)	(n=20)
MET hrs/week	-.519*	-.033	-.302	.249	.063	.606*	-.148	-.256	.040
Kcal/week	-.502*	-.002	-.291	.267	.255	.581	.059	-.064	.164
Meters	-.236	.000	.068	.726**	-.057	.457	-.285	-.530	-.103
VO2peak	-.057	-.040	.012	.469*	-.211	.457	-.219	-716*	.161

*$p < .05$ **$p < .01$ ***$p < .001$

HbA1C = hemoglobin A1C; SBP=systolic blood pressure; DBP=diastolic blood pressure; WHR=waist-to-hip ratio; BMI=body mass index; BF%= percent body fat; MET-hrs per week=amount of time spent performing an activity x MET value of the activity; Kcal/week=kilocalories per week expended in activity of at least moderate intensity; Meters=meters walked in six minutes; VO2 peak = estimated peak oxygen uptake in ml/kg/min

Waist-to-hip ratio (WHR), an indicator of central adiposity, was positively correlated with MET-hours per week (r=.61; p=0.048) indicating that those with a greater WHR reported being more physically active. Note that MET-hours per week data were obtained from self-reported assessments and may reflect that some participants may be over-estimating weekly energy expenditure. Alternatively, some participants with greater WHR may engage in more physical activity to aid in weight loss. Percent body fat was negatively correlated with VO2peak; those with a higher percentage of body fat reported lower functional capacity.

Analysis of DTEF Scores, Fitness, and Physical Activity

Table 4 shows the results of the Pearson correlation analysis using individual scores on the *DTEF* executive function test, as well as the planning and total scores, and scores for fitness and physical activity.

Table 4. Pearson's Correlation Coefficients of *DTEF* Scores, Physical Activity, and Physical Fitness (n=20)

	Med	BG Log	Food	Exercise	BG Check	Planning	Total
MET-hrs/wk	.225	.536*	-.072	-.109	.322	.329	.374
Kilocalories/wk	.205	.544*	-.077	-.019	.313	.307	.386
Meters	.122	.431	.206	-.012	.244	.566**	.472*
VO2peak	.192	.379	-.159	-.215	.209	.389	.246

*$p < .05$ **$p < .01$ ***$p < .001$

Med= sorting medications; BG Log=scanning, correcting errors, identifying patterns; Food=categorizing food pictures by carbohydrate and fat content; Exercise=incorporating exercise into weekly schedule; BG Check=checking BG at specified time; Planning=articulate approach to tasks, use of time to complete tasks; Total= summary score; MET-hrs per week=amount of time spent performing an activity x MET value of the activity; Kcal/week=kilocalories per week expended in activity of at least moderate intensity; Meters=total meters achieved in six minute walk test; VO2 peak = peak oxygen uptake in ml/kg/min

Scores on the blood glucose log task (BG Log), which involves scanning for and identifying patterns of high and low glucose readings, were positively correlated with MET-hours per week (r=.54; p=0.02) and kilocalories expended per week (r=.54; p=0.01), indicating that those who engaged in more weekly physical active achieved higher scores on the scanning task. In addition, a moderate statistically significant correlation was found between planning scores and meters walked in six minutes (r=.57; p=0.009), indicating that those with stronger planning abilities performed better on the walking test. The total score also correlated with meters walked in six minutes (r=.47; p=0.04), which indicates that those who had greater fitness capacity achieved better overall planning, multi-tasking, and time management scores.

Based on the above correlations, multiple regressions were performed to determine whether the variables that reflected executive function predicted the physical activity or fitness variables with which they correlated, shown in Tables 4, 5, and 6 below.

Table 5 shows that although there was an association in the Pearson's correlation coefficients between blood glucose log scores, MET-hours per week, and kilocalories per week (Table 3), blood glucose log scores did not predict physical fitness or physical activity.

