THE EFFECT OF PHYSICAL ACTIVITY COUNSELING ON DIABETICS' MOBILITY: RESULTS OF A SECONDARY ANALYSIS

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ABSTRACT

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The preservation of mobility is essential for maintaining an independent and active lifestyle in old age. However, diabetes greatly increases older people's susceptibility to mobility loss, leading to an increased risk of dependence. Given the increased prevalence of diabetes with age, and the increasing incidence of the disease worldwide, public health initiatives for preventing mobility loss with age must also prove effective for diabetics.

The screening and counseling for physical activity among older people (SCAMOB) study examines the effectiveness of physical activity counseling for the prevention of mobility loss in an older population. Although the cohort as a whole has shown positive results, the effectiveness of the intervention among diabetics, particularly type 2 diabetics, is still unknown. For this reason, I proposed a secondary analysis of the SCAMOB study and 2-year follow-up data, which will evaluate the effectiveness of the SCAMOB intervention for the prevention of mobility loss in older type 2 diabetics versus non-diabetics. The primary findings of this study were as follows: (1) Physical activity counseling does not improve diabetics' habitual physical activity level or mobility; however, it can help diabetics maintain current levels of mobility, by preventing decline in 2 km walking ability. (2) Physical activity counseling influences more change among non-diabetics than it does among diabetics, in regards to both habitual physical activity level and mobility outcomes.

Directions for future research include similar analyses in a more suitable sample, as well as the investigation of supplementary intervention strategies for the reversal of mobility loss in older type 2 diabetics.

Keywords: physical activity counseling, SCAMOB, type 2 diabetes, older people, mobility loss

ABBREVIATIONS

ACSM	American College of Sports Medicine
ADA	American Diabetes Association
AGE	Advanced glycation end-product
BADL	Basic activities of daily living
CDC	Centers for Disease Control and Prevention
CHD	Coronary heart disease
DSM	Diabetes self-management
FDA	Finnish Diabetes Association
FPG	Fasting plasma glucose
HbA1c	Glycosylated hemoglobin
ICF	International Classification of Functioning, Disability, and Health
IDF	International Diabetes Federation
MMSE	Mini-Mental State Examination
NDIC	National Diabetes Information Clearinghouse
OGTT	Oral glucose tolerance test
RCT	Randomized controlled trial
ROS	Reactive oxygen species
SCAMOB	Screening and counseling for physical activity among older people
SD	Standard deviation
T1DM	Type 1 diabetes mellitus
T2DM	Type 2 diabetes mellitus
WHO	World Health Organization

CONTENTS

1 INTRODUCTION

Existing research has consistently linked physical activity to healthy aging. However, habitual physical activity has been shown to substantially decrease with age (Stephens & Caspersen 1994). In a longitudinal study of habitual physical activity among older Dutch men, physically active time decreased by 33% over 10 years, independent of cohort effects and functional status (Bijnen et al. 1998). Given this adverse trend, the promotion of sustained physical activity in older individuals represents an international research priority (Futurage 2011). The realization of this research goal will be beneficial in many ways. Most importantly, it will help older people to maintain independence and postpone institutionalization for as long as possible (Swedish National Institute of Public Health 2006). This will produce many secondary benefits for society by reducing healthcare costs, improving quality of life, and improving economic productivity in early old age (Futurage 2011).

The promotion of habitual physical activity in the older population is complicated by the high prevalence of numerous chronic conditions that can affect physical performance, such as type 2 diabetes (T2DM). Despite diabetics' decreased abilities to and decreased tendencies toward exercise, physical activity is a key component of diabetes self-management (DSM) that helps to prevent diabetic complications and reduce diabetes-related mortality. This makes the promotion of physical activity all the more important for this portion of the older population. In a cross-sectional study of 846 older Japanese individuals with T2DM, higher levels of physical activity were associated with lower prevalence of metabolic syndrome, a condition that contributes to increased cardiovascular morbidity and mortality among older diabetics. The prevalence of metabolic syndrome was not associated with excessive caloric intake. This suggests that increased physical activity, even if not combined with a restricted calorie diet, can help older diabetics to improve DSM, age healthily, and maintain independence (IIjima et al. 2012).

As previously mentioned, the establishment of effective methods for the promotion of habitual physical activity within the older population is an international research imperative. One such study was started at the University of Jyväskylä in 2003. The screening and counseling for physical activity among older people (SCAMOB) study investigates the effectiveness of physical activity counseling for the promotion of physical activity and prevention of mobility loss within the senior population. Results for the study have been positive overall; however, the intervention's efficacy for promoting physical activity and preventing mobility loss in the cohort's most vulnerable participants – diabetics – is hitherto unexamined. For this reason, the present study was conducted to determine the effectiveness of the SCAMOB study intervention for promoting physical activity and preventing mobility loss among older diabetics.

2 AGING AND MOBILITY LOSS

It is well known that aging is associated with mobility loss, even in the absence of diabetes. Both diabetic and non-diabetic mobility loss follow predictable patterns, which can be summarized using disablement models. Although the progression of mobility loss is easily characterized, the definition of mobility loss is in contrast highly variable, and largely depends upon the testing methods available. On the other hand, mobility has been generally defined as the ability to move oneself (whether on foot, with assistive devices, or using transportation) within community environments (Webber et al. 2010). Therefore, even if functional definitions are highly variable, mobility loss can be broadly understood as a decline in the ability to move oneself within community environments.

2.1 Theoretical models

Although multiple models of the disablement process exist, the Nagi model of disablement and the international classification of functioning, disability, and health (ICF) are two of the most widely used. Both employ similar concepts, but certain aspects unique to each serve to complement each other in the present study of mobility loss.

2.1.1 The Nagi model of disablement

The Nagi model is widely used and accepted throughout the US, and highly valued as a theoretical pathway, given its validation in multiple data sets (Guralnik & Ferrucci 2009). In the model, Nagi (1965, 1991) describes the disablement process as a progression of "active pathology" at the cellular level to the point that it affects higher levels of the organism. Active pathology can denote any range of health conditions, including diabetes and cellular senescence. When active pathology manifests at the tissue, organ, or body system level, this is known as a functional impairment (Jette 1994). In the case of age-related mobility loss, an example of functional impairment would be the decrease in muscle strength resulting from senescent processes, such as muscle atrophy (an active pathology).

When a functional impairment begins to affect individual performance, a functional limitation is evident. For example, decreased muscle strength may result in decreased gait speed, or an inability to climb stairs. These functional limitations only constitute a disability once they begin to affect the individual's ability to perform socially defined tasks. For example, when decreased gait speed prevents an individual from using the crosswalk in the time allotted, that individual's functional limitation has progressed to the level of disability.

Successful performance of socially defined basic activities of daily living (BADL) is contingent upon basic mobility. Therefore, once age-related mobility loss has begun to affect one's ability to live independently, a disability is evident (Nagi 1965). The present study will examine mobility loss as occurring at the level of functional limitation, since it does not account for the social expectations implied by disability. Rather, the current study follows an intervention designed to reduce functional limitation, and thereby prevent disability.

2.1.2 The international classification of functioning, disability, and health

Given that the ICF is still in its infancy, it has yet to realize its full potential as a conceptualization of disability (Jette 2009). However, even if fully developed, the ICF cannot completely replace the Nagi model since it does not present a dynamic process model of disability (Institute of Medicine 2007). As a classification scheme, the ICF merely provides a framework for codifying factors related to disability (Freedman 2009). Even so, this classification scheme is capable of enlightening the current investigation through its more explicit emphasis on the mediating role of socio-environmental factors, in regards to the degree of disability experienced (Guralnik & Ferrucci 2009; World Health Organization 2002). This emphasis clarifies an important caveat for the consideration of disability prevention in the present study. The ICF suggests that a comprehensive study of disability prevention requires the consideration of multiple socio-environmental factors, most of which are beyond the scope of this study. Therefore, results from the current study cannot be considered fully representative of disability status. The present study only examines the effects of an intervention on functional limitations; thus, in the absence of additional socio-environmental considerations, the intervention's ultimate effect on disability can only be inferred. However, since the Nagi model suggests that functional limitation is a precursor to disability, directional influences on disability can be deduced for the intervention (Nagi 1965).

The present study will utilize the terminology and process presented by the Nagi model, while recognizing the potential influences of environmental and societal factors as suggested by the ICF.

2.2 Definition and assessment of mobility loss

As previously mentioned, the definition of mobility loss is highly variable and largely depends on the testing methods available. Even so, there are several methods that have achieved common use within research applications. These are briefly reviewed here.