Table 5. Multiple Regression Analysis of *DTEF* BG Log Scores, MET-hours per week, and Kilocalories per week (n=20)

	b	t	p-value
Dependent variable: METS per week			
Sex	-.107	-.481	.638
Age	-.352	-1.320	.207
A1C	-.079	-.373	.715
BG Log	.302	1.069	.290
Dependent variable: Kilocalories per week			
Sex	-.099	-.444	.663
Age	-.314	-1.173	.259
A1C	-.076	-.356	.727
BG Log	.335	1.2081	.246

Table 6 shows that *DTEF* planning scores predicted meters (b=.40; p=.007), indicating that those with greater planning ability completed a greater number of meters in six minutes in the walk test.

Table 6. Multiple Regression Analysis of *DTEF* Planning Scores and Meters (n=20)

	b	t	p-value
Sex	-.674	-5.300	.000
Age	-.172	-1.374	.190
A1C	.19	1.244	.233
Planning	.404	3.115	.007

Table 7 shows the results of the multiple regression model that used the *DTEF* total score as the predictor variable, with meters, MET-hours per week, and kilocalories per week as dependent variables.

Table 7. Multiple Regression Analysis of *DTEF* Total Scores and Meters, MET-hours per Week, and Kilocalories per Week (n=20)

	b	t	p-value
Dependent Variable: Meters			
Sex	-.720		.000
Age	-.068	-.447	.661
A1C	.186	1.279	.220
Total	.364	2.337	.034
Dependent Variable: MET-hours per Week			
Sex	-.172	-.796	.438
Age	-.462	-1.928	.073
A1C	-.019	-.084	.934
Total	.160	.652	.524
Dependent Variable: Kilocalories per Week			
Sex	-.170	-.781	.447
Age	-.433	-1.789	.094
A1C	-.007	-.030	.977
Total	.186	.752	.464

DTEF total scores were predictive of meters (b=.36; p=.034), but were not predictive of MET-hours per week or kilocalories per week. This indicates that a higher overall *DTEF* score did not predict time spent in physical activity, but did predict fitness. Note that linear regression using VO2peak as an outcome was not performed because there was no correlation seen in the bivariate analysis.

Analysis of BREF-A Scores, Fitness, and Physical Activity

Pearson's correlation was also performed to examine the association between *BRIEF-A* Clinical Scales, Index Scores, and Global Executive Composite scores, fitness, and physical activity. **Table 8**

shows that there was a significant negative association between working memory and meters (r=-.49; p=0.03). Note that higher clinical scores on the *BRIEF-A* indicate greater dysfunction.

Table 8. Pearson's Correlation Coefficients of *BRIEF-A* Clinical Scales, Indices, Composite Score, Physical Activity, and Physical Fitness (n=20)

	Inhibit	Shift	Emotional control	Self monitor	Initiate	Working memory	Plan	Task monitor	Organize materials	BRI	MI	GEC
MET-hrs/wk	.266	-.171	-.041	-.024	-.142	-.331	-.120	-.130	-.090	-.027	-.136	-.105
Kcals/wk	.280	-.244	-.030	.073	-.198	-.359	-.138	-.116	-.141	-.011	-.117	-.118
Meters	.330	-.143	-.228	-.255	-.098	-.486*	-.163	-.195	-.293	-.120	-.264	-223
VO2peak	.195	-.090	-.210	-.120	-.109	-.393	-.032	-.095	-.289	-.100	-.292	-.173

*$p < .05$ **$p < .01$ ***$p < .001$

When multiple linear regression was performed, however, working memory no longer predicted meters walked in six minutes, as shown in **Table 9.** However a trend was seen with a p value of 0.15.

Table 9. Multiple Regression Analysis of *BRIEF-A* Working Memory Scores and Meters (n=20)

	b	t	p-value
Dependent Variable: Meters			
Sex	-.678	-4.258	0.001
Age	-.219	-1.478	0.160
A1C	.010	.067	0.947
Working Memory	-.245	-1.515	0.151

Discussion

Adequate executive functioning is essential to meet the demands of managing type 2 diabetes, including planning and maintaining an exercise routine. The proposed study hypotheses were that scores on measures of executive function would be positively correlated with physical activity and fitness in people with type 2 diabetes. The results show that certain dimensions of

executive function were significantly associated with or predictive of physical activity and fitness.

Cognitive Function and Type 2 Diabetes

One of the basic questions underlying the examination of whether there is an association between executive function, fitness, and physical activity in people with type 2 diabetes, is whether people with type 2 diabetes have diminished cognitive function simply by virtue of having the disease, and furthermore, whether these deficits include specific deficits in executive functioning. As discussed earlier, although the evidence is not conclusive, research points to a trend supporting the idea of diabetes–related deficits in cognitive performance in people with type 2 diabetes (Yeung et al., 2009). Royall et al. (2002) observed specific deficits in verbal fluency and abstract reasoning, while Yeung et al. (2009) report that some studies show diabetes-related slowing with a variety of speeded tasks (while not an executive function itself, adequate processing speed is required for adequate executive functioning). A study by Hassing et al. (2004) showed no evidence of diabetes-related cognitive performance deficits at baseline, but observed accelerated longitudinal decline in episodic memory over time. The results of the present study found that variations in scores on working memory (*BRIEF-A*), scanning and identifying patterns (*DTEF* blood glucose log task), planning (articulating a plan, multi-tasking, and time management on the *DTEF*), and total processing (performance on all five *DTEF* tasks) were significantly correlated with physical activity or fitness. Since this is a cross-sectional study, we were unable to compare scores of subjects with type 2 diabetes to scores of healthy subjects, thus it cannot be stated that people with type 2 diabetes have actual deficits (versus simply natural variations) in these dimensions of executive functioning. However, this study did

demonstrate that there are variations in executive function in people with type 2 diabetes, and that these variations are associated with physical activity and fitness.

Executive Function and Physical Activity

For people who are inactive, even small increases in physical activity are associated with meaningful health benefits. Boule et al. (2001, 2003), showed that exercise training reduced HbA1C by an amount that should decrease the risk of diabetic complication and that regular exercise has a statistically and clinically significant effect on VO2max. The present study did not observe a correlation between HbA1C and any other measures of physical activity. However, it was observed that older subjects were less active and also had greater difficulty with the blood glucose log task which involved scanning a weekly log of blood glucose readings, identifying patterns of highs and lows and checking for errors. Blood glucose log scores were not shown to be predictive of physical activity in the multiple regression models, which may indicate that physical activity impacts planning ability rather than the reverse. The question of direction and causality is an interesting and important one and will be discussed further in Recommendations for Future Research in Chapter 5.

Executive Function and Fitness

This study also found that various dimensions of executive functioning: working memory, planning, and overall cognitive processing, were associated with fitness. There was a significant correlation between *BRIEF-A* working memory and fitness (meters walked in six minutes; $r=-.49$; $p=0.03$). Working memory is the very short-term memory (lasting seconds) essential to carrying out multistep activities. People with deficits in the area of working memory can have problems remembering what comes next in a sequence of activities, and so may have

problems following complicated directions. (Specific items that relate to working memory on the *BRIEF-A* questionnaire include “I have trouble with jobs or tasks that have more than one step”, “I forget instructions easily”, and “I forget what I am doing in the middle of things.”)

The *DTEF* proposes to assess executive function by having participants complete tasks that are typical of day-to-day management of diabetes: organizing pills, integrating regular exercise sessions into a busy schedule, categorizing foods by carbohydrate content, remembering to check blood glucose, and recognizing high and low blood glucose patterns. Using individual scores from the *DTEF* in the regression model showed that the *DTEF* planning and total scores, which together reflect planning, multi-tasking, time management, and overall executive processing, predicted meters.

Investigation into whether these same associations between various dimensions of executive function and fitness would be observed in healthy subjects was beyond the scope of this thesis. However, the review by Angevaren et al. (2008) of eleven studies of aerobic physical activity programs for healthy people over the age of 55 years indicates that aerobic exercise interventions resulted in increased fitness of the trained group and an improvement in at least one aspect of cognitive function. In those studies, the largest effects were on cognitive speed, auditory and visual attention. The authors concluded that aerobic physical activities are beneficial for cognitive function in healthy older adults. Consistent with studies of people with diabetes by Royall (2002), Hassing (2004), and Yeung (2009), the cognitive functions which improved were not the same in each study and some comparisons yielded no significant results.