Traditionally, definitions of mobility are set using self-reports and/or performance-based assessments. Self-reported measures have long served as a mainstay for mobility measurement, in both clinical and research practice, and are advantageous for numerous reasons. For instance, they are quickly and easily administered, and can readily differentiate between individuals capable of independent living and those at risk for dependence and disability (Guralnik et al. 1989). As such, self-reported mobility measures are particularly useful for measuring disability according to the Nagi model. However, self-reported mobility measures are limited in their ability to detect clinically significant change in nondisabled individuals, which limits their usefulness when studying relatively healthy populations. Furthermore, self-reports are influenced by culture, level of education, and language, thereby complicating their use in international studies. In these instances, performance-based assessments are particularly useful, given their high face validity, high reproducibility, and broad comparability across cultures. Additionally, the ability of performance-based assessments to detect small and oftentimes subclinical differences in mobility serves to improve the sensitivity of longitudinal studies. This enables more precise study of functional limitations, as defined by the Nagi model. (Hoeymans et al. 1996)

Based on examination of previous studies, it appears that common points of inquiry for self-reports of mobility difficulty include difficulty: walking a quarter of a mile (~400 m), rising from a chair, climbing stairs, and completing mobility-related BADL. While self-reports aid in the assessment of overall mobility, the use of performance-based tests allows researchers to quantitatively examine the progression of functional limitation, using measures such as walking speed, balance, and leg strength. Some of the most common assessments include 6-meter walking speed, standing balance using semi-tandem, full-tandem, and single-leg stands, 5 chair stands, and the narrow walk test. (Figaro et al. 2006; De Rekeneire et al. 2003; Resnick et al. 2002; Volpato et al. 2002)

3 DIABETES AND AGING

Diabetic pathology and biological aging hold many characteristics in common. Diabetes often accelerates and exacerbates aging processes, in addition to increasing the risk of age-related conditions. Furthermore, diabetes is considerably more prevalent among older individuals. This close association between diabetes and aging complicates an etiological determination for diabetic mobility loss. In other words, since it is possible for aging, diabetic pathology, and shared sequelae to contribute to mobility loss simultaneously, their unique effects are difficult to disentangle. For this reason, diabetic mobility loss must be recognized as a highly multifactorial process, which the current study can only partially explore (in the next chapter). However, in order to better understand the synergism between diabetes and aging that exacerbates mobility loss, current theories and shared pathophysiology will be explored.

3.1 Definition and diagnosis of diabetes

Diabetes is a metabolic disease that affects the body's ability to utilize glucose. This difficulty arises because the body no longer makes enough insulin or does not respond to it correctly. Of the different types of diabetes, T2DM is the most common worldwide, and makes up 85% to 90% of diabetes cases in both the US and Finland (Finnish Diabetes Association 2012; National Diabetes Information Clearinghouse 2011). Type 1 diabetes (T1DM), formerly known as juvenile diabetes, is most prevalent among children, and is usually the result of autoimmune destruction of insulin-producing cells in the pancreas. This causes relative or absolute insulin deficiency, and usually necessitates a lifelong insulin regimen. (International Diabetes Federation 2011) Since T2DM is the most common form among older individuals, it will be the sole type addressed in this literature review. Numerous methods are used to ascertain diabetic status, depending on the resources available, time allotted, and importance of diabetic status to the study. Depending on the method of 'diagnosis' used, the definition criteria for diabetes can vary considerably.

If diabetic status is central to study aims, direct diagnosis using repeated blood tests is advisable, given the high rate of undiagnosed diabetes – among individuals aged 20-79, the IDF estimates that 42% and 28% of diabetes cases are undiagnosed, in Finland and the US, respectively (IDF 2012). The 3 diagnostic tests most commonly used to ascertain diabetes status are fasting plasma glucose (FPG), the oral glucose tolerance test (OGTT), and glycosylated hemoglobin (HbA1c). Although relatively inexpensive and easily performed in tandem, FPG and OGTT can complicate study design, due to the fasting requirement. Alternatively, the use of HbA1c does not require fasting, but tradeoffs include decreased sensitivity and higher cost (American Diabetes Association 2012). Results from these tests are then categorized into normal, pre-diabetic, and diabetic ranges, as stipulated by guidelines from the ADA (2012) or the WHO & IDF (2006). It should be noted that these tests do not differentiate between diabetes types; for this kind of determination, patient histories must be consulted.

If diabetes is not the central focus of a study, or if resources are particularly limited, a self-report can replace physiological testing. For diabetes, a self-report may be supplemented with inquiries about type or medications used, or confirmed using FPG, OGTT, or HbA1c (Figaro et al. 2006; De Rekeneire et al. 2003; Resnick et al. 2002; Volpato et al. 2002).

3.2 Diabetic epidemiology in older people

Although diagnoses are being made at progressively younger ages, T2DM is still largely considered an age-related disease. In Finland, the IDF estimates that 2 out of 3 adult diabetics (aged 20-79) are between the ages of 60 and 79 (IDF 2012). In the US, diabetes prevalence jumps from 11.3% to 26.9% when comparing rates between the 20+ and 65+ age groups. Furthermore, the same study indicates that 50% of Americans aged 65+ have pre-diabetes, implying that less than 1 in 4 American seniors exhibits normoglycemia. (Centers for Disease Control and Prevention 2011) This clearly links aging and diabetes, and suggests further physiological similarities between them.

3.3 Theoretical basis for epidemiological and pathological parallels

As discussed previously, advanced age is a well-known risk factor for T2DM. This epidemiological association is thought to be due to physiological changes with age that resemble the early pathogenesis of diabetes. (De Fronzo 1981; Reaven 2003; Wilson et al. 1986) The secretion of insulin in response to glucose decreases with age, as a result of numerous cellular mechanisms (Chen et al. 1985; Gong & Muzumdar 2012). Simultaneously, age-related insulin resistance increases insulin requirements, which the aged individual is unable to meet (van der Heide et al. 2006). These factors contribute to impaired glucose homeostasis and glucose intolerance in the older individual, thereby causing plasma glucose levels to steadily increase with age. This in turn decreases insulin production by producing glucose toxicity in insulin-producing cells, further accelerating deviation from normoglycemia. (Gong & Muzumdar 2012; Stumvoll et al. 2005) Once insulin action is no longer sufficient to keep plasma glucose levels within normal range, overt diabetes can develop (Weyer et al. 1999).

Some authors suggest that this relationship is not due to aging per se, but is rather the result of factors closely correlating with age, namely increased visceral fatness, decreased physical activity, and increased prevalence of sedentary lifestyles (Bryhni et al. 2003; Imbeault et al. 2003; Reaven 2003). However, others contend that these correlatives are not sufficient in themselves for explaining the link between diabetes and aging (Catalano et al. 2005; Iozzo et al. 1999). In any case, it is clear that diabetic pathology and biological aging interact on numerous levels, necessitating the use of theoretical models to make sense of the synergistic relationship.

Although the association between diabetes and aging may arise from several sources, similarities and links between those sources have prompted the application of several theories, including epigenetic theory and the glycation theory of aging. These theories incorporate a life course perspective, and thus are not mutually exclusive. Rather, when considered as a whole, these theories help to elucidate the complex relationship between diabetes and aging.

3.3.1 The life course perspective

The life course perspective is incorporated into many theories of aging, since most consider physiological aging as a lifelong development with a trajectory largely dictated by individual choices. Such a perspective allows researchers to examine personal choice, such as physical activity level, and measure the effects of that choice on various outcomes, such as diabetes incidence and mobility loss. However, this perspective also acknowledges the influence of factors external to the individual, such as cultural, socioeconomic, and historical factors. These factors alter life course trajectories because they dictate which choices are available to the individual. In turn, this can result in cumulative health disadvantages, and predispose certain individuals to health conditions in later life. (Elder et al. 2003) This idea is also reflected in the ICF, as discussed previously.

This perspective is relevant to the current study because it points to one potential explanation of the association between diabetes and aging. As stated by Wilson et al. (1986): “Individuals now have a longer life span during which to become diabetic, live with diabetes, and die of diseases associated with the diabetic process.” In other words, increased longevity and age increases the likelihood that individual choices will affect health status. This emphasis on age as a risk factor, due to the increased exposure it represents, is unique to the life course perspective (Hogan & Goldscheider 2003). Furthermore, the influence of the life course perspective on study design and data analysis is apparent, given the use of longitudinal data to examine the accumulation of health advantages and disadvantages.

3.3.2 Epigenetic theory

Epigenetics is a recently developed field within biology that examines the regulatory effects of environmental factors on gene expression. Various environmental factors influence individual phenotypes by dictating which parts of the genome will be expressed, and to what degree. These alterations in expression can remain in place for decades or even become permanent – thus illustrating a mechanism by which cumulative disadvantage and personal choices throughout the life course can affect aging processes at the cellular level. (Rodenhiser & Mann 2006)

However, epigenetic influence is not unique to aging. In 1991, this theory was applied to demonstrate a link between T2DM incidence and poor prenatal nutrition as evidenced by low birth weight (Hales et al. 1991). In their subsequent thrifty phenotype hypothesis, the authors asserted that poor pancreatic development programs a low basal metabolic rate, as preparation for an *ex utero* environment assumed hostile to life (Hales and Barker 1992). However, subsequent overabundance of *ex utero* nutrition overwhelms the metabolism set during *in utero* development, making the individual that much more susceptible to impaired glucose tolerance and T2DM in later life (Hales & Barker 2001).

In relation to the current study, epigenetic theory and the thrifty phenotype hypothesis serve to reiterate the significance of environmental exposures to ultimate health outcomes, and thus the importance of following them in the study. Furthermore, they demonstrate that mechanisms influencing the aging process also influence the development of T2DM.