Limitations

Significant evidence was found to support the hypothesis that a relationship exists between executive function, fitness, and physical activity, but that there are some limitations to the generalizability of this study. The study sample was a convenience sample of Joslin Diabetes Center patients with type 2 diabetes and therefore does not reflect the general population of all people with type 2 diabetes, those who have other types of diabetes, or people without the disease. The small sample size (n=20) limited the power of the study. Finally, the *DTEF* is a newly developed assessment tool that has not been validated. However, the *DTEF* was developed using the same paradigm as two well established assessments of executive function (the 6 Element Task and the Hotel Task) and it has been reviewed by a multi-disciplinary team including clinical and research psychologists, a neuropsychologist, a cognitive psychologist, nurses, and a physician. Preliminary results evaluating the psychometric properties of the *DTEF* strongly suggest that it effectively measures diabetes-specific planning and time management strategies.

Practical Application of Findings

By having a better understanding of the basis for low exercise adherence, it will be possible to develop more effective interventions to help people with type 2 diabetes initiate and maintain exercise. Researchers continue to study both the role of exercise in diabetes management and barriers to exercise maintenance; a variety of lifestyle interventions have been developed to support people in adopting more active lifestyles. Although many of these interventions are effective in the short term, long term adherence rates are low and the fact remains that many adults with type 2 diabetes are not nearly as active as they need to be.

Perhaps understanding the association between fitness, physical activity and cognition, especially executive function, could lead to the development of more effective interventions. If one considers the complexity of many exercise recommendation that require remembering various guidelines regarding exercise modalities, intensity, duration, frequency sets, repetitions, correct form and the use of various types of cardiovascular and resistance training equipment, the benefit of strengthening working memory, planning, multitasking, and time management ability becomes apparent. Some people with type 2 diabetes and deficits in executive function may need more time to learn certain exercises, so a class setting where participants are learning together as a group may be more frustrating and less effective for that individual than working one-on-one with an exercise physiologist. If we know that a person has deficits in working memory and therefore may have challenges in remembering all of the steps in a particular exercise plan, the material could be broken down into smaller modules, condensed into fewer steps, or presented visually.

The findings of this study have relevance when we consider the toll that diabetes can take on the nearly 24 million people in the United States who have this disease, and the millions who will be diagnosed in the future. We know that with proper nutrition and physical activity, type 2 diabetes is a mostly preventable disease and those who already have it can minimize the potentially devastating impact of diabetes complications by adopting a healthy lifestyle. Therefore, a better understanding of the factors that may contribute to integrating exercise into people's lives is imperative and this investigation provides some interesting findings to investigate further.

Chapter V

Summary, Conclusions, and Recommendations

Summary

The purpose of this study was to investigate the association between executive function, physical activity, and physical fitness in people with type 2 diabetes. Twenty participants (mean age 62.6±5.9 years) with type 2 diabetes were studied. Subjects were fifty percent female; 80% White, 20% Black, mostly college-educated and married, with a mean HbA1C of 7.9%±1.5 and a mean duration of diabetes of 14.9±8.7years. The majority of subjects had a body mass index classified as obese (≥ 30 kg/m^2), with an average systolic blood pressure measure of 131±14 mmHg and diastolic blood pressure of 71±8 mmHg. Subjects completed a demographic survey; tests of executive function, consisting of the *Behavior Rating Inventory of Executive Function – Adult (BRIEF-A)* and the *Diabetes Task of Executive Function (DTEF)*; a physical activity self-report interview, the *7-day Physical Activity Recall (PAR)*; and assessments of physical fitness consisting of the *Duke Activity Status Index (DASI)* questionnaire and the *6-Minute Walk Test (6MWT).* BMI and waist to hip ratio were calculated and percent body fat blood pressure was obtained. Data was analyzed with SPSS using Pearson's correlation coefficient and multiple linear regression. *BRIEF-A* working memory scores were significantly correlated with meters walked in six minutes (r=-0.49; p=0.03), but did not predict VO2peak, meters walked in six minutes, MET-hours per week, or kilocalories per week. Significant correlation was found between *DTEF* blood glucose log scores and MET-hours per week (r=0.54; p=0.02), and kilocalories per week (r=.54; p=0.01) but did not predict VO2peak, meters