3.3.3 The glycation theory of aging

Advanced glycation end-products (AGEs) result from the non-enzymatic glycation and oxidation of proteins and lipids throughout the body. Their concentrations generally increase with age, but they become particularly pronounced under hyperglycemic conditions, such as those found in diabetics. In fact, HbA1c, which is a commonly used indicator of long-term diabetes management, is itself an early glycation end-product, and thus a precursor to AGEs. (Ramasamy et al. 2005) Additionally, AGEs are known stimulants of pro-inflammatory cytokines and reactive oxygen species (ROS), which have also been implicated in the aging process (Uribarri et al. 2007). For these reasons, glycation has been explored as a possible causative link between aging and diabetes incidence (Ramasamy et al. 2005). Glycation of proteins and lipids has also been linked to the development of the long-term complications of diabetes, including nephropathy, neuropathy, and impaired healing (Gugliucci 2000; Uribarri et al. 2007).

The glycation theory is important to this study because it demonstrates the close relationship between senescent processes and diabetic pathology. Furthermore, it suggests that physical activity counseling will produce better mobility outcomes at follow-up, by helping diabetics reduce their plasma glucose levels (Colberg & Sigal 2011).

4 DIABETES AND MOBILITY LOSS: A MULTIFACTORIAL PROCESS

As previously indicated, diabetic pathology is multifactorial, and can thus contribute to mobility loss at many levels through complications evident in various body systems. Additionally, common comorbidities can exacerbate these complications, further compounding functional limitation. In order to elucidate the mechanisms by which the SCAMOB intervention could improve diabetic mobility outcomes, relevant diabetic complications and comorbidities will be discussed.

Extensive literature (Beisswenger 2012; Bruce et al. 2003; Volpato et al. 2002) has already confirmed that diabetics usually face multiple chronic conditions, further compounding mobility loss. Debate as to whether or not diabetic mobility loss arises due to diabetes per se (Gregg et al. 2000; De Rekeneire et al. 2003; Resnick et al. 2001) or due to associated comorbid conditions (Schwartz et al. 2002; Volpato et al. 2002) is still ongoing. Since the intervention can potentially impact the effects of both diabetic complications and comorbidities, this debate will not be addressed in the present study. Instead, both complications and comorbidities will be considered equivalent targets for preventing diabetic mobility loss. Additionally, potential targets for the intervention will be noted.

4.1 Microvascular complications and comorbidities

The microvascular complications of diabetes provoke mobility loss by causing localized functional impairment in the eyes and nerves. Vision can deteriorate as a result of diabetic retinopathy, which is usually present to some extent in all diabetes cases (ADA 2012). Although progression of the condition is slow, it can sporadically impair vision, in addition to causing retinal detachment and permanent blindness in advanced stages (Home 1993). In the US, this is the leading cause of incident blindness in adults (CDC 2011). In addition to retinopathy, a study by Gregg et al. found that diabetics were significantly more likely than non-diabetics to suffer from visual impairment; among women, diabetes nearly doubled the prevalence of conditions such as cataracts and macular degeneration (2000). Poor eyesight contributes to mobility difficulties in numerous ways. Psychologically, it increases individuals' fear of falling, which can decrease mobility by discouraging physical activity (Coyne et al. 2004; Wang et al. 2012). Additionally, visual impairment poses a physical threat to mobility, since it increases the risk of injurious accidents among older people (Kulmala et al. 2008).

Diabetic neuropathy is also quite common, with 60% to 70% of all diabetics experiencing it to some extent. All 4 types of diabetic neuropathy – peripheral, autonomic, proximal, and focal – can impact mobility, albeit in different ways. Peripheral neuropathy is the most common type, and most clearly affects diabetic mobility through its affects on extremities. It can cause numbness, sensitivity, or pain in the feet, thereby precipitating losses in balance and coordination and increasing fall risk (Schwartz et al. 2002). Gait abnormalities and foot deformities can also develop as a result. Additionally, altered gaits can cause sores on paresthetic portions of the foot that become infected easily. (NDIC 2009) Autonomic neuropathy further contributes to infection risk by impairing the diabetic's ability to sweat, which causes extremely dry skin and increases the likelihood of foot ulceration. These ulcerations fester easily due to impaired blood flow and healing ability (Singh et al. 2005; Wukich & Sung 2009). If such wounds are neglected, they can infect the bone, necessitating amputation (Pataky et al. 2007; Tesfaye et al. 2010). In the United States, diabetes is the root cause of more than 60% of non-traumatic lower-limb amputations (CDC 2011).

Proximal and focal neuropathies, although less common, are most prevalent among older diabetics. Proximal neuropathy causes unilateral pain in the lower body, and can ultimately lead to decreased lower body strength. Focal neuropathy can cause sporadic pain throughout the body, but it most commonly affects the feet, chest, and lower back. (NDIC 2009) If the SCAMOB intervention succeeds at increasing physical activity among the intervention group, diabetics could benefit from increased blood flow, decreased HbA1c, and reduced inflammation, all of which can improve microvascular complications (Balducci et al. 2006; Sigal et al. 2007; Zoppini et al. 2006).

4.2 Macrovascular complications and comorbidities

Several macrovascular conditions, more prevalent among diabetics, can impact mobility at a systemic level. Perhaps the most common of these is coronary heart disease (CHD). Diabetic pathology is known to drive the development of atherosclerotic plaques, thus contributing to high-grade or multi-vessel coronary atherosclerosis in most diabetics (Goraya et al. 2002; NDIC 2011). Some clinical guidelines even go so far as to equate of diabetic status with CHD diagnosis (De Backer et al. 2003; National Cholesterol Education Program 2002). This bears massive implications for diabetic mobility, since CHD impairs oxygenated blood flow to the heart.

Peripheral artery disease is also common among diabetics, and can problematize mobility even further. In this condition, intermittent claudication causes pain in the legs and buttocks when walking. In especially severe cases, rest pain, atrophy, or gangrene may occur, with the last significantly increasing the risk of lower-extremity amputation. (ADA 2003) Cardiovascular risk factors, such as hypertension, are also much more prevalent among diabetics. This, in combination with an increased risk for dyslipidemia, serves to exacerbate the already elevated cardiovascular morbidity seen in diabetics (Nathan 1993; NDIC 2011). Given that the vast majority of type 2 diabetics are also obese, the presence of chronic, low-grade inflammation can further contribute to functional decline (Albu & Pi-Sunyer 1998; Figaro et al. 2006).

Taken in sum, these conditions contribute to accelerated mobility and functional declines in older diabetics. In women of the same age, recent studies have shown that diabetics experience more difficulty than non-diabetics with climbing stairs and doing chair stands, which suggests that diabetics' muscle strength deteriorates more quickly (Gregg et al. 2000; De Rekeneire et al. 2003). Decreases in joint mobility and cardiorespiratory capacity have also been noted (Estacio et al. 1998; Pataky & Vischer 2007).

4.3 Nonvascular complications and comorbidities

Diabetics also face nonvascular threats to their mobility, such as depression and bone fracture. An Australian study found the rate of depression among older diabetics to be 7 times higher than among older non-diabetics, which adds a significant psychological obstacle for diabetics' maintenance of mobility. (Bruce et al. 2002) Depression can severely affect exercise motivation, thus facilitating the muscular degeneration already afflicting those of advanced ages (Foreyt & Poston 1999). Additionally, bone health can have a major impact on mobility. Numerous studies (Gregg et al. 2000; Hamann et al. 2012; Yamamoto et al. 2009) have found that diabetes significantly increases fracture risk. When fractures occur in the lower extremities, they can pose a severe threat to mobility. Hip fractures are particularly immobilizing, and can require months of treatment and rehabilitation, all the while increasing mortality risk (Keene et al. 1993).

5 PHYSICAL ACTIVITY IN DIABETES SELF-MANAGEMENT

Diabetes self-management (DSM) encompasses a diverse set of health practices that aim to normalize blood glucose levels and minimize diabetic complications. A full discussion of DSM practices is beyond the scope of this review. Briefly, they include blood glucose monitoring, medication compliance, foot care, diet, and physical activity, among others. Research suggests that, regardless of diabetes type or mode of treatment, diabetics greatly benefit from recommended diet and physical activity regimens, but also find them to be the most difficult prescriptions. (Ahola & Groop 2013) Since diet alterations are beyond the scope of the current study, this section of the review will focus on the role of increased physical activity for improved DSM, in addition to the intervention methods used to help diabetics overcome difficulties with habitual physical activity.

5.1 Benefits of increasing physical activity

Along with diet and medication, habitual physical activity rightly serves as one of the three main cornerstones of DSM, due to its effectiveness for improving glycemic control and diminishing the risk of diabetic complications (Pierce 1999). Habitual physical activity also reduces the risk of mobility loss due to diabetic comorbidities, including cardiovascular disease, obesity, and peripheral artery disease (Colberg et al. 2010; Colberg & Sigal 2011). Therefore, it is clear that diabetics can combat their excess risk of mobility loss – caused by diabetes, its complications, and its comorbidities – by increasing their level of physical activity (Colberg et al. 2010; Sigal et al. 2006).

A joint position statement, issued by the American College of Sports Medicine (ACSM) and the ADA, recommends a combination of aerobic and resistance training for diabetes managment. Specifically, type 2 diabetics should undertake ≥ 150 minutes of moderate to vigorous aerobic exercise each week. Aerobic activity should be spread out over ≥ 3 days of the week with no more than 2 days between each session, in order to achieve optimal and consistent improvements in insulin action. Resistance training for type 2 diabetics should also be moderate to vigorous, and performed 2-3 days each week. Such an exercise program, in addition to increases in unstructured physical activity, helps diabetics achieve improved disease management and risk reduction through numerous physiological and biochemical mechanisms, which will hence be described in greater detail. (Colberg et al. 2010)

5.1.1 Physiological benefits

Exercise produces immediate physiological improvements in type 2 diabetics, if moderate exertion is achieved. Given the poor physical conditioning of most older type 2 diabetics, brisk walking usually results in mild exertion, which makes the disease management benefits of physical activity readily accessible to diabetics (Foreyt & Poston 1999). In type 2 diabetics, 1 bout of moderately exertive physical activity increases hepatic and muscular insulin sensitivity for $\leq$ 16 hours, with repeated exercise producing a consistent reduction in insulin resistance. Additionally, moderately exertive physical activity produces immediate improvements in total glucose disposal and skeletal muscle uptake, effectively reducing hyperglycemia. Improvements in blood flow, which further help to reduce the risk of diabetic mobility loss, are also observed. (Pierce 1999) Combinations of aerobic and resistance training have proven particularly effective for type 2 diabetics, due to their synergistic effects on complementary metabolic pathways – while aerobic training improves insulin action and thus insulin-dependent glucose metabolism, resistance training encourages the increased recruitment of non-insulin-dependent metabolic pathways. This provides additional mechanisms for plasma glucose control, and thus helps to reduce HbA1c in the long term. (Gulve 2008)

5.1.2 Biochemical benefits

The immediate physiological effects of exercise, which help to improve DSM, are complemented by numerous biochemical alterations that reduce the risk of diabetic complications and comorbidities in the long run. These gradual changes lessen the upregulation of age-related biochemical processes seen in diabetic pathology, and thus combat the age-related complications and comorbidities that are more prevalent among diabetics. (De Lemos et al. 2012) In order to better understand how these exercise-induced biochemical changes lead to risk reduction at the system level, the particular effects of exercise on diabetics' oxidative and inflammatory processes will be explored further.

Exercise and increased oxidative stress in diabetics. Diabetic hyperglycemia increases normal oxidative stress by creating a microenvironment that facilitates glucose auto-oxidation, the overproduction of ROS, non-enzymatic glycation, and utilization of the polyol pathway. The production of AGEs by non-enzymatic glycation further increases oxidative stress by up-regulating NADPH oxidase, which results in more ROS. The excess ROS exhibited during hyperglycemia activate numerous stress-sensitive kinases, which ultimately act to increase insulin resistance. Additionally, these excess ROS and AGEs promote cardiovascular dysfunction by increasing endothelial adhesion to the vascular wall, producing atherosclerosis and decreased aerobic capacity. Regular physical activity can ameliorate much of the excess oxidative stress seen in diabetics, through its immediate action on plasma glucose levels. (De Lemos et al. 2012) Additionally, regular exercise combats oxidative stress by increasing cellular resistance to oxidative stress and by up-regulating cardiovascular antioxidant defenses, thereby providing both short- and long-term relief for the excess oxidative stress observed in diabetic pathology (Pierce 1999).

Exercise and increased inflammatory response in diabetics. Diabetic pathology causes chronic inflammation, which increases susceptibility to infection. In extreme cases, this can severely impact mobility, by facilitating gangrene and necessitating foot amputation. (Home 2003) However, even in less extreme circumstances, the heightened inflammatory response observed in diabetics increases the risk of complications and adversely affects disease management via numerous mechanisms. In particular, hyperglycemia-induced oxidative stress leads to an inflammatory cascade that increases endothelial cell damage, microvascular permeability, and inflammatory cytokine release. In pancreatic beta cells, these cytokines can induce further increases in oxidative stress, thereby decreasing insulin secretion and even causing cell death. By reducing hyperglycemia, and thus hyperglycemia-induced oxidative stress, regular exercise can potentially counteract the root causes of the increased inflammatory response seen in diabetics. This is demonstrated by the consistent preservation of beta cell mass in physically active diabetics. (De Lemos et al. 2012) However, in order to achieve these positive effects, it is imperative for physical activity to be regular. Otherwise, temporary increases in inflammatory response, that do not confer antioxidant benefits, could result. (Pierce 1999)

5.2 Interventions for increasing physical activity

Systematic reviews of physical activity interventions have shown that regardless of format, physical activity interventions generally increase older adults' physical activity in the short term (van der Bij et al. 2002; Conn et al. 2003; King et al. 1998; Taylor et al. 2004). However, observed increases in the short term rarely meet the threshold for health improvement. Furthermore, long-term changes are difficult to achieve, and are rarely tracked more than 12 months post-intervention, if tracked at all. (von Bonsdorff 2009; Conn et al. 2003; King et al. 1998) This, in addition to the wide variation between intervention protocols, complicates definitive judgment regarding which components contribute to an intervention's overall effectiveness. In practice, no widely tested intervention attribute has dramatically improved, or even consistently produced, successful outcomes. For these reasons, the present review will discuss the most common areas of difference in intervention design, and point to their relative merits for older diabetics, rather than expound upon absolute effectiveness of intervention attributes, for which no conclusive evidence exists. (Conn et al. 2003)

Given the increased awareness of preventive health measures and their importance to continued health, recent years have seen a relative proliferation of physical activity promotion (von Bonsdorff 2009; Marcus et al. 1998). Due to the highly sedentary nature of and high healthcare costs for the older population, many public health efforts have focused on physical activity promotion and lifestyle interventions to improve the health of seniors. Although many methods have been tried, no single approach has emerged as a 'golden standard' for physical activity interventions within the older population, most likely due to protocol irregularities and variable physical activity preferences among participants. (Conn et al. 2003) However, due to the particular idiosyncrasies of older diabetics, certain intervention characteristics have been clearly proven as suboptimal for promoting physical activity within this population (Colberg et al. 2010). Therefore, particular successes and failures in various aspects of previous intervention protocols will be highlighted in order to better estimate the characteristics of a physical activity intervention that benefits older diabetics.

Theoretical basis. Not all physical activity interventions incorporate theoretical justifications for the approach selected. However, for whatever reason, several meta-analyses have found that theoretically-based interventions more frequently result in positive outcomes (Conn et al. 2003; Taylor et al. 2004). Most commonly, physical activity interventions incorporate theories or models regarding behavioral change, such as social cognitive theory and the trans-theoretical model (von Bonsdorff 2009; King et al. 1998). Social cognitive theory acknowledges that environment, personal, and behavioral factors all affect behavioral change; however, it also states that the individual ultimately controls personal behavior and therefore behavioral change. For this reason, social cognitive theory emphasizes the roles of self-efficacy and stimulus control, which both encourage personal agency and proactive environmental modification in order to achieve long-term behavioral changes. (Bandura 1977) The trans-theoretical model is based on the idea that interventions should be tailored to match an individual's receptivity to help and willingness to change. By adapting an intervention to target an individual's current stage in the change-making process, it is posited that an intervention's effectiveness can be maximized. (Prochaska & DiClemente 1983)

Theory has also been applied to disease management and physical activity promotion among older diabetics. Recently, the chronic care model has emerged as an alternative to the widely used acute care model, which has proved largely ineffective for diseases like diabetes that require daily management. The chronic care model avoids pedantic prescriptions, and instead approaches patient care as a cooperative effort among equals. Like the trans-theoretical model, the chronic care model acknowledges that didactic prescriptions are useless unless the individual is willing to comply; furthermore, the only way to discern willingness is to interact more extensively with the patient. In addition to individualized treatment plans, the chronic care model emphasizes the notion of empowerment, which closely parallels the concept of self-efficacy. Empowerment is based on the assumption that the patient is the primary decision maker in regards to his or her health, with health professionals only fulfilling a secondary, educational role. Additionally, it posits that patients must be able to affect change in their personal behavior, social context, and environment in order to be healthy. (Anderson et al. 1991) When compared to the didactic methods of the acute care model, randomized controlled trials (RCT) have shown that the philosophy of empowerment included in the chronic care model is more effective for improving self-care practices (including habitual physical activity) among type 2 diabetics (Anderson et al. 2005; Norris et al. 2001).

Counseling. Most physical activity interventions incorporate some type of counseling, albeit for different purposes. At the most basic level, counseling is used as an educational tool in an individual or group setting. This is done to inform participants about topics relating to the particular intervention, such as exercise programs and health promotion. However, systematic reviews have shown that educational counseling, although necessary, is not sufficient for habit formation. (King et al. 1998; Taylor et al. 2004) In order to encourage long-term habit formation, many physical activity interventions now incorporate motivational counseling, which focuses on providing participants with tools to promote self-efficacy. These tools include problem-solving skills, goal setting, relapse prevention training, constructive feedback, motivational support, and self-monitoring techniques. Meta-analysis shows that interventions incorporating these cognitive behavioral tools are more effective, at least in the short term, than health education alone. However, motivational techniques for the promotion of long-term behavioral change are still lacking. (King et al. 1998)

As informed by the chronic care model, educational counseling is essential to the success of the empowerment philosophy, and therefore to DSM. Otherwise, older diabetics would lack the knowledge required for informed decision-making about their daily disease management, including physical activity. Similar to self-efficacy, the facilitation of empowerment requires the provision of strategies to help diabetics cope with being the primary decision maker. Such strategies include goal setting, problem solving, identifying barriers, cultural sensitivity, and self-awareness. (Funnell & Anderson 2004) Many of these strategies bear a strong resemblance to those used in motivational counseling. Therefore, a physical activity intervention, which combines both educational and motivational counseling techniques, appears best suited for the needs of the older diabetic population.