walked in six minutes, MET-hours per week, or kilocalories per week. *DTEF* planning scores predicted meters walked in 6 minutes (b=.404; p=.007), as did *DTEF* total scores (b=.364; p=.034). The results of this study demonstrate that intra-individual variations in working memory, planning, multitasking, and time management abilities are associated with weekly physical activity and fitness in people with type 2 diabetes.

Conclusions

The following conclusions seem warranted based on the findings obtained in this study:

1) There was significant correlation between *DTEF* blood glucose log scores and MET-hours per week, and kilocalories per week, but no correlation was found between other *DTEF* scores or any *BRIEF-A* scores with MET-hours per week or kilocalories per week. Therefore research hypothesis one is partially accepted.
2) There was significant correlation between *BRIEF-A* working memory scores, *DTEF* planning scores, and *DTEF* total scores and meters walked in six minutes, and but no correlation between other *BRIEF-A* and *DTEF* scores and meters, or with VO2peak and any *BRIEF-A* or *DTEF* scores. Therefore research hypothesis two is partially accepted.

Recommendations for Future Study

The results of this study showed statistically significant correlations between certain aspects of executive function and measures of physical activity and fitness. Based on these results, a longitudinal study would be needed to determine whether there is a causal relationship between any of these measures of executive function and physical activity or fitness.

This study relied on participants' self reporting of daily and weekly activity type, intensity, and duration to determine physical activity (MET-hours per week and kilocalories per week). Although the *PAR* has been validated as a suitable assessment of physical activity for research purposes, future research should consider using pedometers or accelerometers to obtain more accurate objective recordings of activity.

Future studies should also include a greater number of subjects, more minority participants, and participants with a broader range of HbA1C levels to increase the generalizability of the results.

Since this study design did not use a control group, only intra-individual differences in executive function, physical activity, and fitness were observed; a study using a matched control group without diabetes would clarify the question of whether the variations and correlations seen in this study are also present in a healthy population.

APPENDIX A

Human Subjects Research Applications

i. Joslin Diabetes Center IRB Human Subjects Research Application and Consent Form
ii. Northeastern University IRB Human Subjects Research Application

APPENDIX B

Demographic Survey and Assessments

i. Demographic Survey

ii. Executive Function
   - Behavior Rating Inventory of Executive Function -Adult (BRIEF-A)
   - Diabetes Task of Executive Function (DTEF)

iii. Physical Activity
   - 7-Day Physical Activity Recall

iv. Physical Fitness
   - Duke Activity Status Index (DASI)
   - 6-Minute Walk Test (6MWT)
   - Anthropometric Measurements

REFERENCES

Allan, J. L., Johnston, M., & Campbell, N. (2008). Why do people fail to turn good intentions into action? The role of executive control processes in the translation of healthy eating intentions into action in young Scottish adults. *BioMed Central Public Health, 8*(123).

Allen, K. V., Frier, B. M., & Strachan, M. W. J. (2004). The relationship between type 2 diabetes and cognitive dysfunction: longitudinal studies and their methodological limitations. *European Journal of Pharmacology, 490*, 169-175.

American Diabetes Association Standards of Care (2008). *Diabetes Care, 31*(s1), s22.

American Thoracic Society. (20020. ATS Statement: Guidelines for the six-minute walk test. *American Journal of Respiratory Critical Care Medicine, 166*, 111–117.

Åke Sjöholm, T. N. (2006). Inflammation and the etiology of type 2 diabetes. *Diabetes/Metabolism Research and Reviews, 22*(1), 4-10.