Interventionists. The choice of interventionists is often opportunistic for physical activity interventions, and may thus receive no explicit consideration of suitability. Past studies have utilized individuals who are minimally trained in exercise intervention tactics, including graduate students, physicians, and public health students (van der Bij et al. 2002; Green et al. 2002; Pinto et al. 1998). Some studies do not even specify interventionists' qualifications (Araki et al. 2012). However, other studies channel more effort into the selection of interventionists, choosing individuals from well-suited professions, including physical therapy, exercise gerontology, and exercise physiology (Jancey et al. 2008; Leinonen et al. 2007; Rejeski et al. 2005).

For older diabetics, it is imperative that interventionists be carefully chosen. They must be well versed in diabetes management, and familiar with participants' health. This is because certain medications for and complications from diabetes require special consideration when devising an exercise plan. For instance, individuals being treated with insulin or insulin secretagouges are at increased risk for exercise-induced hypoglycemia, which can be life-threatening if not addressed. Thus, interventionists must be able to identify the condition, and be knowledgeable about compensatory strategies, such as medication dose reduction and carbohydrate supplementation. (Gulve 2008; Pierce 1999) Additionally, individuals with advanced diabetes complications require special consideration. For instance, individuals with advanced peripheral neuropathy should not be prescribed weight-bearing or high-impact exercise (Colberg & Sigal 2011). Also, those with advanced stages of diabetic retinopathy or macular degeneration should be advised against activities that are jarring or increase intraocular pressures, since these increase the risk of hemorrhage

(Colberg et al. 2010). Since laymen would not be aware of such necessary modifications, and the health consequences of unsuitable exercise can be particularly severe for diabetics, it is clear that medical staff should be involved in physical activity interventions catering to this population.

Delivery. In order to minimize cost while still maximizing effectiveness, many modes of intervention delivery have been investigated. These include in-person counseling sessions, telephone calls, and information by mail, in addition to less conventional, fully mediated approaches, such as computerized telephone systems and videotaped exercise instruction. Telephone-based support has been proven as effective as face-to-face support for long-term behavioral change, while fully mediated approaches have achieved some positive results in the short term. (King et al. 1998) Given that diabetic exercise programs often need to be highly individualized, a fully automated approach would most likely prove ineffective for this population (Praet & van Loon 2007).

Setting. A systematic review of 29 physical activity interventions for older people illustrates that most interventions fall into 1 of 3 settings: home, group, or community. Home-based interventions occur in each participating individual's home, while group-based interventions occur in predetermined public areas. In contrast to these types of interventions, which utilize interventions designed by the researcher, community-based interventions utilize resources already available within the community, with the goal that participants will continue using these resources after the intervention has concluded. (King et al. 1998) No specific guidelines for the setting of diabetic physical activity interventions have been made; however, group-based settings have been used successfully to foster social support (Anderson et al. 2001; Colberg et al. 2010).

Supervision. The use of supervision remains a point of contention when designing physical activity interventions. Although interventionists' supervision does encourage active participation in the short term, it is questionable if habits formed will continue after the supervision is removed, and the intervention is concluded. On the other hand, the recommendation of unsupervised exercise may be insufficient for promoting physical activity among those with low motivation. (Conn et al. 2003) For diabetics, regular supervision is overwhelmingly recommended, for a number of reasons. Firstly, the additional health risks that some diabetics face when exercising may necessitate supervision (Colberg et al. 2010). Secondly, most type 2 diabetics have reduced exercise tolerance, which complicates adherence in the absence of supervision (Praet & van Loon 2007). Reviews of physical activity interventions for diabetics have repeatedly shown that the interventions achieving the greatest reductions in plasma glucose levels all involved supervised physical activity by qualified trainers. Once that supervision was removed, glycemic control and compliance consistently decreased. (Colberg & Sigal 2011) Lastly, the often comorbid condition of obesity can make exercise difficult, subsequently demotivating the individual. Thus, additional supervision is often warranted in order to ensure safety and promote the initial development of self-efficacy among diabetics. (Colberg & Sigal 2011; Foreyt & Poston 1999)

Type of physical activity. The type of physical activity initiated is highly dependent upon other characteristics of the intervention, such as setting, supervision, and delivery. Furthermore, in the case of highly individualized interventions, the consistent prescription of a particular activity is unlikely. Systematic reviews indicate that aerobic exercise is prescribed more often than resistance training, most likely due to the emphasis on cardiovascular health within the older population (van der Bij et al. 2002; King et al. 1998). For older diabetics, the mode of exercise appears largely insignificant, as long as moderate intensity is reached. However, it should be noted that alternative therapies, such as yoga and tai chi, have produced inconsistent results for diabetics. (Colberg et al. 2010)

6 AIM AND RESEARCH QUESTIONS

The aim of the present study was to determine if physical activity counseling among older diabetics is similarly associated with changes in mobility and habitual physical activity, as compared to its effect among older non-diabetics. To this end, the impact of physical activity counseling on the mobility indicators of *maximal walking speed* and *2 km walking ability* was examined. Additionally, longitudinal changes in *habitual physical activity* according to diabetes status were examined. In order to identify potential differences between study groups, the primary research questions were as follows:

1) Does physical activity counseling influence change in mobility or habitual physical activity among diabetics?
2) If so, how does the influence of physical activity counseling on mobility and habitual physical activity changes among diabetics compare to those among non-diabetics?

7 PARTICIPANTS AND METHODS

7.1 Participants and study design

The data utilized in the present study derive from SCAMOB study conducted at the University of Jyväskylä between 2003 and 2005. In order to locate potential participants for the single blinded RCT, investigators used the population registry for the city of Jyväskylä. Screening occurred in 4 phases: (1) informational letter, (2) telephone interview, (3) in-person interview, and (4) physical examination. Informational letters were sent to all those within the target population, namely registered residents of the Jyväskylä city center aged 75-81 years (n=1,310). At this stage, 110 refused, 52 could not be reached, 42 suffered from poor health or memory impairment, and 6 died prior to screening, leaving n=1,100 eligible for interview by telephone. (Leinonen et al. 2007)

During the phone screening, researchers asked potential participants about their self-rated health, ability to walk 0.5 km, habitual physical activity level, and willingness to participate in the study. This was done to identify individuals most likely to benefit from participation; namely, those who were able to move outdoors independently but who were primarily sedentary. Additionally, this selectivity acted to minimize floor and ceiling effects at follow-up. Individuals indicating that they were unable to walk 0.5 km or suffering from memory impairment were deemed unable to move outside independently. Additionally, potential participants who characterized their physical activity as working out several times per week or competing in sports were considered too active to benefit from participation. (Rasinaho et al. 2012) At this point, 192 individuals were excluded from the study, since they did not fit the inclusion criteria – 71 had preexisting mobility impairment, 112 were too physically active to benefit from participation, and 9 suffered from memory impairment. Therefore, 908 subjects were considered eligible for a home interview, but only 727 individuals (80%) agreed to a home visit. (Leinonen et al. 2007)

During the home interview, researchers obtained informed consent, as well as more in-depth information regarding mobility, physical activity, and memory. Memory was assessed using the Mini-Mental State Examination (MMSE), and having impaired memory was defined as scoring ≤ 21 (Folstein et al. 1975). Researchers assessed mobility limitation by asking participants about their ability to walk distances of 2 km and 0.5 km (Rasinaho et al. 2011). Information on demographics and chronic conditions was also collected at the in-person interview. After this stage, researchers excluded 36 individuals – 5 suffering from mobility impairment, 7 too physically active to benefit from participation, and 24 suffering from impaired memory. Additionally, 34 individuals refused further contact, leaving n=657 eligible for physical assessment. (Leinonen et al. 2007)

During the physical examination, a nurse determined individuals' suitability to participate, finding 530 definitely eligible and referring 127 to a physician for further assessment. The physician excluded 18 people due health conditions contraindicating participation in the study, and 7 additional subjects refused further participation at this point. In the end, this left 632 subjects for randomization, all of whom met the following inclusionary criteria: (1) ability to walk 0.5 km without someone's assistance, (2) physical activity level characterized as sedentary or moderate, (3) absence of memory impairment (MMSE ≥ 22), (4) absence of medical contraindications for participation, and (5) informed consent to participate. These participants were then randomly assigned to the intervention (n=318) or control (n=314) group and assessed for baseline function. (Leinonen et al. 2007; Rasinaho et al. 2011)

7.2 Measures in present study

As mentioned previously, this study defines mobility loss as a functional limitation, rather than as a disability. In order to adhere to this definition, assessments of mobility loss should be restricted to measures of individual functioning that exclude societal valuations of performance (Jette 1994). Furthermore, since the present study represents a secondary analysis, methods used to assess mobility loss must be selected from those originally included in the SCAMOB study. Having taken into account (1) the traditional modes for assessing mobility loss, and (2) the restrictions imposed by experimental design, the following variables are included in the present study.

Maximal walking speed. This was calculated over 10 meters and assessed by direct observation during functional assessments for the SCAMOB study. This type of measurement has shown high test-retest reliability in numerous populations, and has been validated for construct against the Berg balance scale (r = .85) and the timed up and go test (r = -.75) (Liston & Brouwer 1996; Mathias et al. 1986; Steffen et al. 2002). Additionally, gait speed has shown a high correlation to self-reported physical function – in a study by Cress et al. (1995), gait speed was the strongest independent predictor of self-reported physical function among 617 individuals (aged 75.4 ± 5.5 years).

2 km walking ability. This was assessed via self-report. Participants were asked to rate their ability as corresponding to 1 of 5 options: (1) able without difficulty, (2) able with minor difficulty, (3) able with major difficulty, (4) able only with help from another person, or (5) unable even with someone's help. To facilitate analysis, these categories were condensed into (1) able without difficulty, and (2) with difficulty or unable. By incorporating both the concepts of difficulty and dependence, this scale presents a more complete picture of the disablement process, and reflects a growing tendency to view disability as a continuum rather than dualistically (Pine et al. 2000). Furthermore, the concepts of difficulty and dependence produce complementary data, thus providing richer fodder for analysis (Gill et al. 1998).

Diabetes status. Since diabetic status was not central to SCAMOB study aims, information on diabetes status was only collected by self-report. During the at-home interview, potential SCAMOB participants were asked if they had any chronic conditions (defined as lasting ≥3 months), and the interviewer transcribed their responses. This method showed high reliability (r=.89) for determining the overall number of chronic conditions. However, when coded, no differentiation was made between T1DM and T2DM. (Leinonen et al. 2007)

Habitual physical activity was assessed via self-report. Randomized participants categorized their normal amount of physical activity into 1 of 5 categories: (1) mainly resting or only minimal physical activity, (2) most activities performed sitting down, (3) light physical activity 1-2 hours per week, (4) moderate physical activity 3 hours per week, or (5) moderate physical activity ≥4 hours per week (Rasinaho et al. 2012). In order to normalize variable distribution, response groupings were condensed into 3 categories: (1) sedentary to light physical activity ≤ 2 hours per week, (2) moderate physical activity ~3 hours per week, and (3) moderate physical activity ≥ 4 hours per week. (Leinonen et al. 2007)

Self-perceived economic status was measured as very poor, poor, satisfactory, good, or very good. Since no participants listed their economic status as very poor at baseline or follow-up, the current study utilizes the following condensed categories: (1) poor to moderate and (2) good to very good.

Marital status. During the at-home interview, participants categorized their marital status as one of the following: (1) married, (2) cohabiting, (3) single, (4) divorced or separated, or (5) widowed. For this analysis, this response set has been condensed to 2 responses: 'married' and 'not married'.

7.3 Intervention

The study intervention consisted primarily of 2 parts: (1) a physical activity counseling session with a physiotherapist, and (2) phone check-ups 3-5 times a year during the 2-year follow-up period. Additionally, intervention group participants were invited to participate in lectures related to aging, disability, home calisthenics, and exercise class opportunities. Participants in the intervention group were also mailed an illustrated, home-based exercise program. Both the intervention and control groups participated in 3 biannual assessments to ascertain changes from baseline. Researchers conducting these assessments were blinded to participants' group assignment. (Rasinaho et al. 2011)

An individual, motivational physical activity counseling session was held for each individual in the intervention group, approximately 2 weeks after baseline. These sessions, lasting 50 minutes on average, addressed (1) present level of physical activity, (2) personal interest in beginning or maintaining physical activity or exercise, (3) willingness to be active in the course of everyday chores, and (4) personal preferences regarding exercising alone or in a supervised group session. The potential for support from family and friends was also discussed. If desired, the physiotherapist formulated an individualized, home-based gymnastics program for the participant, and gave the participant written instructions for its performance. Problem-solving methods were employed to overcome perceived obstacles to physical activity and encourage the use of available exercise facilities. The session concluded with the formation of a personal physical activity plan, which the participant agreed to and signed. (Leinonen et al. 2007)

The physiotherapist supplemented the initial counseling session with regular phone communication 3-5 times a year, approximately 10-15 minutes at a time. This was done to review progress and to encourage lasting behavioral change, as well as to revise goals and physical activity plans. In-person reevaluations were administered as necessary. (Leinonen et al. 2007; Rasinaho et al. 2012)

7.4 Statistical analyses

For the present study, 1 participant from the intervention group was excluded from all analyses, due to missing data on diabetes status. For baseline characteristics, it should be noted that exclusions were also made in maximal walking speed (for 1 non-diabetic control) and in self-perceived economic status (for 1 diabetic in the intervention group), due to missing data. For the longitudinal analysis, numerous exclusions were made necessary by missing data. For maximal walking speed, 50 non-diabetic controls, 33 non-diabetics in the intervention group, 8 diabetic controls, and 3 diabetics in the intervention group were excluded, because they lacked data on maximal walking speed at baseline and/or follow-up. In the longitudinal analysis of habitual physical activity, 31 non-diabetic controls, 22 non-diabetics in the intervention group, 6 diabetic controls, and 2 diabetics from the intervention group were excluded due to missing data at follow-up. Additionally, 26 non-diabetic controls, 21 non-diabetics in the intervention group, 5 diabetic controls, and 2 diabetics in the intervention group were excluded from the analysis of 2 km walking ability, due to missing data at follow-up.

When determining baseline characteristics, one-way analysis of variance was used to calculate variations in age, years of education, number of chronic conditions, and maximal walking speed. Levene's test indicated that the variable years of education violated the assumption of homogeneity; thus, this variable was analyzed using the Welch statistic. The chi-squared test for independence was used to determine between-group variation in categorical variables, namely sex, marital status, self-perceived economic status, habitual physical activity, and 2 km walking ability.

For the longitudinal analysis, maximal walking speed was analyzed using a paired samples t-test. Additionally, one-way analysis of variance for repeated measures, utilizing Wilks' lambda, was used to determine the significance of within- and between-subject factors for the variation observed. For habitual physical activity and 2 km walking ability, cross-tabulations were conducted to ascertain improvements and digression in status. The McNemar-Bowker test was then used to determine the significance of the variations between pre- and post-intervention distributions. Additionally, transition tables of (1) pre- and post-intervention habitual physical activity and (2) pre- and post-intervention 2 km walking ability were performed to juxtapose the degree of the intervention's effects on diabetics as opposed to non-diabetics. Changes in distribution were assessed for significance using the marginal homogeneity test. All statistical tests utilized in the present study were performed using version 20.0 of SPSS Statistics.

8 RESULTS

Baseline characteristics according to randomization group and diabetic status are presented in table 1. Diabetics accounted for approximately 6.9% of the intervention group and 8.6% of the control group. A one-way analysis of variance was conducted to investigate between-group differences for continuous variables. Significant differences between groups were observed for years of education and maximal walking speed. Non-diabetic participants had more education than diabetic participants, with non-diabetic controls having the most and diabetics in the intervention group having the least education (p=.033). As for maximal walking speed, the largest difference was seen between diabetics and non-diabetics in the intervention group, who had the lowest and highest walking speeds, respectively (p=.018).

Cross-tabulations utilizing chi-squared tests for independence were also used to examine baseline characteristics and between-group differences for categorical variables. Most participants were female and unmarried. Participants in all subgroups were more likely to rate their economic situation as 'poor to moderate', as opposed to 'good to very good'. Most participated in moderate physical activity, approximately 3 hours per week. The majority of participants indicated no difficulty walking 2 km at baseline. No significant differences between groups were observed in categorical variables at baseline.

TABLE 1. Baseline characteristics by randomization and diabetes status.

		Non-Diabetic Control (n=287)	Non-Diabetic Intervention (n=295)	Diabetic Control (n=27)	Diabetic Intervention (n=22)	
		N=631				
		Mean ± SD				P-value
Age (years)		77.54 ±1.93	77.60 ± 1.94	78.07 ± 2.07	76.95 ± 1.96	.246 °
Years of education		9.33 ± 4.55	9.16 ± 4.11	8.37 ± 2.64	7.66 ± 2.59	.033 ° a
Number of chronic conditions (adjusted)		2.91 ± 1.85	2.88 ± 1.87	3.48 ± 2.38	3.64 ± 2.28	.142 °
Maximal walking speed (m/s)		1.35 ± .37	1.40 ± .35	1.29 ± .31	1.19 ± .40	.018 °
		%				
Female		74.9	73.9	77.8	81.8	.842 x
Married		44.6	37.3	33.3	40.9	.280 x
Self-perceived economic situation	Good to very good	41.1	43.7	44.4	28.6	.557 x
	Poor to moderate	58.9	56.3	55.6	71.4	
Habitual physical activity	Sedentary to light physical activity ≤ 2 hrs/wk	25.8	22.7	18.5	45.5	.278 x
	Moderate physical activity 3 hrs/wk	48.8	52.2	48.1	40.9	
	Moderate physical activity ≥4 hrs/wk	25.4	25.1	33.3	13.6	
2 km walking ability	without difficulty	67.9	67.3	70.4	50.0	.368 x
	with difficulty or unable	32.1	32.5	29.6	50.0	

a.Equal variances not assumed, utilized Welch statistic.
° = one-way analysis of variance
x = χ^2 test for independence

Changes in outcome measures at follow-up are presented in table 2. Longitudinal analysis of maximal walking speed showed overall improvements for the non-diabetic controls (p < .001), as well as for the non-diabetics in the intervention group (p < .001). The non-diabetics in the intervention group demonstrated a larger improvement. No statistically significant differences in maximal walking speed were observed in the diabetic groups.