Albright, A., Franz. M., Hornsby, G., Kriska, A., Marrero, D., Ullrich, I., & Verity L.S. (2000). American College of Sports Medicine Position Stand: Exercise and type 2 diabetes. *Medicine and Science in Sports and Exercise, 32*(7), 1345-1360.

Angevaren, M., Aufdemkampe, G., Verhaar, H., Aleman, A., & Vanhees, L. (2008). Physical activity and enhanced fitness to improve cognitive function in older people without known cognitive impairment. *Cochrane Database of Systematic Reviews, 2*. Art. No.: CD005381.

Beverly E.A., Weinger K. (2008). *The Diabetes Task of Executive Functioning*. In preparation.

Blair, S., Haskell, W., Ho, P., Paffenbarger, R., Vranizan, K., Farquhar, J., et al. (1985). Assessment of habitual physical activity by a seven-day recall in a community survey and controlled experiments. *American Journal of Epidemiology, 122*, 794-804.

Boule, N., Haddad, E., Kenny, G., Wells, G., & Sigal, R. (2001). Effects of exercise on glycemic control and body mass in type 2 diabetes mellitus: a meta-analysis of controlled clinical trials. *Journal of the American Medical Association, 286*(10).

Boule, N., Haddad, E., Kenny, G., Wells, G., & Sigal, R. (2003). Meta-analysis of the effect of structured exercise training on cardiorespiratory fitness in type 2 diabetes mellitus. *Diabetologia, 46*, 1071-1081.

Centers for Disease Control and Prevention. National Center for Health Statistics. National Health and Nutrition Examination Survey Data. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention. http://www.cdc.gov/nchs/nhanes/Databriefs.htm.

Centers for Disease Control and Prevention. (2008) National diabetes fact sheet: general information and national estimates on diabetes in the United States, 2007. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention.

Church, T. S., Cheng, Y. J., Earnest, C. P., Barlow, C. E., Gibbons, L. W., Elisa L. Priest, et al. (2004). Exercise capacity and body composition as predictors of mortality among men with diabetes. *Diabetes Care, 27,* 83-88.

Colberg, S. R., Somma, T., & Sechrist, S. (2008). Physical activity participation may offset some of the negative impact of diabetes on cognitive function. *Journal of the American Medical Directors Association, 9,* 434-438.

Cukierman, T., Gerstein, H. C., & Williamson, J. D. (2005). Cognitive decline in diabetes: a systematic overview and meta-analsis of observational studies. American Diabetes Association, *Diabetes Pro*. http://professional.diabetes.org.

Davis, J. N., Hodges, V. A., & Gillham, M. B. (2006). Physical activity compliance: differences between overweight/obese and normal-weight adults. *Obesity, 14,* 2259-2265.

Durstine, J. L. (Ed.). (2007). *ACSM's exercise management for persons with chronic diseases and disabilities.* Champaign, IL: Human Kinetics.

Ebady, S. A., Arami, M. A., & Shafigh, M. A. (2008). Investigation on the relationship between diabetes mellius type 2 and cognitive impairment. *Diabetes Research and Clinical Practice, 82,* 305-309.

Gioia, G. A., Isquith, P. K., & Steven C. Guy. (n.d.). *BRIEF: Behavior Rating Inventory of Executive Function*. Psychological Assessment Resources, Inc.

Grodstein, F., Chen, J., Wilson, R. S., & Manson, J. E. (2001). Type 2 diabetes and cognitive function in community-dwelling elderly women. *Diabetes Care, 24*(6), 1060-1065.

Hall, P. A., Fong, G. T., & Epp, L. J. (2008). Executive function moderates the intention-behavior link for physical activity and dietary behavior. *Psychology & Health, 23*(3), 309-326.

Hltaky, M.A., Boineau, R.E. Higginbotham, M.B., Lee, K.L.,Mark, D.B., Califf, R.M., et al. (1989). A brief self-administered questionnaire to determine functional capacity (The Duke Activity Status Index). *The American Journal of Cardiology, 64*, 651-654.