Longitudinal changes in habitual physical activity were assessed by cross-tabulation, to determine the percentage of participants within each group that improved their level of physical activity, kept it the same, or decreased their level of physical activity. In all groups, the majority of the participants either increased their level of weekly physical activity or kept it stable. Statistically significant improvements were observed in the non-diabetic control group ($p < .001$), as well as in the non-diabetic intervention group ($p < .001$). Statistically significant changes in habitual physical activity were not observed in the diabetic groups.

In order to examine longitudinal changes in 2 km walking ability, a cross-tabulation was performed to determine the percentages within each group for which 2 km walking ability improved, stayed the same, or declined over the follow-up period. In all groups, the majority of participants indicated that their ability to walk 2 km had either improved or remained stable since baseline. Statistically significant changes in 2 km walking ability were observed in both the diabetic and non-diabetic control groups. The diabetic control group showed the least (i.e., no) improvement in this measure, as well as the greatest decline ($p=.016$). In the non-diabetic control group the majority of participants indicated that their ability to walk 2 km remained unchanged; of the remainder, a higher percentage indicated decline as opposed to improvement ($p=.002$). No statistically significant differences in the distribution of this measure were seen in either of the intervention groups.

TABLE 2. Differences in mobility-related measures at 2-year follow-up.

		Non-Diabetic Control (N=287)	Non-Diabetic Intervention (N=295)	Diabetic Control (N=27)	Diabetic Intervention (N=22)
		N=631 Mean ± SD			
		n=237	n=262	n=19	n=19
Difference in walking speed (m/s)		.06 ± .24	.08 ± .24	- .05 ± .34	.03 ± .18
	P-value	< .001 [t]	< .001 [t]	.512 [t]	.446 [t]
		%			
		n=256	n=273	n=21	n=20
Habitual physical activity	Improved	30.1	33.0	9.5	45.0
	Unchanged	50.4	53.1	61.9	40.0
	Worsened	19.5	13.9	28.6	15.0
	P-value comparing pre- and post-intervention distributions	< .001 [x]	< .001 [x]	.362 [x]	.189 [x]
		n=261	n=274	n=22	n=20
2 km walking ability [a]	Improved	9.2	8.8	0	15.0
	Unchanged	70.9	77.0	68.2	65.0
	Worsened	19.9	14.2	31.8	20.0
	P-value comparing pre- and post-intervention distributions	.002 [x]	.077 [x]	.016 [x]	1.000 [x]

a. Binomial distribution used.
t = paired samples t-test
x = McNemar-Bowker test

In order to better illustrate the degree of change in maximal walking speed, figure 1 shows pre- and post-intervention values for all 4 study groups. When compared to the improvement observed in the non-diabetic control group, the improvement seen in the non-diabetic intervention group represents not only greater absolute change, but also greater relative change, considering baseline values. The ranking of study groups within the study population (fastest group, 2nd fastest group, etc.) was not affected by the intervention. Additionally, no statistically significant differences in maximal walking speed were observed for either of the diabetic groups. One-way analysis of variance for repeated measures revealed a significant effect for diabetes*time ($p=.042$), but not for time ($p=.121$), randomization*time (p=.200), or randomization*diabetes*time (p=.444), with regards to within-subject differences. When determining between-subject differences, diabetes status was shown to have a significant effect (p=.006), but the effects of randomization (p=.642) and diabetes*randomization (p=.232) were shown to be insignificant.

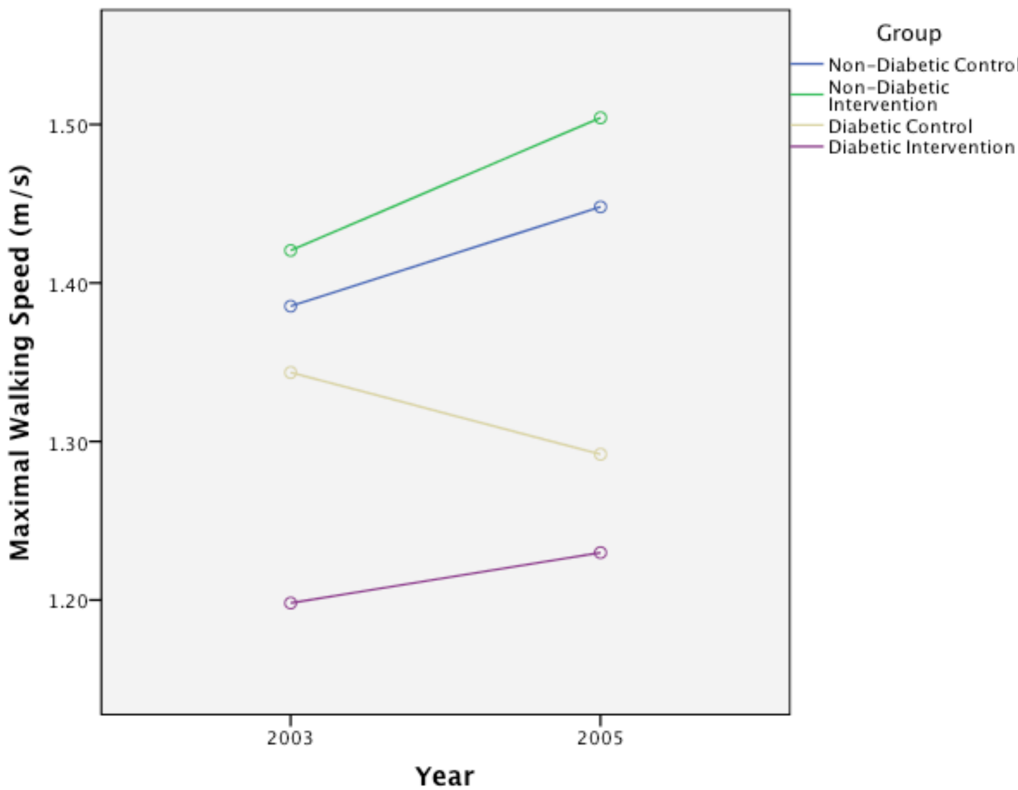

FIGURE 1. Change in maximal walking speed by randomization and diabetes status.

In order to investigate the degree to which the intervention influenced change in habitual physical activity in diabetics as opposed to non-diabetics, table 3 presents a transition table of pre- and post-intervention habitual physical activity for both intervention groups. Testing for marginal homogeneity indicated statistically significant improvement in habitual physical activity for the non-diabetics ($p < .001$) but not for the diabetics (p=.083). In the non-diabetic intervention group, 61.0% of those in the lowest activity category at baseline were able to improve their level of habitual physical activity. Of the non-diabetics who started in the middle category, 48.6% were able to maintain and 38.0% were able to improve their level of physical activity. Lastly, 73.6% of non-diabetics with the highest activity level at baseline were able to maintain their high level of habitual physical activity.

TABLE 3. Transition table of pre- and post-intervention habitual physical activity in intervention group by diabetes status.

			Habitual physical activity at baseline %				P-values comparing pre- and post-intervention distributions
			Sedentary to light physical activity 1-2 hrs/wk	Moderate physical activity 3 hrs/wk	Moderate physical activity ≥4 hrs/wk	Total	
Non-Diabetic Intervention (n=273)	Habitual physical activity at follow-up	Sedentary to light physical activity 1-2 hrs/wk	39.0	13.4	1.4	15.8	
		Moderate physical activity 3 hrs/wk	42.4	48.6	25.0	41.0	< .001 [b]
		Moderate physical activity ≥4 hrs/wk	18.6	38.0	73.6	43.2	
	Total		100.0	100.0	100.0	100.0	
Diabetic Intervention (n=20)	Habitual physical activity at follow-up	Sedentary to light physical activity 1-2 hrs/wk	50.0	22.2	0.0	30.0	
		Moderate physical activity 3 hrs/wk	50.0	22.2	33.3	35.0	.083 [a b]
		Moderate physical activity ≥4 hrs/wk	0.0	55.6	66.7	35.0	
	Total		100.0	100.0	100.0	100.0	

a. 9 cells (100.0%) have expected count less than 5. The minimum expected count is .90
b. Marginal homogeneity test

In order to better illustrate the degree of the intervention's effect on 2 km walking ability among diabetics as opposed to non-diabetics, table 4 presents a transition table of pre- and post-intervention 2 km walking ability for both diabetics and non-diabetics in the intervention group. Testing for marginal homogeneity indicated no statistically significant change in 2 km walking ability for either the non-diabetic intervention group (p=.059) or the diabetic intervention group (p=.705).

TABLE 4. Transition table of pre- and post-intervention 2 km walking ability in intervention group by diabetes status.

			2 km walking ability at baseline % without difficulty	with difficulty or unable	Total	P-values comparing pre- and post-intervention distributions
Non-Diabetic Intervention (n=274)	2 km walking ability at follow-up	without difficulty	79.6	28.9	64.2	
		with difficulty or unable	20.4	71.1	35.8	.059 [b]
	Total		100.0	100.0	100.0	
Diabetic Intervention (n=20)	2 km walking ability at follow-up	without difficulty	63.6	33.3	50.0	
		with difficulty or unable	36.4	66.7	50.0	.705 [a b]
	Total		100.0	100.0	100.0	

a. 2 cells (50%) have expected count less than 5. The minimum expected count is 4.50
b. Marginal homogeneity test

9 DISCUSSION

In the current study, data regarding the influence of physical activity counseling on habitual physical activity level and mobility outcomes, in both diabetic and non-diabetic older persons, have been presented. Based on the results of this study, the primary findings were: (1) Physical activity counseling does not improve diabetics' habitual physical activity level or mobility; however, it can help diabetics maintain current levels of mobility, by preventing decline in 2 km walking ability. (2) Physical activity counseling influences more change among non-diabetics than it does among diabetics, in regards to both habitual physical activity level and mobility outcomes..

In the present study, physical activity counseling was not an effective method for improving mobility or increasing habitual physical activity in diabetics. Diabetics in the intervention group showed no significant changes in maximal walking speed, 2 km walking ability, or habitual physical activity level. This finding is supported by existing literature, which suggests that diabetics experience additional difficulty maintaining physical activity regimens (Ahola & Groop 2013; Colberg & Sigal 2011; Foreyt & Poston 1999). However, previous studies also indicate that physical activity counseling can significantly improve habitual physical activity in diabetic subjects (Avery et al. 2012). While diabetics in the intervention group demonstrated no significant change over the follow-up period, diabetics in the control group showed significant decline in 2 km walking ability. This contrast suggests that, while physical activity counseling may not improve diabetics' mobility, it may serve to protect diabetics from mobility decline.

The observed association between physical activity counseling and decreased mobility loss in diabetics is weakly supported in the existing literature. Since improved glycemic control is the main outcome measure in most physical activity counseling studies for diabetics, no studies with mobility-specific outcome measures could be located. However, poor glycemic control has been linked to mobility disability – in the National Health And Nutrition Examination Survey cohort, diabetics were 2.06 times as likely to experience lower extremity mobility disability, with 10% of diabetics' excess risk being attributable to poor glycemic control (Kalyani et al. 2010). This suggests that physical activity counseling's directional influence on mobility loss can be minimally inferred based on its influence on glycemic control. Studies have shown statistically significant improvements in HbA1c among diabetics receiving physical activity counseling (Avery et al. 2012; Plotnikoff et al. 2011). Therefore, physical activity counseling may ultimately decrease mobility loss in aging diabetics, through positive effects on glucose management. However, it should be noted that studies of physical activity counseling among diabetics, using mobility indicators as primary outcome measures, are needed in order to definitively determine the relationship between physical activity counseling and mobility loss within the older diabetic population.

The current study also suggests that the effectiveness of physical activity counseling is lessened in diabetic populations as opposed to non-diabetic populations. While diabetics in the intervention group showed no significant change in outcome measures, non-diabetics in the intervention group showed significant improvements in both maximal walking speed and habitual physical activity. Furthermore, diabetes status was shown to significantly impact within- and between-subject change in maximal walking speed over the follow-up period. Studies examining the differential effects of physical activity counseling according to diabetes status could not be located in the literature, which complicates validation of these findings. However, the diminution of physical activity counseling's effectiveness in diabetics does make intuitive sense, given (1) the exceptional difficulty that diabetics experience when trying to maintain physical activity regimens, and (2) the increased prevalence of and tendency toward sedentary lifestyle among diabetics (Avery et al. 2012; Colberg & Sigal 2011; Foreyt & Poston 1999).

The strengths of the present study are largely due to the design of the original SCAMOB trial. The inclusion of a control group theoretically allowed for the approximation of longitudinal change in the absence of the intervention. However, given the significant improvements in the non-diabetic control group, control conditions in this study were likely violated by unintentional activation of control subjects and by information flow across randomization groups (Rasinaho et al. 2011). During functional assessments, the single-blinded design prevented differential treatment of the randomization and control groups by researchers. Additionally, the well-characterized randomization helped to reduce demographic differences between study groups and minimize selection bias. Furthermore, the longer-than-average follow-up time contributed to a more accurate estimation of long-term changes in physical activity and mobility.

Having examined the intervention characteristics best suited for diabetics, it appears that the SCAMOB intervention had considerable potential for promoting physical activity among diabetics. By incorporating the behavioral concepts of social cognitive theory and the trans-theoretical model, the SCAMOB intervention provided a platform for the promotion of long-term behavioral change through empowerment and self-efficacy. Additionally, the involvement of health professionals throughout the screening, counseling, and exercise processes served to maximize safety for diabetics. Since nurses initially screened all participants for cardiovascular health, visual difficulties, and impaired sensation in the feet, it is unlikely that any diabetics were accidentally recommended physical activity regimens that were contraindicated by diabetic complications. Furthermore, the utilization of telephone follow-up served as a convenient, low-cost method for promoting long-term adherence in diabetic subjects, who generally require additional supervision. (Leinonen et al. 2007)

The highly individualized nature of the SCAMOB intervention could either enhance or decrease the suitability of the intervention for diabetics, depending on the options selected. Since participants were counseled based on stated preferences, it is possible that selected activities differed significantly from general activity recommendations for diabetics. Additionally, given that ADA and ACSM guidelines were not used to formulate diabetics' activity plans, it is unlikely that their plans reflected the rigorous specifications of these guidelines. (Leinonen et al. 2007, Colberg et al. 2010)

Despite the probability that diabetic participants did not follow ADA and ACSM physical activity guidelines, the SCAMOB intervention could still benefit the older diabetic population. Although the present study indicated minimal effectiveness for physical activity counseling among diabetics, the SCAMOB intervention could potentially influence small changes in diabetics' physical activity, which could later serve as a foundation for measurable increases in physical activity. Numerous studies state the importance of promoting gradual increases in physical activity, since these are (1) more likely to be maintained and (2) more effective for improving self-efficacy (Ahola & Groop 2013; Foreyt & Poston 1999; Sigal et al. 2006) Diabetics often begin with below-average fitness levels, so the SCAMOB intervention could serve as a crucial first step for long-term DSM through physical activity (Colberg & Sigal 2011).

The weaknesses of the present study are considerable, and primarily result from the limitations inherent to secondary analyses. Data were not collected with the present analysis in mind, so the resultant dataset was not well suited for a comparison of diabetic and non-diabetic populations. The small number of diabetics within the sample significantly impaired statistical analysis, in numerous ways. Firstly, the small number of diabetics relative to non-diabetics significantly affected the homogeneity of baseline characteristics between groups, as evidenced by statistically significant differences in years of education and maximal walking speed at baseline. Secondly, since the diabetic subgroups had sample sizes less than 30, it is unlikely that tests for independence were robust enough to compensate for abnormal distributions in the diabetic groups. Inadequate sampling most likely contributed to the statistical insignificance of findings in diabetics, since similar changes resulted in statistically significant findings for the more populous non-diabetic groups. Lastly, the small diabetic sample size affected nonparametric analysis by contributing to violations of assumed minimum expected cell frequency in transition tables. In order for p-values from marginal homogeneity tests to be valid, at least 80% of cells in the table should have counts greater than or equal to 5. However, inadequate sampling of diabetics resulted in violations of this assumption in tables 3 and 4, most likely affecting the validity of statistical tests performed for these analyses.

Additionally, the methods used to discern diabetes status in the SCAMOB study are not optimal for the present analysis. Definitive determination of diabetes status was not essential to initial study aims, so diabetes status was only defined by self-report. For the present study, in which diabetes status is of primary importance, this is problematic, mainly due to the high prevalence of undiagnosed diabetes. In Finland, approximately 250,000 people are known to have T2DM, but it is estimated that an additional 200,000 Finns have undiagnosed T2DM (FDA 2012). For this reason, it is likely that some of the individuals in the non-diabetic groups were actually diabetic.

The method used to define diabetes is also problematic because it does not differentiate between T1DM and T2DM. Since this study focuses on T2DM, contamination of the sample with type 1 diabetics would be problematic. However, contemporary estimates of diabetes prevalence in Finland indicate that the number of type 1 diabetics in the sample is most likely negligible. Registry data indicate that, as of 2002, 74% of known diabetes cases in Finland were of type 2, while type 1 and unknown type accounted for only 13% each. Furthermore, the average age of diabetic participants was 77.57 ± 2.08 years in 2003; in 2002, there were only 42 known cases of T1DM *nationwide* among Finns aged 75-79. Since this number represents only 0.2% of diabetes cases in the 75-79 age bracket, it is not likely that type 1 diabetics represent a significant proportion of diabetics in the study. (Niemi & Winell 2006)

10 CONCLUSION

The primary findings of this study are as follows: (1) Physical activity counseling does not improve diabetics' habitual physical activity level or mobility; however, it can help diabetics maintain current levels of mobility, by preventing decline in 2 km walking ability. (2) Physical activity counseling influences more change among non-diabetics than it does among diabetics, in regards to both habitual physical activity level and mobility outcomes..

These findings suggest that, although physical activity counseling for diabetics may not be effective at reversing mobility loss, it can still effectively prevent mobility loss in this population. Additionally, these findings suggest that diabetics require additional intervention in order to achieve equal improvements in habitual physical activity and mobility outcome measures. Directions for future research include similar analyses in a more suitable sample, as well as the investigation of supplementary intervention strategies for the reversal of mobility loss in older diabetics.

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