Hassing, L., Grant, M., Hofer, S., Pedersen, N., Nilsson, S., Berg, S., et al. (2004). Type 2 diabetes mellitus contributes to cognitive decline in old age: a longitudinal population-based study. *Journal of the International Neuropsychological Society, 10*, 599-607.

Jacobs-Issac, R. (2008). ENDO 2008, the Endocrine Society 90th Annual Meeting.

Jae, S. Y., Heffernan, K. S., Lee, M.K., Fernhall, B., & Park, W. H. (2008). Relation of cardiorespiratory fitness to inflammatory markers, fibrinolytic factors, and lipoprotein (a) in patients with type 2 diabetes mellitus. *The American Journal of Cardiology, 102*(6), 700-703.

Kim, Y. S., Secher, N. H., & van Lieshout, J. J. (2008). Resistance exercise and control of cerebral blood flow in type 2 diabetes. *Diabetologia, 51*(9), 1755-1756.

Kirk A, M. N., MacIntyre P, Fisher M. (2003). Increasing physical activity in people with type 2 diabetes. *Diabetes Care, 26*(4), 1186-1192.

Koenigsberg, M. R., Bartlett, D., & Cramer, S. (2004). Facilitating treatment adherence with lifestyle changes in diabetes. *American Family Physician, 69*, 309-324.

Manschot, S. M., Biessels, G. J., de Valk, H., Algra, A., Rutten, G. E., van der Grond, J., et al. (2006). Brain magnetic resonance imaging correlates of impaired cognition in patients with type 2 diabetes. *Diabetes, 55*, 1106-1113.

Manschot, S. M., Biessels, G. J., de Valk, H., Algra, A., Rutten, G. E., van der Grond, J., et al. (2007). Metabolic and vascular determinants of impaired cognitive performance and abnormalities on brain magnetic resonance imaging in patients with type 2 diabetes. *Diabetologia, 50*, 2388-2397.

Morrato, E., Hill, J., Wyatt, H., Ghushchyan, V., & Sullivan, P. (2006). Are health care professionals advising patients with diabetes or at risk for developing diabetes to exercise more? *Diabetes Care, 29*(3), 543-548.

Morrato, E. H., Hill, J. O., Wyatt, H. R., Ghushchyan, V., & Patrick W. Sullivan, P. (2007). Physical activity in u.s. Adults with diabetes and at risk for developing diabetes. *Diabetes Care, 30*, 203-209.

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behaviour. In R. J. Davidson, G. E. Schwartz & D. Shapiro (Eds.), *Consciousness and self-regulation* , *4*, 1-18. New York: Plenum Press.

Royall, D. R., Lauterbach, E. C., Cummings, J. L., Reeve, A., Rummans, T. A., Kaufer, D. I., et al. (2002). Executive control function: a review of its promise and challenges for clinical research. *Journal of Neuropsychiatry and Clinical Neurosciences, 14*(4), 377-405.

Sallis, J. F., Haskell, W.L., Wood, P.D., Fortmann, S.P., Rogers, T., Blair, S.N., et al. (1985). Physical activity assessment methodology in the Five-City Project. *American Journal of Epidemiology, 121,* 91-106.

Schillerstrom, J. E., Horton, M. S., & Royall, D. R. (2005). The impact of medical illness on executive function. *Psychosomatics, 46*(6), 508-516.

Sigal, R., Kenny, G., Wasserman, D., Castaneda-Sceppa, C., & White, R. (2006). Physical Activity/Exercise and Type 2 Diabetes: A Consensus Statement from the American Diabetes Association. *Diabetes Care 29*(6), 1433-1438.

Stagnitti, M. N. (2001). Statistical Brief #34: The Prevalence of Obesity and Other Chronic Health Conditions among Diabetic Adults in the U.S. Community Population.

Wing, R., Jakicic, J., Neiberg, R., Lang, W., Blair, S., Cooper, L., et al. (2007). Fitness, fatness, and cardiovascular risk factors in Type 2 Diabetes: Look AHEAD Study. *Medicine and Science in Sports and Exercise, 39.*